FISHERY ASSESSMENT REPORT

TASMANIAN ROCK LOBSTER FISHERY 2000/2001

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Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania

This assessment of the rock lobster resource is the sixth in the series and the fourth to be produced by the Tasmanian Aquaculture and Fisheries Institute (TAFI) and uses input from the Rock Lobster Fishery Assessment Working Group (RLAWG).

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The fishery description was obtained from the Fish Policy Document (Anon,1997).

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Rock Lobster Fisheries Assessment: 2000/2001

Summary

The 2000/2001 assessment investigated a number of issues relating to the rock lobster assessment model. These were:

1. correction of systematic errors in the catch and effort database associated with translations between catch weight estimation errors;
2. incorporation of new recreational catch estimates and the ability to vary this annually;
3. changes in the fleet dynamics component of the model;
4. adjustments to the size at onset of maturity in each area; and
5. evaluation of the magnitude of lobster movement between areas.

The effects of these changes are documented in this report.

No trigger points were reached in this year’s assessment. Catch rates (commercial and research), legal-sized biomass and egg production were all above the reference years. Compared to the 1999/2000 fishing season, indicators were either stable (catch rates) or improving (legal-sized biomass). Egg production was improving in northern regions except in area 4, which had a decline. This decline follows the rapid increase in egg production estimated in 1998/1999 and 1999/2000 fishing seasons as a large recruitment pulse occurred in the fishery in this region.

Puerulus settlement indices in eastern Tasmania continue to provide a strong correlation with 5 year lagged catch rates from the fishery for the East Coast. If this correlation is maintained, the puerulus index indicates that catch rates on the East Coast will decline and remain relatively low over the next 5 years. Although the period of puerulus settlement monitoring has not been sufficient to determine a relationship between puerulus index and lagged catch rates in north-western Tasmania, a relatively large puerulus settlement occurred in 1999 which may result in improved catch in this region over forthcoming years. The ability of the fleet to move to different locations to improve or maintain catch rates (fleet dynamics) is therefore likely to be important over the next 5 years.

Harvest strategies based on the current TACC of 1500 tonnes and increases to 1523, 1550 and 1576 tonnes were evaluated up to 2004. In general TACC’s of up to 1550 tonnes show relatively stable projections of biomass to the year 2004, although there is considerable uncertainty around the 2004 estimates. Regionally, predicted biomass improvements in the east are expected to be offset by declines in the west. Statewide

egg production predictions increased under all TACC scenarios. Egg production in northern regions is currently less than the target of 25% of an unharvested population. Expected future trends in these regions were mixed with improvements expected in north eastern regions while minor declines are expected in north western regions. None of the TACC scenarios indicate that egg production in northern regions will reach the 25% target by 2004.

Future projections of regional biomass and egg production estimates are dependent on the movement of the fishing fleet between regions. Evaluation of a number of fleet dynamic models using differing years of data suggests that there has been a change in fishing patterns since the introduction of the ITQ management system in March 1998. However, as only two years of data are available for a purely post-ITQ fleet dynamics model, future projections are based on a 10 year data set from 1990 to 2000. As the majority of data is from the pre-ITQ period, caution is required when interpreting regional estimates.

The number of recreational licences has continued to increase although estimates of catch have not increased at the same rate. Nevertheless, the catch is moving towards the 10% of commercial catch trigger point and monitoring needs to be continued.

Projects focusing on socio-economics of the fishery, ecosystem interactions and aquaculture are underway and details of these projects are incorporated in the report. Ecosystem projects are addressing the increased prevalence of the barren forming urchin *Centrostephanus rodgersii*, the impact of the major loss of the giant kelp *Macrocystis pyifera* and the biology and ecology of a main lobster predator *Octopus maorum*.

Aquaculture is dependent on obtaining post-larval lobsters from the wild. To compensate for their removal a percentage of these lobsters have to be returned to the wild after one year in culture, Research projects are addressing issues such as mortality rates, growth and disease to ensure minimal impact on the resource and no negative impact on the commercial catch.

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1. Introduction

Tasmania's rock lobster fishery is distributed around the entire coastline of Tasmania from sub-tidal reefs to deeper reefs on the continental slope. From humble beginnings of approximately 70,000 lobsters valued at $1,456 recorded from the Hobart fish market in 1888, the rock lobster industry today lands around 1.75 million lobsters annually with a landed value of approximately $AU50 million.

The rock lobster fishing industry is the backbone of Tasmania's fishing fleet with the majority of vessels working out of Tasmania's coastal rural towns. Over 80% of the licenses are held by Tasmanians, with the majority being owner-operators. The industry spends between 24 to 36% of the $50 million landed value of the catch on materials and approximately 41% on labour, thus being a valuable contributor to regional employment and economic activity. The processing sector is dependent on live holding facilities as approximately 74% of the catch is marketed live. The rock lobster processing sector is highly specialised adding to the socio-economic benefits that the rock lobster industry contributes to Tasmania.

The commercial fishing fleet comprises approximately 220 vessels, which are licensed to use between 15 and 50 pots. Additionally, the rock lobster resource supports an active recreational fishery with over 16,000 licenses issued in 2001.

Historically, the commercial fishery developed around the established towns on the weather protected East Coast in the late 1800's and early 1900's. As catch declined in these regions and technology improved, vessels moved to deeper and less protected waters off the West Coast. Today, the majority of the catch comes from the West Coast.

Markets have adapted to technology change with local markets dominating until after the second world war when refrigeration enabled a rapid expansion into the American frozen tail market. With the advent of live transport this market has been replaced by markets for live lobsters in Asia. The southern rock lobster is considered the premium lobster species and commands a high price on both the domestic and international market.

Although rock lobsters are harvested from coastal waters right around the state, the patterns of commercial fishing vary dramatically from region to region. Biological parameters such as growth and maturity of lobsters also vary dramatically around the state. For this reason the information presented in this report is often split into the 8 assessment areas shown in Figure 1.

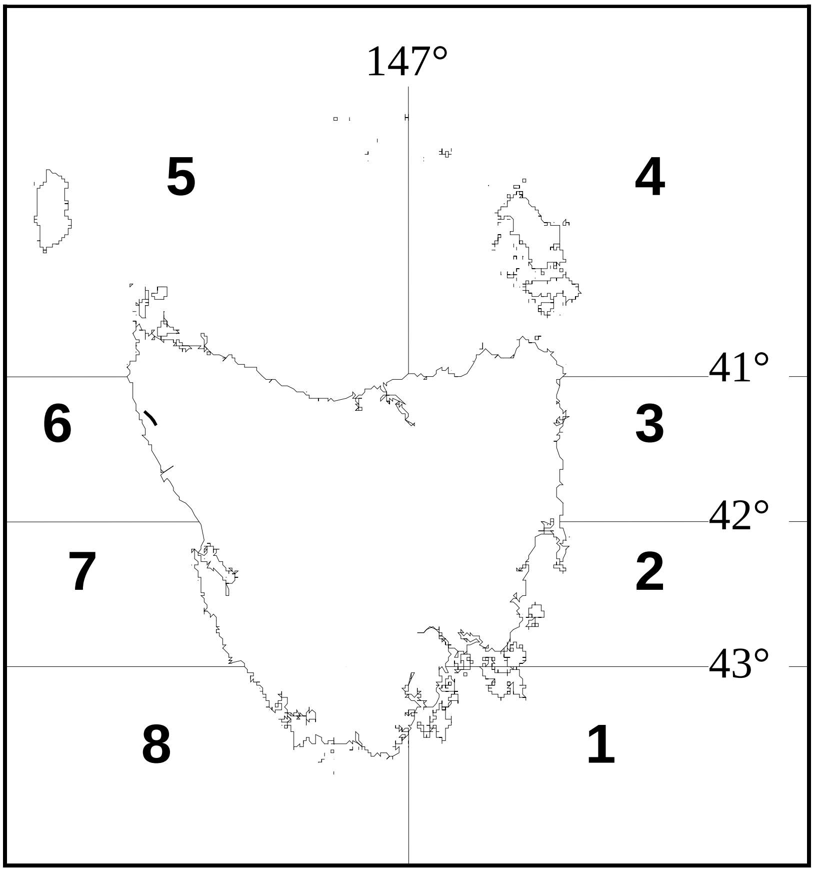


Figure 1. Divisions used for stock assessment areas.

1.1 Management

Rock lobsters were an important source of food for coastal aboriginal tribes and this was also the case for the first European settlers, which arrived in Hobart in 1804. In 1882 a Royal Commission into the fisheries of Tasmania produced what was effectively the first Tasmanian rock lobster stock assessment report. This report led to the introduction of regulations in 1889, which 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 protected by a seasonal closure.

Since the inception of catch records in the 1880's, catch steadily increased in the rock lobster fishery to a high in 1984 of over 2,250 tonnes. During this time concerns about overfishing were expressed by industry, and resulted in government intervention. The most important changes were the restriction of the number of licenses in 1951 and a ceiling on the number of pots in the fishery at 10,000 in 1967.

Since 1984, the catch has declined to a low of 1,440 tonnes in 1994. Recognising the declining trend in biomass, industry adopted an individual transferable quota (ITQ) management system in March 1998.

Management has remained relatively stable since the introduction of quota. One of the more important changes from a stock assessment perspective is the extension of the open season into September in 2000 and 2001. This was intended to provide fishers with flexibility to take lobsters when the prices were higher.

2. Previous Assessments

This report is the sixth assessment report and uses data available up until 1st March 2001. It includes data for the first three years since ITQ implementation.

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

3. Recent Developments

3.1 The Fishery

On the 1st March 1998, management of the Tasmanian fishery changed from input controls based primarily on licence limitations and closed seasons, to an output controlled fishery based on individual transferable quotas (ITQ's). In adopting the ITQ system, several of the input controls have been maintained, including the limitation of the maximum number of pots allowed in the fishery and seasonal closures which had been implemented to protect moulting lobsters.

This change has had the effect of increasing focus on the value of the finite number of animals landed each season. The change in the dynamics of the fleet was discussed extensively in the last assessment Gardner *et al.* (2001), but a key observation was a shift in effort towards winter when prices are highest. Associated changes include an increase in night fishing using lights, and trial extensions to the open season for males so that September remained open in 2000 and 2001.

3.2 Developments in stock assessment reporting

This Stock Assessment Report continues with changes in the format and content introduced in the previous report, which addresses the management objective of ecologically sustainable development (ESD).

The National Strategy for Ecologically Sustainable Development released in 1992 defines ESD as: ‘using, conserving and enhancing the community’s resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased’. Assessments that address ESD principles are considered important for industry accreditation (e.g, Marine Stewardship Council) and marketing. Additionally, an increased understanding of the marine ecosystem and the effect of sustainable ecological fishing activities should improve community perceptions of the fishing industry.

Although ESD is a significant issue that will require a large and sometimes new research investment, past research has made a contribution to ESD management.

Past research has focused on species-specific biological issues such as lobster size at maturity, growth rates, fecundity, and fishery specific issues such as exploitation rate and biomass. Under the ESD principles, socio-economic and environmental aspects need to be more fully integrated with current knowledge.

This Assessment Report will maintain the normal assessment approach based on species-specific knowledge, adding to these chapters on socio-economic and environmental/ecosystem issues. Future assessment reports will build on these areas as knowledge becomes available.

This document also includes more basic data on the lobster resource with historical patterns in size structure of animals collected in research sampling reported as an appendix.

3.3 Assessment Model

Several improvements to the assessment process were made over the last year. These include:

a) correction of systematic errors in the catch and effort database associated with translations between catch weight estimation methods.

b) adjustments to the size at onset of maturity in females.

c) incorporation of new recreational catch estimates and the ability to vary this annually.

d) changes to the fleet dynamics component of the model.

e) evaluation of the magnitude of lobster movement between areas.

These changes are discussed in more detail below.

It is important to note the tendency of the model to be biased upwards in the last year of hind-cast fits, as discussed in detail in last year’s assessment report. This bias is more of a problem with legal-sized biomass than egg production. We have not been able to determine the cause of this bias and thus we have highlighted areas where the estimates of legal-sized biomass and egg production estimates are of concern (see Gardner, 2000 for more detail).

3.3.1 Correction of database errors

During 2001, several errors were detected in the Oracle database that stores commercial catch and effort information (Craybase). The problems were mainly centred around conversions between different weight or number estimation methods used by fishers in reporting their daily catch. A staff member was dedicated to this problem for a period of several months to locate and correct errors. To assess the impact of these corrections, stock assessment model runs were repeated for previous stock assessment (1999/00) to evaluate if the changes to the database made a substantial change to our interpretation of the state of the resource. Most of the errors related to catches for the last few years, so we were most interested in model outputs from this period.

Results from this test showed that the effect of correcting these errors was very small. Estimates of legal-sized biomass and egg production were virtually the same using the original data and the corrected data (Figure 2 and Figure 3). We suspect that the reason for the high degree of overlap is because some errors overestimated the catch while others underestimated it; their combined affect appears to be cancel out. This exercise of correcting the database was clearly a necessary step, but appears to have no implications for our interpretation of the state of the Tasmanian lobster resource. Importantly, the alterations to the database did not affect the outputs of the previous assessment reports.

Figure 2. Model estimates of total legal-sized biomass from each of the 8 assessment areas fitted up to February 2000, with model fits from original data and corrected data overlayed. Note that the two model fits overlay each other almost perfectly, which implies that the presence of these errors would not have affected conclusions from previous stock assessments.

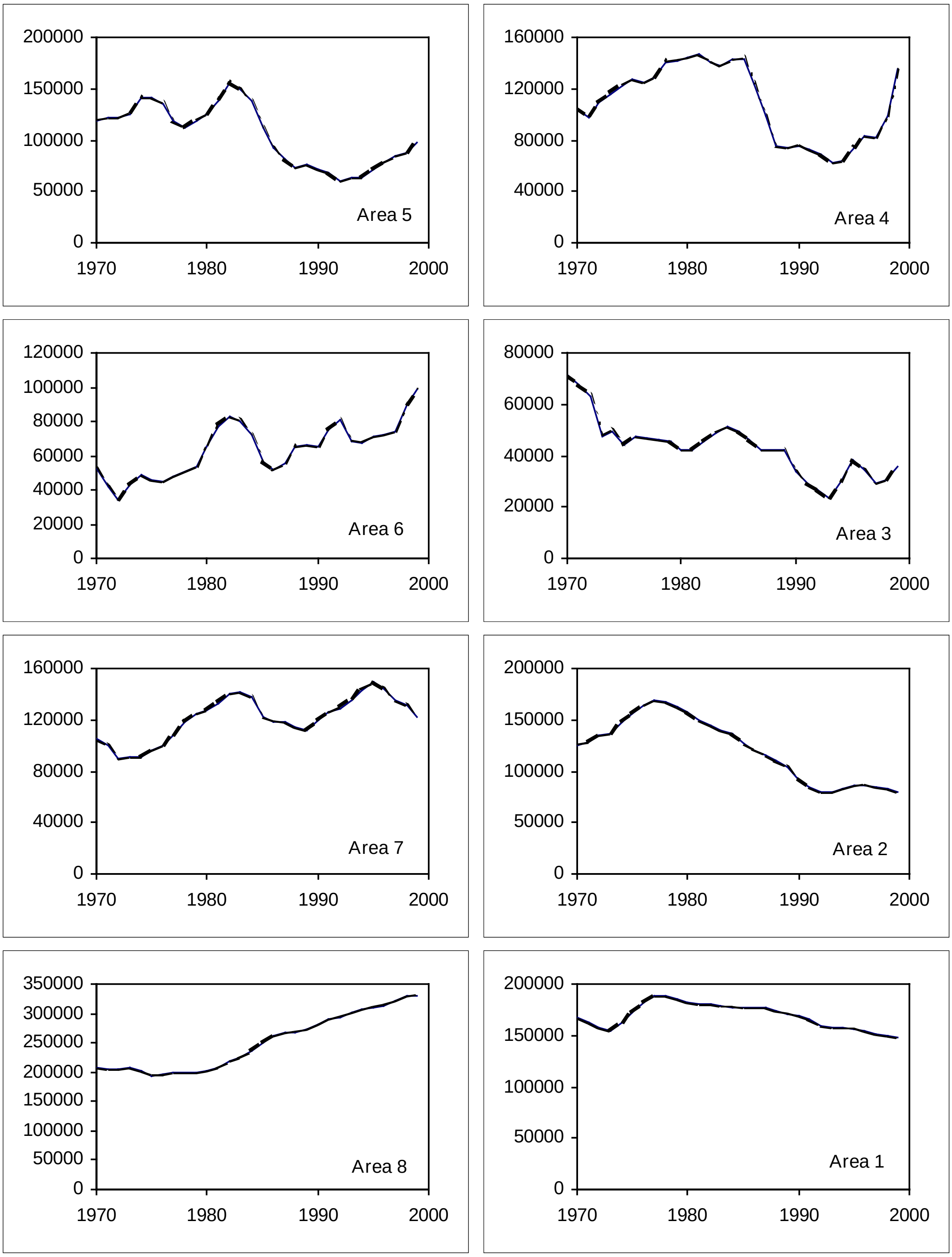


Figure 3. Model estimates of egg production from each of the 8 assessment areas fitted up to February 2000, with model fits from original data and corrected data overlayed. Note that the 2 model fits overlay each other almost perfectly, which implies that the presence of these errors would not have affected conclusions from previous stock assessments.

3.3.2 Onset of maturity of females

The model incorporates information on the size at onset of maturity (SOM) of females for each region as this influences estimates of egg production. Information on size at onset of maturity is collected through research catch sampling where the maturity of all females is recorded. Maturity is determined by the presence or absence of fully developed setose pleopods or, during the egg bearing period, the presence of eggs. Females with partially developed setae or those without setae are considered immature (Figure 4).

Figure 4. Partially setose pleopods of a female southern rock lobster (left), indicating immaturity, compared to the fully setose pleopods of a mature female (right).

The parameters used to define SOM for previous assessments were derived several years ago with far less data than we now have. This increase in data is a result of intensive catch sampling that has occurred over the last decade.

SOM parameters (as P50% and P95%) were re-estimated for this year's assessment using pooled data for all females within an assessment area by standard least squares regression to a logistic model. SOM was substantially different for many areas, which is a function of increased data in these areas (Figure 5). Latest estimates for SOM are generally lower than those estimated previously. Note that there was previously insufficient data to estimate SOM in some areas so these parameters were assumed to be equivalent to other areas of similar latitude. Although areas 3, 4 and 7 show substantial changes in the SOM estimates, it is area 4 that is of most interest as the estimated SOM now indicates that the majority of females are expected to mature prior to becoming vulnerable to the fishery, which differs from before.

The substantial difference between the latest estimates of SOM and those used previously highlights the need for ongoing biological research in this important fishery. SOM can have a profound impact on the evaluation of basic management tools, such as size limits. Although the estimates of SOM have changed from those used previously, it remains an important issue because of the large variation between areas around the State (Figure 6). Animals in area 5 tend to mature above the size limit while those in areas 7 and 8 tend to mature well below the limit.

The revised parameters for SOM have a large effect on estimates of absolute numbers of eggs produced. However, this is of less interest for management than the effect of the revised SOM on egg production relative to virgin production. The effect of changes in SOM parameters on estimates of virgin egg production are shown in Figure 7. Although significant differences were observed in many areas, these differences were not of such a large magnitude that management conclusions from previous assessments would have been affected.

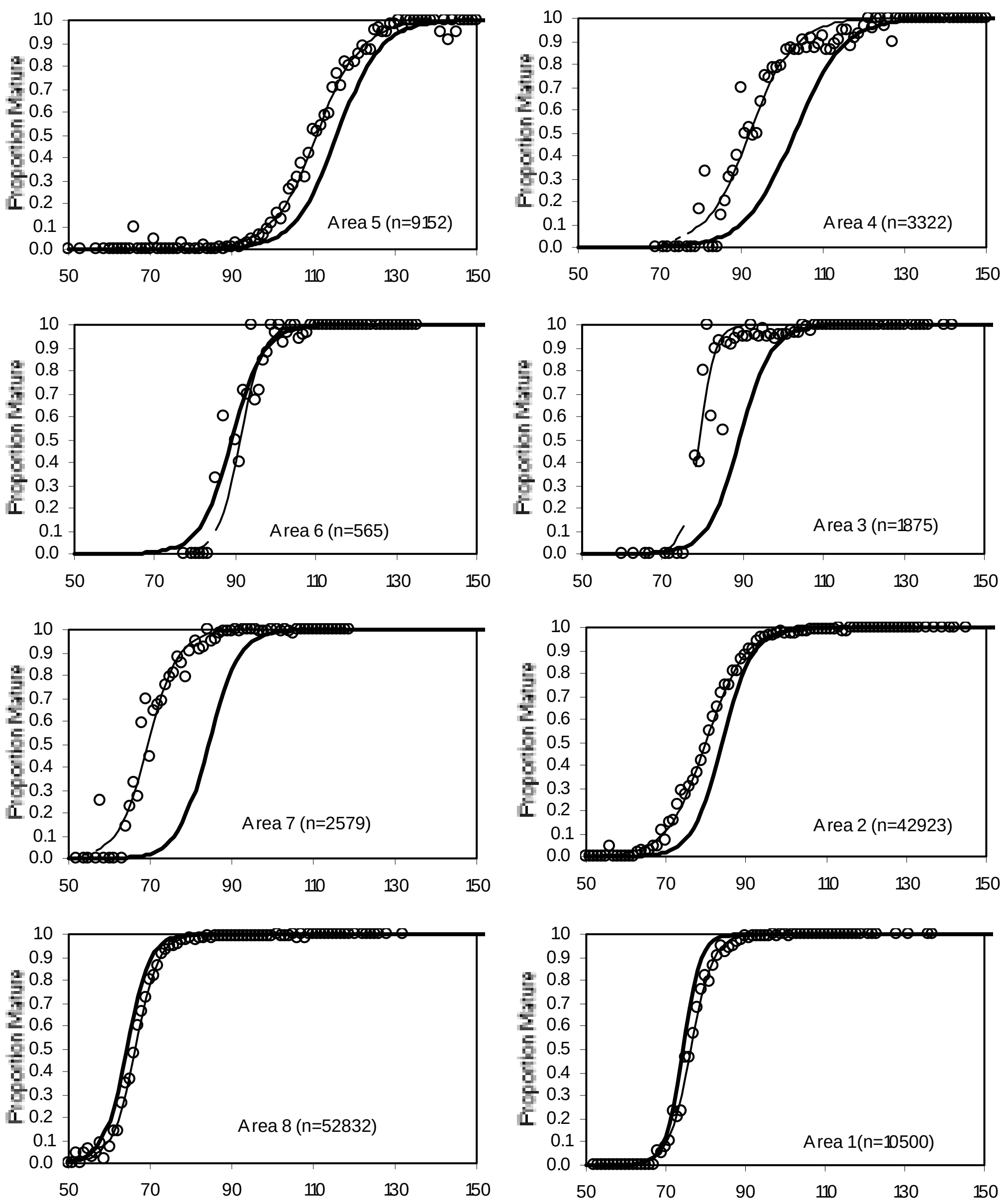


Figure 5. Size at onset of maturity of female lobsters in relation to carapace length (x-axis) for each of the assessment areas. The model defined by parameters used in previous assessments (heavy line) is shown in relation to estimates produced with the latest data (thin line). Spaces in curves represent a lack of data and therefore uncertainty.

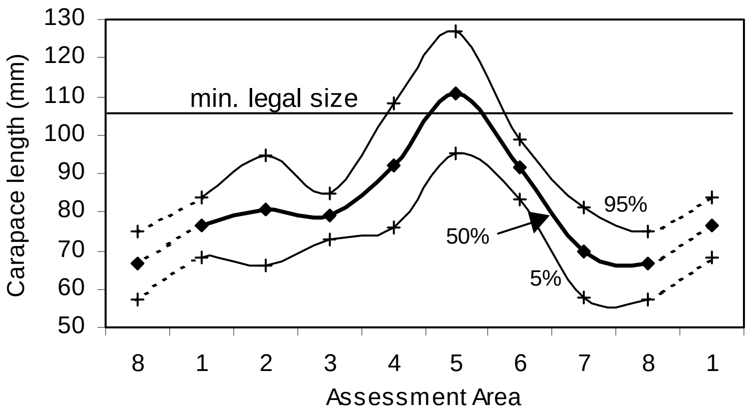


Figure 6. Summary of parameter estimates for size at onset of maturity for females from each stock assessment area. The heavy line represents the estimated size at which 50% of the population is mature, with the other two lines representing the estimated size at which 5% and 95% of animals are mature.

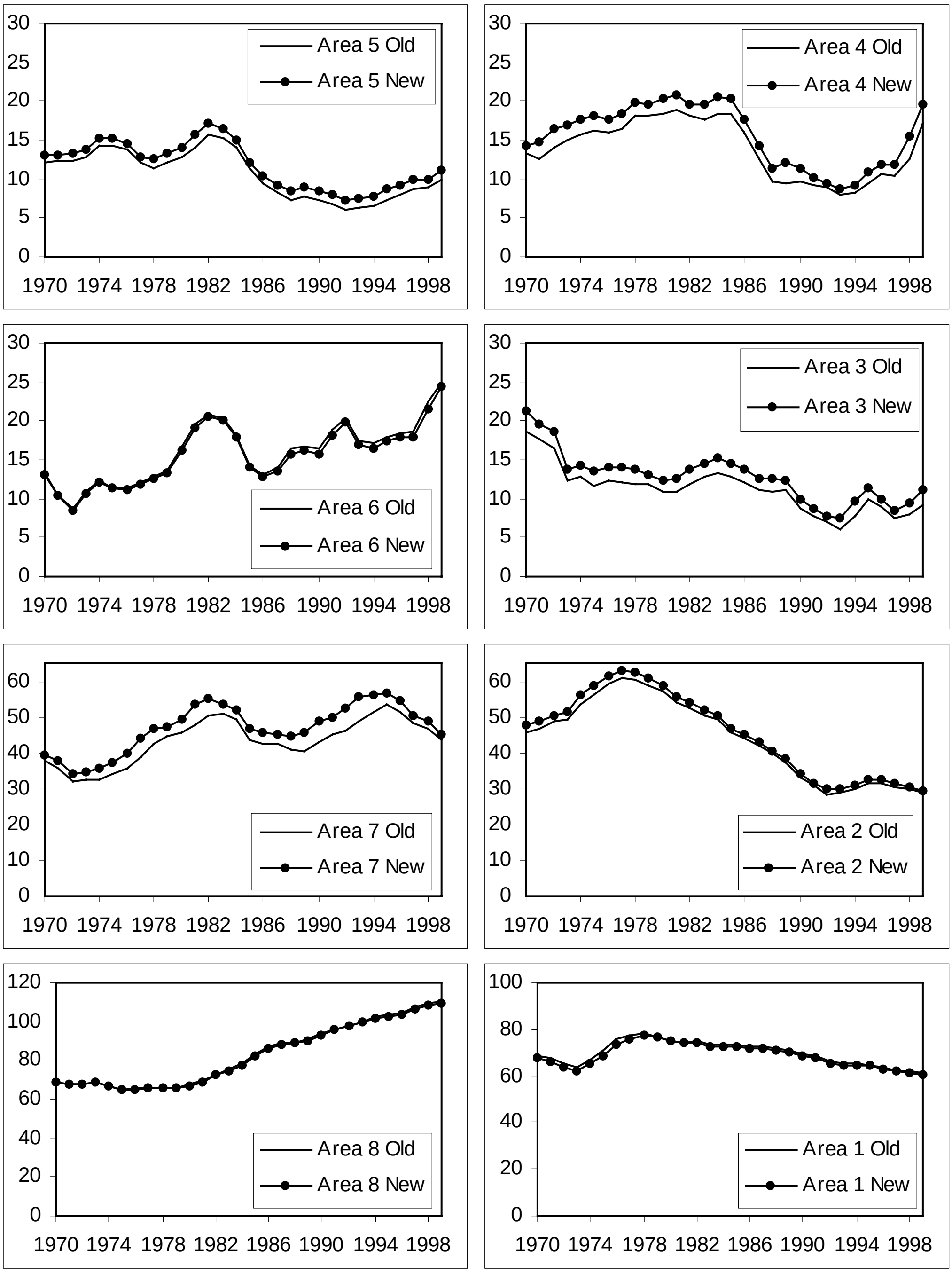


Figure 7. Change in rock lobster stock assessment model estimates of virgin egg production with revised parameters for size at onset of maturity of females (“new”) from 1970 to 1999. These estimates are contrasted with those from the 1999/2000 stock assessment using the original size at onset of maturity parameters (“old”).

3.3.3 Estimation and incorporation of recreational catch

Surveys of recreational rock lobster catch have been conducted sporadically in the past and a survey was completed during the 2000/2001 season in time for the latest assessment. This survey highlighted the need for adjustments to the assessment model so that changes in recreational catch could be included on a yearly basis, rather than simply as a single fixed value for each area for all years (Figure 8). This change was made to the program code for the 2000/2001 assessment.

Associated with this change was the need to adjust historical input parameters for recreational catch. For those years where no data was available, the recreational catch was taken as the average of the years either side. Also, detailed spatial information was collected in the latest survey, which allowed catch to be split into each of the 8 assessment areas, rather than 5 as used previously (where areas 1,2 and 3 were grouped, and areas 7 and 8 were grouped). The ratio of catch between areas was adjusted for previous years on this same spatial division. The greatest effect of this change was on the east coast where we now know that the proportion of total catch taken recreationally is much greater in areas 1 than areas 2 or 3.

The combined effects of these changes was minor but the greatest impact on model estimates of legal sized biomass and egg production occurred in areas 1, 2, 3, 4 and 6. This is not surprising given that these are the areas with highest recreational catch (Figure 9 and Figure 10). Note that the estimates of recreational catch used in the stock assessment modelling process were calculated by estimates of the number of lobster caught by recreational rather than the weight. This would produce an underestimate of recreational catch if the mean weight of a recreationally caught lobster is greater than that of a commercial fisher. This issue is discussed in more detail later in this report (section 4.1.8, page 33).

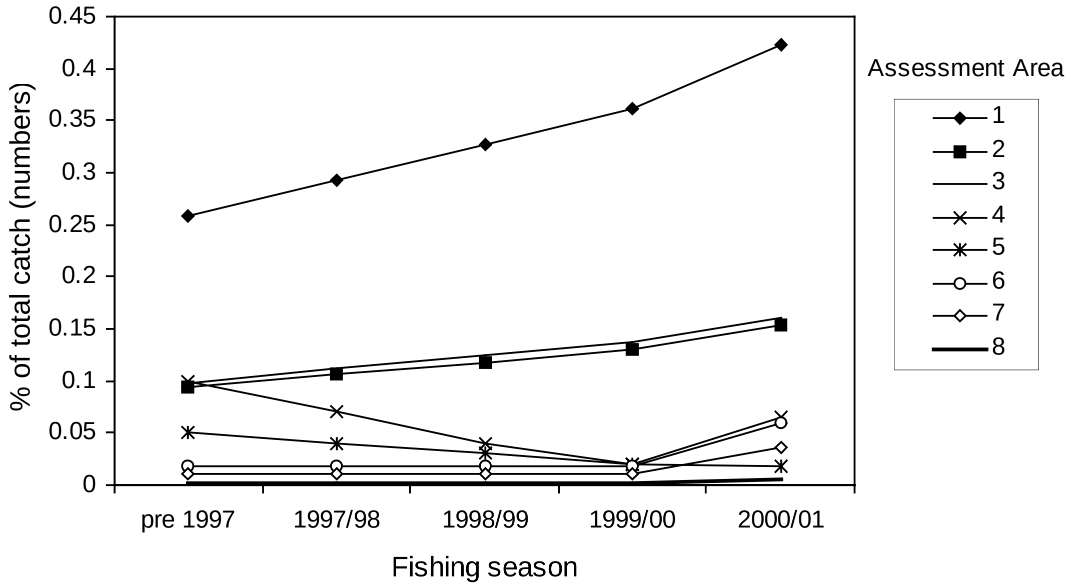


Figure 8. Values of recreational catch as a proportion of total catch as included in each of the 8 stock assessment areas in the stock assessment model for 2000/2001.

Table 1. Recreational catch estimates used in the model, expressed as a percentage of total commercial catch. These values are the same as those plotted in Figure 8.

	Percentage of total commercial catch (numbers)							
	Assessment Area							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
pre 1997	25.8	9.3	9.8	10.0	5.0	1.8	1.1	0.2
1997/98	29.3	10.6	11.2	7.0	4.0	1.8	1.1	0.2
1998/99	32.7	11.8	12.5	4.0	3.0	1.8	1.1	0.2
1999/00	36.1	13.1	13.8	2.0	2.0	1.8	1.1	0.2
2000/01	42.2	15.3	16.1	6.5	1.8	6.0	3.6	0.6

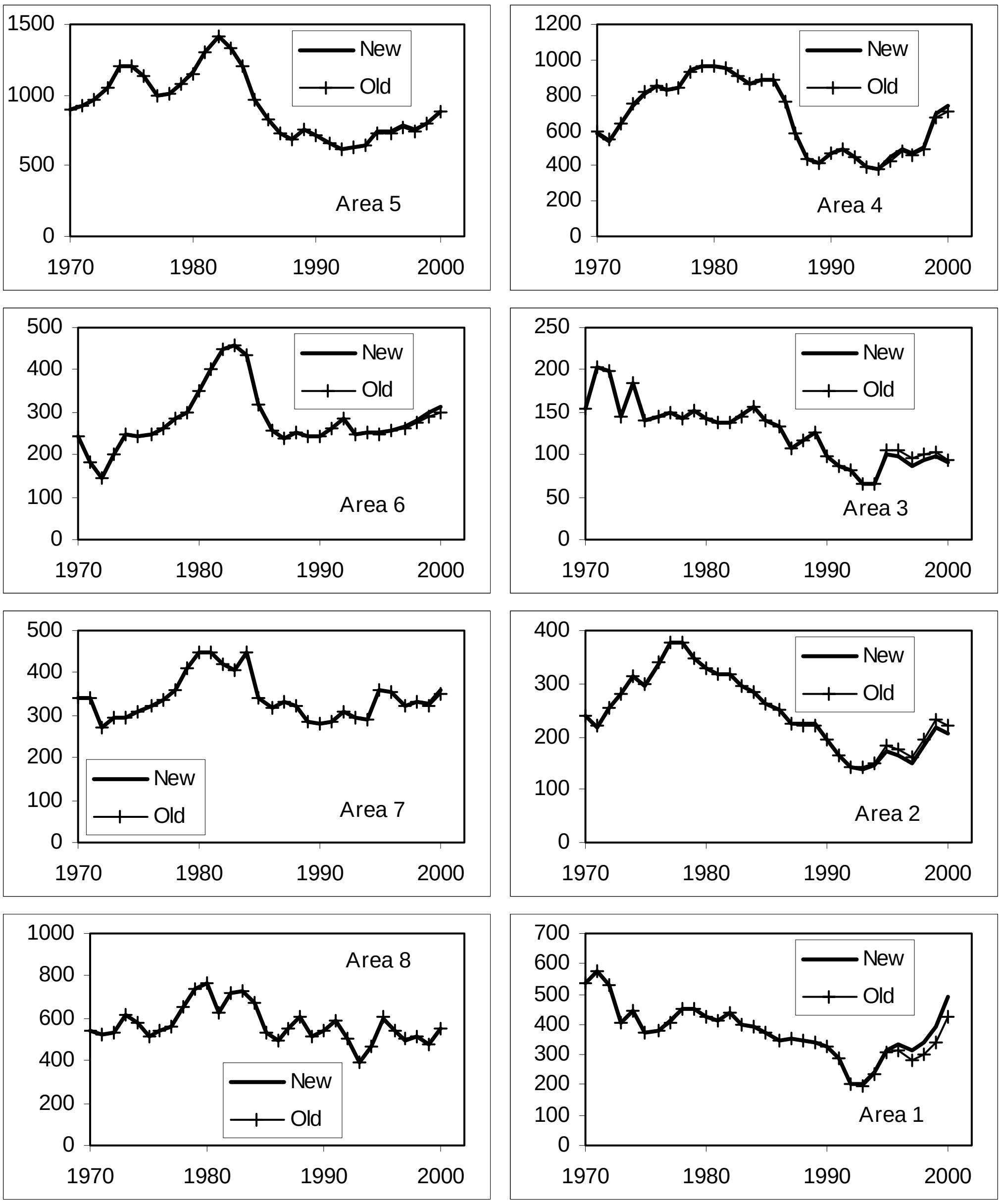


Figure 9. Effect of change to recreational catch modelling on estimates of legal sized biomass. Greatest effect is in areas 1, 2, 3, 4 and 6 where recreational catch is highest.

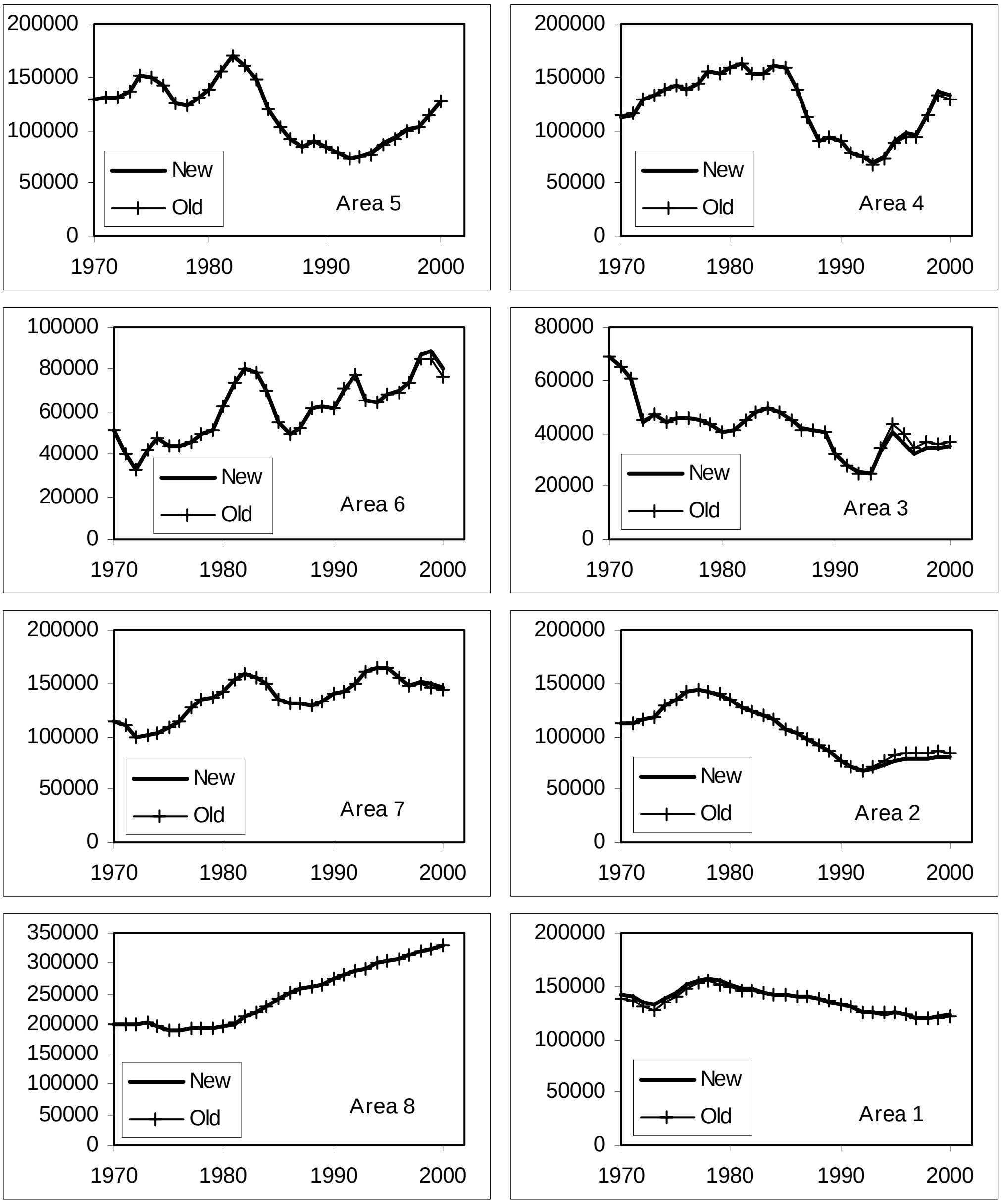


Figure 10. Effect of change to recreational catch modelling on estimates of egg production.

3.3.4 Fleet dynamics

The "fleet dynamics model" is a component of the larger stock assessment model that determines how effort is spread between different areas when the model is being used for future projections. It aims to mimic commercial effort shift between areas in the model in a fashion similar to that of the real Tasmanian fishing fleet, which is why it is a vital part of future projections. The model estimates the relationship between a number of explanatory variables such as monthly and regional catch rates and the distribution of effort by the fishing fleet. It then uses this relationship to distribute fishing effort between stock assessment areas as the explanatory variables change in the future projections.

The original fleet dynamics model was produced during the initial development of the Rock Lobster Stock Assessment Model (Kennedy and Punt 1997). Unfortunately little documentation on the original fitting of the model has been found. It is, however, most likely that the model parameters were found by fitting the generalised linear model

$$\mathrm{Ln}(f)=m+a+m*cpue+a*cpue$$

to data for the years 1990 until 1995 (when this is done parameter values very similar to the originals are obtained). In this statistical model the independent variables m and a are categorical and represent *month* and *area*, respectively. Thus m can take on a value from 1 to 12, although as September and October were closed to fishing from 1990 until 1995, values of 9 and 10 are disallowed. The values for a range from 1 to 8, representing each of the 8 statistical areas used for assessment purposes (see Figure 1). The variables f and $cpue$, the *harvest rate* and *catch per unit effort* respectively, are continuous variables which depend on m and a. The harvest rate f was computed by $f = C / B$ where C is the catch in kilograms and B is the exploitable biomass in tonnes for a given month m and area a.

As the optimal statistical model and that model's parameters were based on data prior to 1995 there was concern that the model no longer reflects the dynamics of the fishery especially given that quota was introduced in 1998 and this is believed to have affected fishing patterns. For this reason the model was refitted using alternative years of data, and alternative models were investigated to see if they more closely reflect the observed effort distribution during those years. This work, which is part of the FRDC project 1999/140 to investigate any impacts of a change to ITQs in the rock lobster fishery, is still in progress and will be completed early in 2002. At the time that the Rock Lobster Model was run for this year's assessment, this work was partially complete. Therefore, although all proposed changes could not be investigated in this year's report, we did have the opportunity to trial some of the changes and investigate the effects they will have on the assessment.

Tested Models

No month-area interaction term was included in the original fleet dynamics model. This assumes, therefore, that any effects of seasonality are independent of fishing region. This is no longer considered a reasonable assumption in the fishery so all possible models involving month, area and cpue and allowing for month-area interaction were compared for performance in terms of how well they described the data sets used.

The Data Sets

It is suspected that the fleets fishing patterns may have changed since the introduction of quota management in 1998. However data collected since the introduction of quota (Mar 1998 until Feb 2000) [1] provides us with just two data points for each month-area combination. There is a clear risk that this limited history of fishing patterns may not be indicative of future patterns. For instance, these two years may have demonstrated an exceptional recruitment in one area or unseasonal weather patterns. However, if it were

[1] Although the 00/01 catch and effort data is available, the biomass estimates for that year, which are needed to fit the model, can only be obtained after the Rock Lobster assessment model is run.

the case that fishers behaviour have altered drastically in these two years and that these changes are indicative of future fishing patterns, then data prior to this period would provide little information for future projections and the 1998 to 2000 data set would be the most appropriate period for calibrating the statistical model.

At the other extreme, adding all data collected since the original model was created to the data set would result in data covering the years from 1990 until Feb 2000. To give a balanced representation of month we only include data from March 1990 until Feb 2000 in this data set, which we will refer to as the “90-00 data set”. This data set includes eight years worth of data prior to, and two years of data since, the introduction of quota. The problem with this data set is that as each year’s fishing pattern is considered equally relevant more weight is given to the years prior to the introduction of quota. This biases the model toward pre-quota fishing patterns.

It has been suggested that prior to quota, fishers were already adopting different fishing practices in response to the knowledge that quota was to be introduced (Gardner, C. et al., 2001). These changes were considered to be taking effect from at least 1995. The effect this may have on the fleet dynamics model is dependent upon the nature and the magnitude of these changes. If these changes are spatial or temporal in nature then they will directly impact on the fleet dynamics model. Whether their impact is useful for future predictions depends on whether fishers were moving towards the fishing practices now shown, or whether they were acting in an atypical manner that has not continued to the present time.

Thus, to obtain some indication on the relevance of different years of data we have fitted models to each of 4 different data sets. The 90-95 data set, the 90-00 data set, the 98-00 data set, and the 95-00 data set. It is hoped that by comparing the model fits on all four data sets a clearer insight into how previous years affect the model can be seen.

Optimal Models

The inclusion of a month-area interaction into the model greatly increases the number of parameters. It is for this reason that we have used the Corrected AIC (AICC) as a comparison tool rather than the standard Akaike’s Information Criteria (AIC) (Anderson et al., 2000).

Replacing $a+m$ by $a*m$[2] in the models increases their fit to the 90-95 data set (Table 2). The optimal model, $\ln f = a*m + m*cpue$ has an AICC of -243.7. This improves on the AICC of $\ln f = a + m + a*cpue + m*cpue$, the model originally chosen, by 80. Therefore an $m*a$ interaction is a worthwhile refinement of the original fleet dynamic model when judged by its fit to the 90-95 data set.

Looking at the fits to the 98-00 data set, it is clear that the AICC is most strongly influenced by the number of parameters with the smaller number of parameter giving rise to the best model. This is a reflection of the small size of this data set. Thus, basing our results on this data set it would be best to not change the model structure from the

[2] Replacing $a+m$ by $a*m$ in the model is equivalent to adding $a*m$ to the model as the term $a+m$ becomes redundant.

original. Keeping the model structure as it is but updating the parameters based on this data set has a significant affect on model projections.

Both the 90-00 and 95-00 data sets suggest that the model, $\ln f = a*m + a*cpue + m*cpue$ is optimal.

Table 2 : AICC for models fitted to different data sets. Number of Obs is the number of observations in the data set and pars is the number of parameters in each model. Optimal model choice for each data set is represented by the bold figure.

Date Range		90-95	90on	95on	98on
Number of Obs		457	777	392	160
Model	**pars**	**AICC**	**AICC**	**AICC**	**AICC**
m + a + m * cpue + a * cpue	34	-323.7	-592.4	-242.7	**-76.0**
a * m	80	-295.0	-527.4	-256.1	-207.4
a * m + a * cpue	88	-258.4	-516.2	-236.6	-239.5
a * m + m * cpue	90	**-243.7**	-459.8	-243.9	-258.8
a * m + m * cpue + a * cpue	97	-248.8	**-454.4**	**-233.1**	-316.2

This Year's Assessment

During the preparation of this year's stock assessment report the model was projected using three different models. The original model that has been in use in previous assessments, and the updated model $\ln f = a*m + a*cpue + m*cpue$ fitted to both the 90-00 and 98-00 data sets. Clearly many other combinations have yet to be tested and these will be assessed during the coming months.

The model projections from each of these three models are shown in Figure 11. The new model fitted to all data since 1990 gives predictions not too dissimilar from that of the original fleet dynamics models. However, the new model, fitted only to data since the introduction of quota, predicts that biomass in Region 2 will increase exponentially in the future (Figure 11). Unfortunately, there are many reasons why this prediction may not reflect the actual situation.

Firstly, as the model was based on very little data for such a large parameter set the appropriateness of the model is questionable. That is, even if the model did accurately reflect the data of the last two years it is not clear that these two years will reflect future fishing patterns. If there was a change in fishing patterns that was linked to a change in weather or another variable that is not likely to remain consistent in future years, then the model will incorrectly predict effort patterns in the future. However, it is clear that this data set shows differences in fishing patterns compared to previous year's data. Thus, it appears that there may be a change in fishing behaviour since the introduction of quota and it is important to continue to investigation these changes and to find the model that more closely represents expected fishing patterns in the future.

We conclude that fitting the fleet dynamics model to the 98-00 data set is undesirable and that more years of data following the introduction of quota are needed before only post-quota data can be used. For this reason, projections shown later in this report are based on the optimum fleet dynamics model fitted to data from 1990 to 2000. This is judged to be the most appropriate model of those tested so far. Once this study has been completely, however, a larger range of models will be available with a more thorough understanding of which is most appropriate.

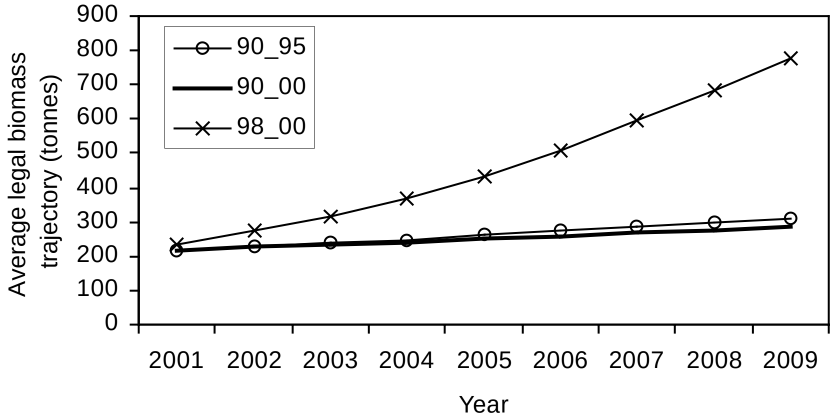


Figure 11. Projections of biomass in area 2 with a TACC of 1500 tonnes under 3 different fleet dynamic model options. These models were fitted to catch data either from: (a) 1990 to 1995 (the original model used in previous assessments); (b) 1990 to 2000 (that is, based on a longer data set including recent years); (c) 1998 to 2000 (for years since the introduction of quota management).

A comparison of projections using the fleet dynamics model fitted to data from either 1990 to 1995 (as per previous assessments) and from 1990 to 2000 is shown in Figure 12. This shows that the new fleet dynamics model tends to predict lower biomass in areas 2 and 8, but higher biomass in other areas. An important conclusion from this is that the precise fleet dynamics model used strongly influences projections and therefore continued attention to this part of the overall model is warranted.

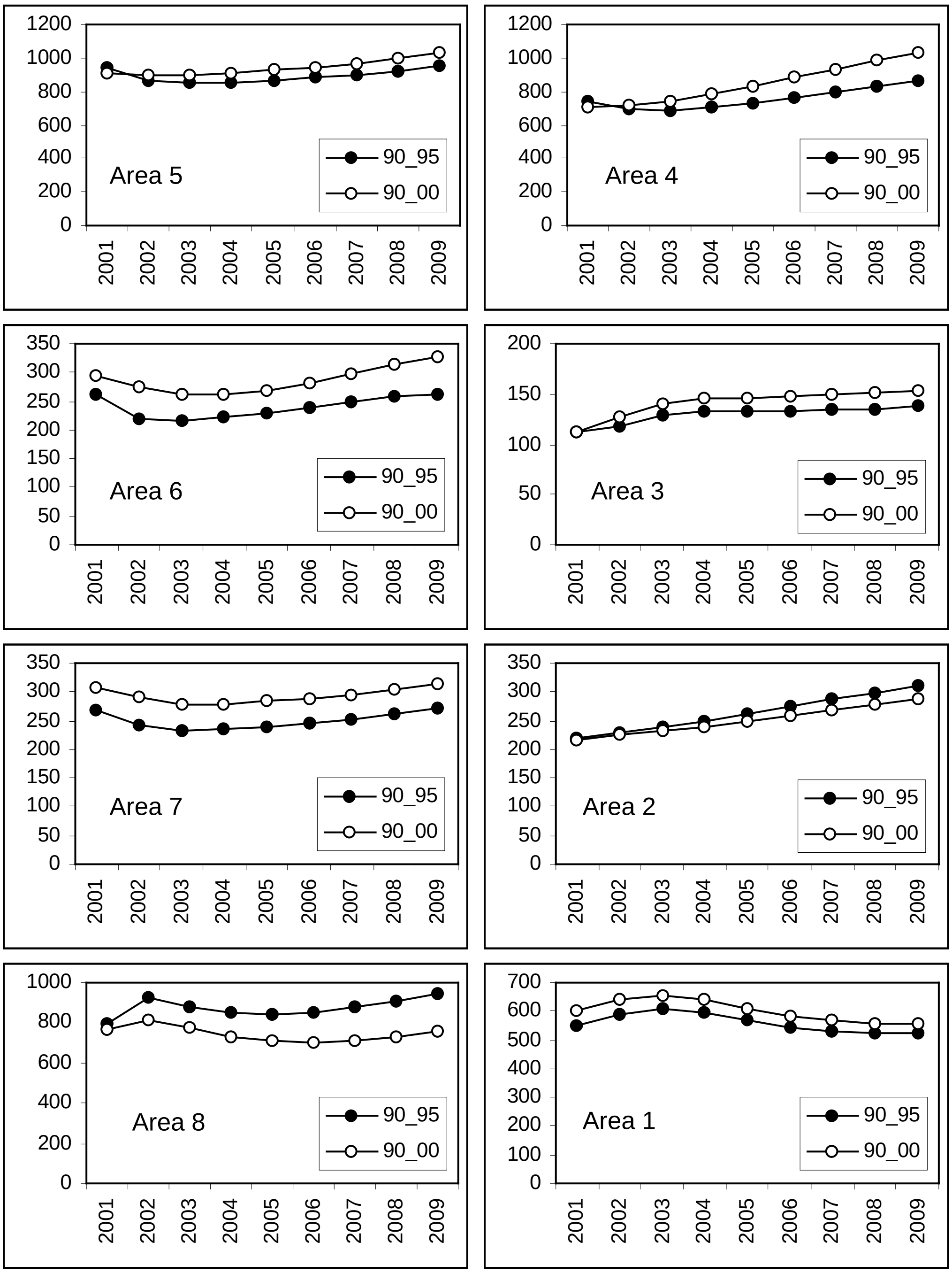


Figure 12. Projections of biomass under a scenario of 1500 tonnes TACC for each of the 8 assessment areas, using alternative fleet dynamics model components. These alternatives are for the model to be fitted to data from 1990 to 1995 (as per previous assessments) or from 1990 to 2000. Note that different scales are used for each plot to help distinguish between different projections.

Future Model Refinement

The optimal model discussed above (Ln *f* = a * m + m * cpue + a * cpue) is being fitted to various data sets to determine a model that most accurately captures the expected fishing patterns in the future. Work is underway to improve the model structure further, however, this is not fully completed and is therefore not available for incorporation into this report. Models including a month-area-cpue interaction have been found to out perform the other models tested. In addition, a time delay term is being added to the model. It is hoped that this term will capture the trend across years that has become apparent in the effort distribution.

3.3.5 Lobster movement

The 8 stock assessment areas used in the model are linked only by the movement of fishers between them through the fleet dynamics component. Aside from this, in the model each area is a biologically independent unit. In practice, we would expect some movement of animals between areas, both as drifting planktonic larvae and later as benthic juveniles and adults that can walk. Larval movement is beyond the scope of the model as no stock-recruitment relation has been defined for southern rock lobster and larval dispersal patterns are still poorly understood.

Large scale movement of migrating southern rock lobsters has been observed in New Zealand (Street, 1971) so it is possible that similar events occur around Tasmania. When the model was originally constructed it was planned to review the potential for movement between areas at a later date when sufficient tag-recapture data had been collected.

This analysis has been conducted over the last year and is described in detail elsewhere (Gardner *et al.*, submitted). Briefly, no large scale directed movement was detected in any region of Tasmania (Figure 13). Therefore, the current assumption of the model appears to be valid, that is, that movement over boundaries between stock assessment areas is likely to be trivial. Thus treating each assessment area as a discrete biological unit is appropriate.

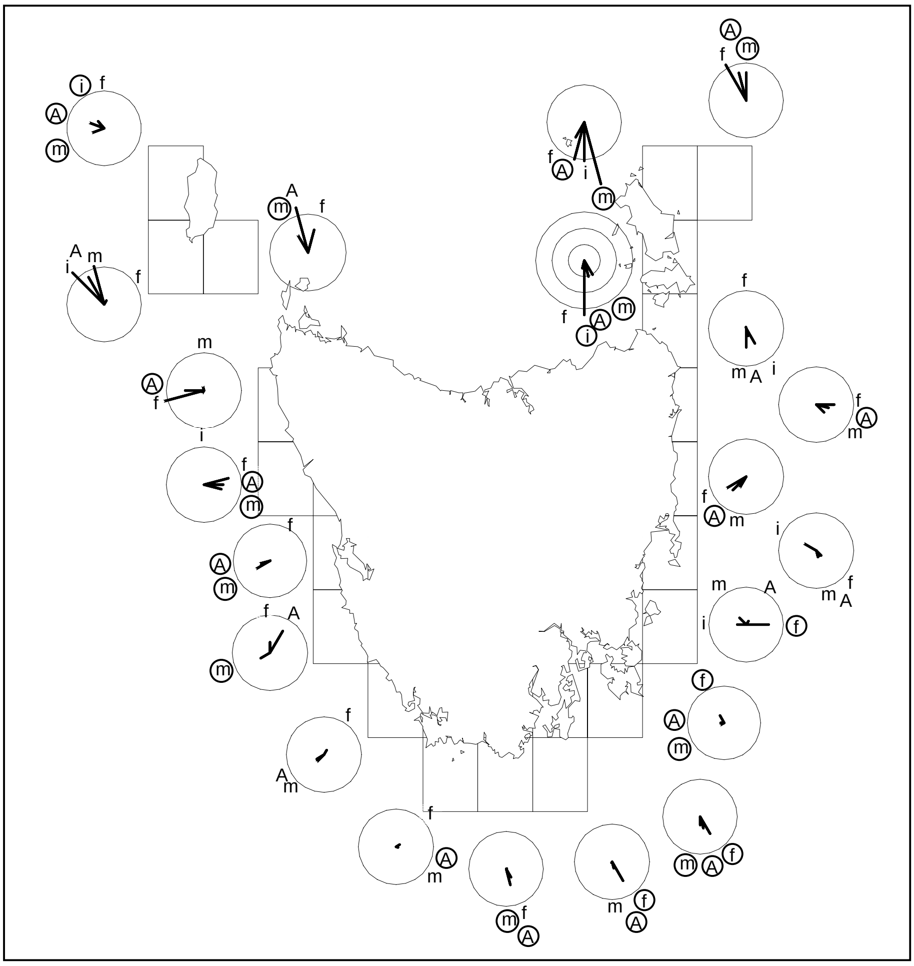


Figure 13. Mean movement vectors of rock lobsters for different stock assessment blocks. Several of these blocks make up each stock assessment area (Figure 1). Vectors are scaled to the circle surrounding each plot, which represent movement of 1 km/annum (3 km in one NE block). Vectors are for males (m), females (f) and both sexes combined (A). Movements that were in a significantly (P<0.05) consistent direction are indicated by circles around symbols.

4. Fishery Assessment

4.1 Evaluation of Trigger Points

4.1.1 Commercial catch rates

Commercial catch rates indicate there was no overall improvement in 2000. Unlike previous assessments, where catch rates were increasing each year, the current year suggests that this trend has ceased. While commercial catch rates do not suggest that biomass is increasing as per the objective of the management plan, they are still above the values of the reference year and thus have not triggered that performance indicator.

Although declines of 7% occurred in areas 3 and 6, these were offset by an 8% increase in commercial catch rate in area 5, which contributes substantially to the overall Tasmanian catch (see Figure 58, Section 12.3, Page 78).

Table 3. Change in annual commercial catch rates. Negative values indicate a decline in the change. The reference year is defined as the year with lowest CPUE among 1993, 1994 and 1995. Included also are commercial catch statistics for 2000.

Region	**Reference Year**	**Commercial catch rates (kg/potlift)**			**% change in 2000**		**Commercial catch stats 2000 (Jan-Dec)**	
		Ref. Year	**1999**	**2000**	**vs Ref. Year**	**vs 1999**	**Catch (t)**	**Effort (1000 potlifts)**
Statewide	1994	0.82	1.01	**1.00**	+22%	-1%	1528	1521
1	1994	0.52	0.73	**0.72**	+38%	-1%	97	134
2	1994	0.54	0.73	**0.72**	+33%	-1%	88	122
3	1994	0.44	0.58	**0.54**	+23%	-7%	75	140
4	1994	0.63	1.00	**1.02**	+62%	+2%	242	237
5	1995	0.90	1.04	**1.12**	+24%	+8%	323	289
6	1995	1.21	1.65	**1.53**	+26%	-7%	255	166
7	1994	1.11	1.30	**1.26**	+14%	-3%	127	100
8	1993	0.77	0.98	**0.98**	+27%	0%	329	337

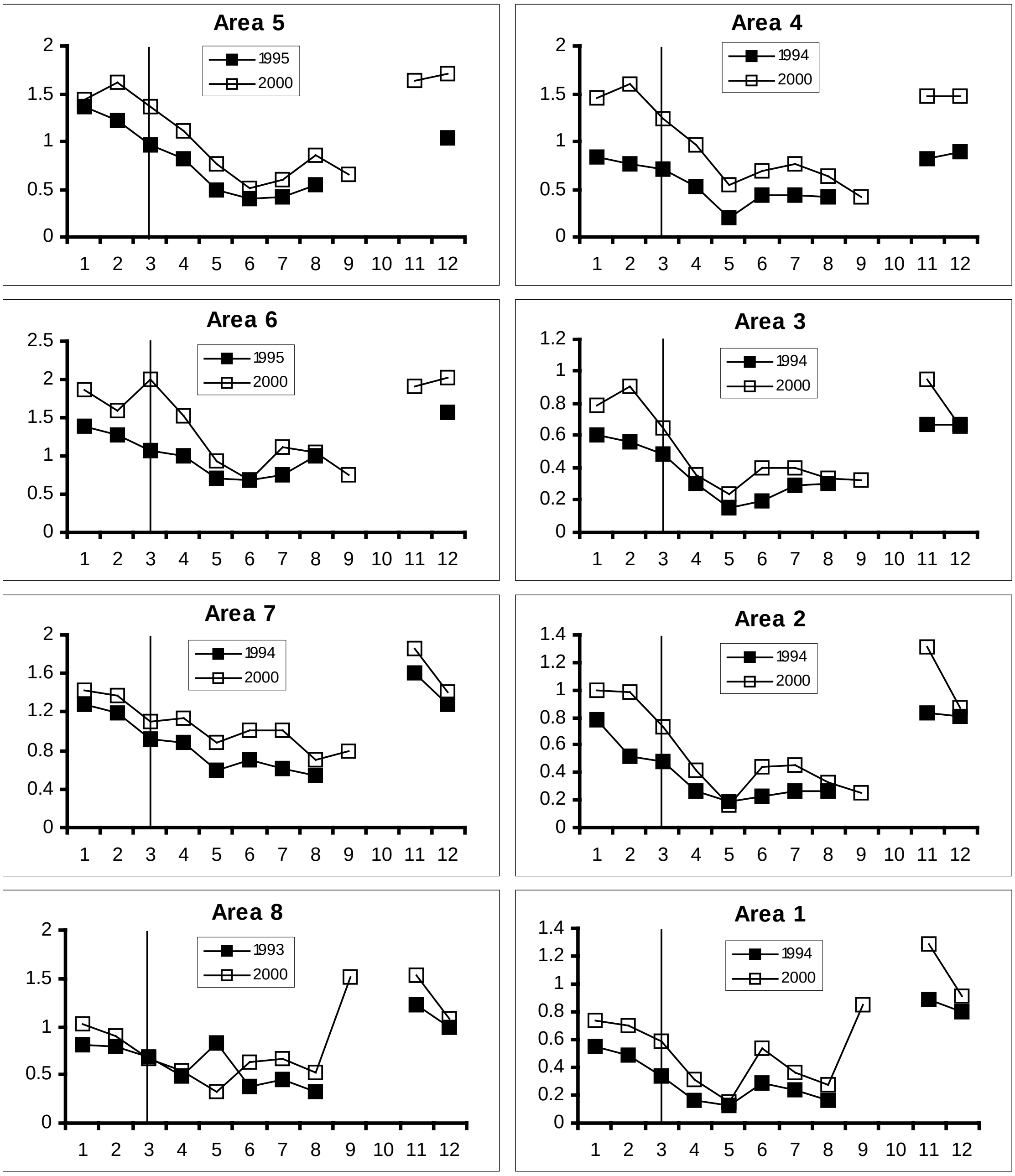


Figure 14. Change in catch-rate (CPUE, kg/pot lift) between months for 2000 and for reference year. Vertical line in each plot indicates the start of the quota season.

Monthly commercial catch rates within each season remain higher or equal to the representative catch rates of the reference year. The only exception to this was May in area 8 where an uncharacteristic elevated catch rate was achieved in 1993. Catch rates in September are only available for the current year as this month was reopened to allow fishers to take advantage of the higher price obtained for lobsters during winter. The rapid increase in catch rates in areas 1 and 8 reflect the male moult that occurred in early September in these areas. After moulting and hardening of the new shell, lobster catchability substantially increases as lobsters seek food to replace nutritional reserves depleted during the moulting process. Moulting was restricted to southern regions of Tasmania during September 2000 (Cheshuk 2001, Cheshuk and Philips 2001).

4.1.2 Research catch rates

Table 4. Change in November catch rates from research surveys on the East and South Coasts of Tasmania.

Region	Depth	Reference	Catch Rates (kg/ pot lift)			% change	
	(metres)	Year	Ref. Year	1999	2000	vs Ref. Year	vs 1999
Area 8	45 - 100	Nov'93	0.97	1.08	1.73	+78%	+60%
Area 2	30 - 50	Nov'94	1.36	3.36	2.59	+90%	-23%
Area 2	< 30	Nov'94	1.06	1.49	1.21	+14%	-19%

Research catch rates remain higher than the reference year. Declines over the last year in Area 2 are considered to reflect the lower recruitment that was expected from the puerulus settlement trends (Figure 46, Section 5, page 51). While no trigger points have been triggered for this performance indicator, there is concern that the decline in catch rate in the deeper water regions of Area 2 is greater than the improvement in catch rate seen over the last 7 years. As the puerulus index indicates reduced settlement over the next 5 years, the catch rate may fall below the reference year and trigger the trigger point.

4.1.3 Legal - sized biomass

Table 5. Change in legal-sized biomass in October. Negative values indicate a decline in the percentage change. Shaded lines are regions with greater uncertainty in biomass estimates. "State (adj)" is statewide data excluding regions 1, 4, and 8 where biomass is estimated poorly for recent years (i.e. includes only areas 2,3,5,6 and 7).

Region	Reference	Sized biomass estimate (tonnes)			% change in 2000	
	Year	Ref. Year	1999	2000	vs Ref. year	vs 1999
Statewide	1993	2348	3271	3628	+55%	+11%
State (adj)	1993	1362	1701	1852	+36%	+9%
1	1993	200	393	488	+144%	+24%
2	1993	122	178	206	+69%	+16%
3	1994	65	98	90	+38%	-8%
4	1994	385	698	737	+91%	+6%
5	1993	636	801	885	+39%	+10%
6	1995	251	298	312	+24%	+5%
7	1994	291	326	358	+23%	+10%
8	1993	391	478	551	+41%	+15%

The rock lobster assessment model indicates that there has been continued stock rebuilding over the last year (Table 5). On a regional level, biomass is seen to decline slightly in only the north east coast area (3). The decline in this area was predicted last year on the basis of lower puerulus settlement index in 1996 than in 1995; that is, these areas had high catch rates in 1999 due to a recruitment pulse that has now past. Table 5 also includes values for statewide biomass "adjusted". This adjusted value excludes biomass estimates from areas 1, 4 and 8, as these have been found to consistently over-estimate biomass in the final years of the hind-cast fits (Gardner, 2000). It is encouraging that this adjusted value also indicates stock rebuilding over the last 12 months. In addition, estimated biomass remains substantially higher (>20%) than the reference years in all regions and thus this performance indicator is not affected.

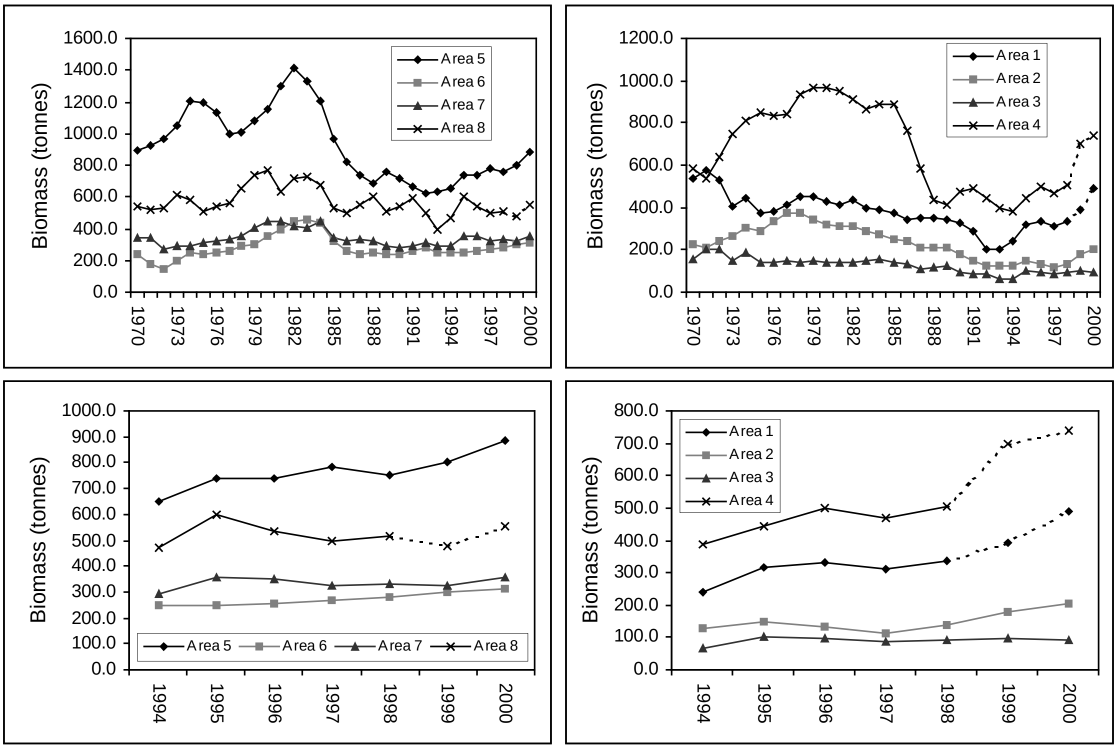


Figure 15. Regional legal-sized biomass estimates for the Tasmanian rock lobster fishery from (upper) 1970 to 2000 and (lower) from 1994 to 2000. All estimates are for October. Interannual changes, which are likely to be less accurate, are dashed.

Biomass estimates for Area 8 obtained from both research and model estimates, appear in general agreement except for the last two years (Figure 16). As noted in the previous assessment report (Gardner *et al*., 2001) there is concern that the pre-season scientific catch rates are being reduced by the September opening that has been in place in 1999 and 2000. As these fishery independent catch rates have been reduced by a portion of the new recruits being fished in September at the end of the previous fishing period, exploitation rates would be lower which would result in over-estimates of biomass using the change-in-ratio method. Continued use of both legal-sized catch rates and exploitation rate estimates using the change-in-ratio method needs to be reviewed if September is to remain opened.

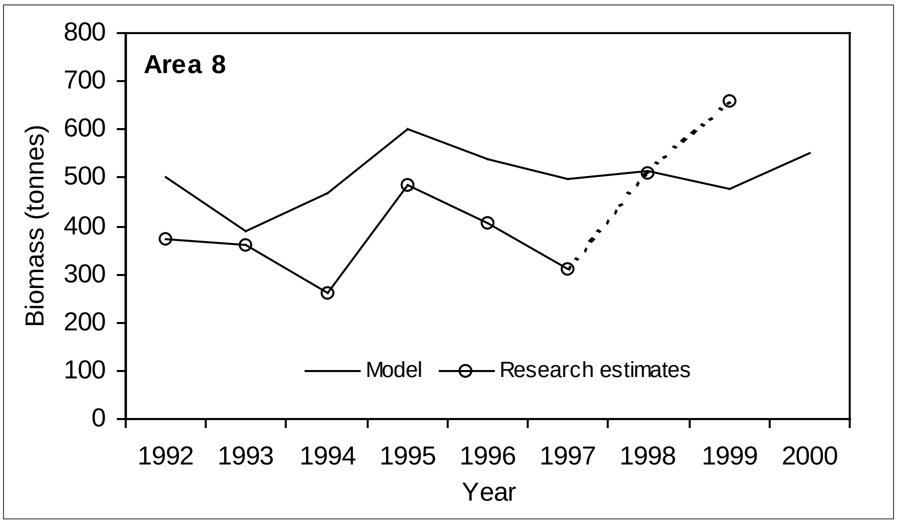


Figure 16. Estimates of legal-sized biomass in Area 8 using change-in-ratio method (Research estimates) and the rock lobster assessment model (Model). All biomass estimates are at the beginning of the open season in November. Research estimates using the change-in-ratio method are based on partial year sampling to March. Dashed lines represent years when research biomass estimates were compromised by the September opening.

4.1.4 Egg production

Egg production estimates are shown in Table 6. Note that the values shown here for reference years varies from that of previous assessments due to the change in parameters used to estimate size at onset of female maturity, as described in Section 3.3.2, page 8.

Table 6. Change in relative egg production from the reference year to 2000, and the level of egg production in 2000 as a percentage of virgin 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. Shaded lines are regions with greater uncertainty in egg production estimates. "State (adj)" is statewide data excluding region 6, where egg production is estimated poorly for recent years. Note: different reference years from previous assessments, due to change in size at onset of maturity parameters (see section 2.3.2).

Region	Reference Year	Relative Egg Production			% change in 2000		% Virgin prodn. in 2000
		Ref. Year	1999	2000	vs Ref. year	vs 1999	
Statewide	1993	876	1057	1067	+22%	+1%	+30%
State (adj)	1993	811	968	987	+22%	+2%	+30%
1	1995	124	121	123	-1%	+2%	+58%
2	1992	63	90	93	+48%	+3%	+36%
3	1993	24	34	35	+46%	+3%	+10%
4	1993	69	137	133	+93%	-3%	+17%
5	1992	72	114	127	+76%	+11%	+13%
6	1986	49	89	80	+63%	-10%	+21%
7	1989	132	149	146	+11%	-2%	+49%
8	1994	300	323	330	+10%	+2%	+112%

Egg production has increased in all areas relative to the reference years except area 1. This decrease may be due to the increase in Tasmanian recreational fishing effort, most of which is directed to this area (section 3.3.3, page 12).

Although egg production is generally increasing relative to reference years, it remains a concern in northern regions. Our estimates of size at maturity of females from northern zone are substantially smaller than has been estimated previously, however, it still appears that the state-wide minimum legal size limit fails to protect a substantial proportion of mature female lobsters in these northern areas (Figure 6, page 11). These regions still have egg production below the 25% suggested by Frusher (1997a)(Table 6). While egg production has increased in northern regions in comparison to the reference years, the decline in egg production in areas 4 and 6 over the last year is of concern (although the extent of the decline in area 6 is uncertain as estimates from this region are often biased (Gardner 2000)). The decline in egg production in area 7 is of limited concern as estimates of the percentage virgin egg production is 49%.

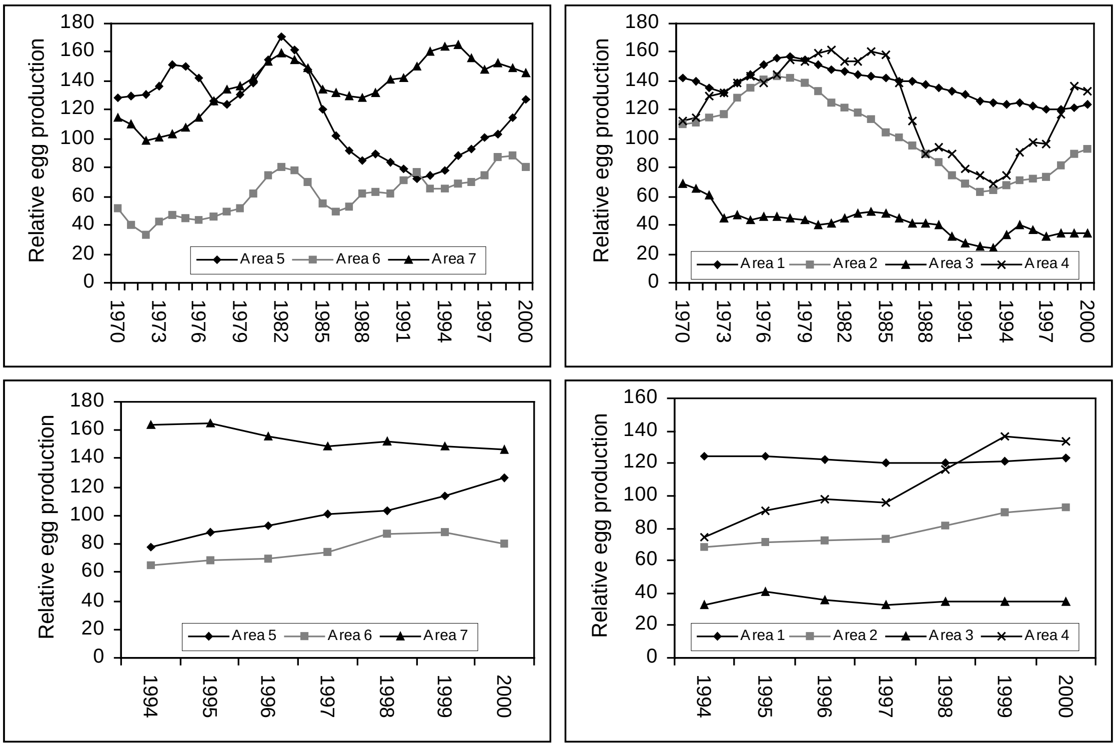


Figure 17. Relative egg production from 7 Areas around Tasmania, western regions to the left, eastern regions to the right. Area 8 is not included due to problems mentioned in the text. Interannual changes, which are likely to be less accurate, are dashed.

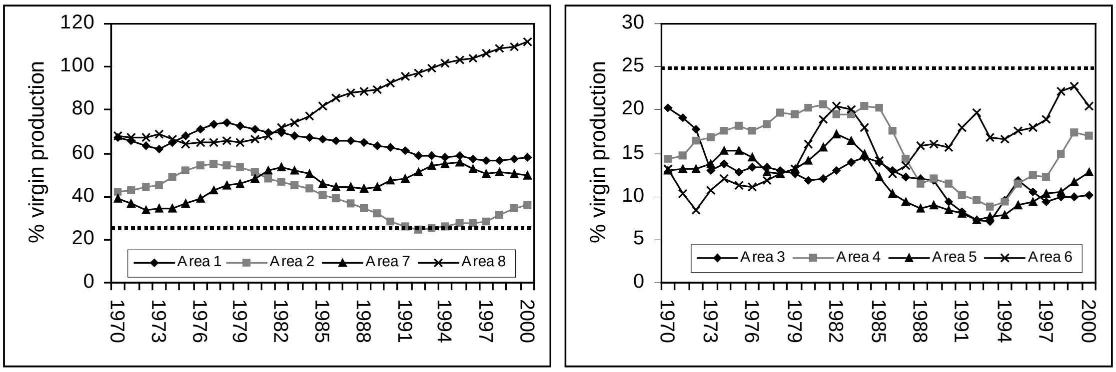


Figure 18. Percentage of virgin egg production from eight Areas around Tasmania, southern Areas to the left, northern Areas to the right. The horizontal bar in each plot represents the management target of 25%. The last year of the plot for Area 6 should be accepted cautiously.

4.1.5 Relative abundance of undersized lobster

Research estimates

For the abundance of pre-recruit lobsters (undersized lobster equivalent to one growth increment below legal size) to be relevant as a performance indicator, a relationship between the catch rate of pre-recruits and the catch rate of newly recruited lobster in the following year needs to be established.

A link between the abundance of undersize and subsequent catch rates has only been defined on the south coast (see Section 4.3) where undersize males of greater than 105 mm CL are assumed to moult to legal size in the following season.

Only sites at Maatsuyker Island have been continuously sampled in Area 8 since the fishery independent surveys commenced in 1992. The lowest catch rate of undersized lobsters (1.43kg/pot lift) was achieved in the pre-season survey (October/November) in 1995. The undersized catch rate from these sites increased to 2.16 in 1999 and to 3.94 in 2000 (Table 7). The 2000 catch rate of undersize lobsters is still substantially higher than the reference year so the undersize trigger gives no cause for concern.

From 1996, research sites at Port Davey were included to increase the number of sites sampled in Area 8. The catch rates of pre-recruits from the Maatsuyker sites and the combined sites (Maatsuyker and Port Davey) are different and thus the combined catch rates cannot be compared to the 1995 reference year. We have included last year's catch rates for the combined sites in Table 7 to determine if the trends in Maatsuyker are reflected in the more extensive data. Both the Maatsuyker and the combined dataset show a positive improvement in fishery independent catch rates of undersized lobsters. The percentage change in catch rate was greater in the more southerly Maatsuyker sites although the absolute change was comparable.

Table 7. Comparison of fishery independent catch rates of undersized male lobsters sampled from waters adjacent to Maatsuyker Island (Maat) and these sites combined with sites at Port Davey (Maat + PD) in similar depths. For Maatsuyker Is, 390 pot lifts were undertaken in the reference year compared to 100 in both 1999 and 2000. Samples from Port Davey are based on 100 pot lifts in both 1999 and 2000. No sampling was undertaken at Port Davey in the reference year of November 1995.

Region	**Reference Year**	**Catch Rates (kg/pot lift)**			**Actual Change (kg/pot lift)**		**% change**	
		Ref. Year	**1999**	**2000**	**vs Ref. Year**	**vs 1999**	**vs Ref. Year**	**vs 1999**
Maat	Nov'95	1.43	2.16	3.94	+2.51	+1.78	+176%	+82%
Maat + PD			3.44	4.72		+1.32		+37%

Model Estimates of Undersized Biomass

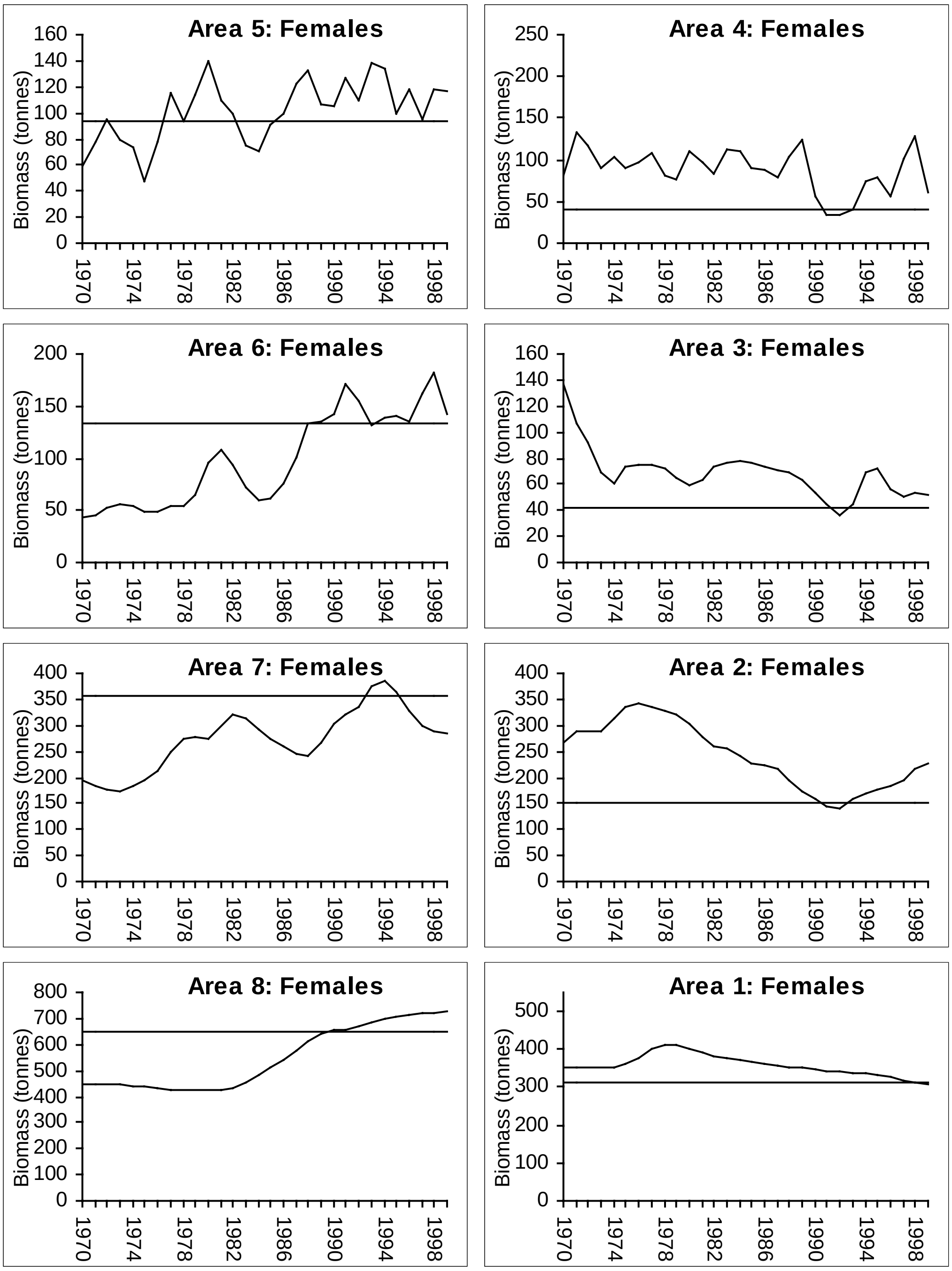


Figure 19. Undersized biomass estimates for female lobsters from 80mmCL to 104mmCL. The horizontal line represents the value of 95% of the reference year. These estimates are back calculated from recruitment estimates of the model.

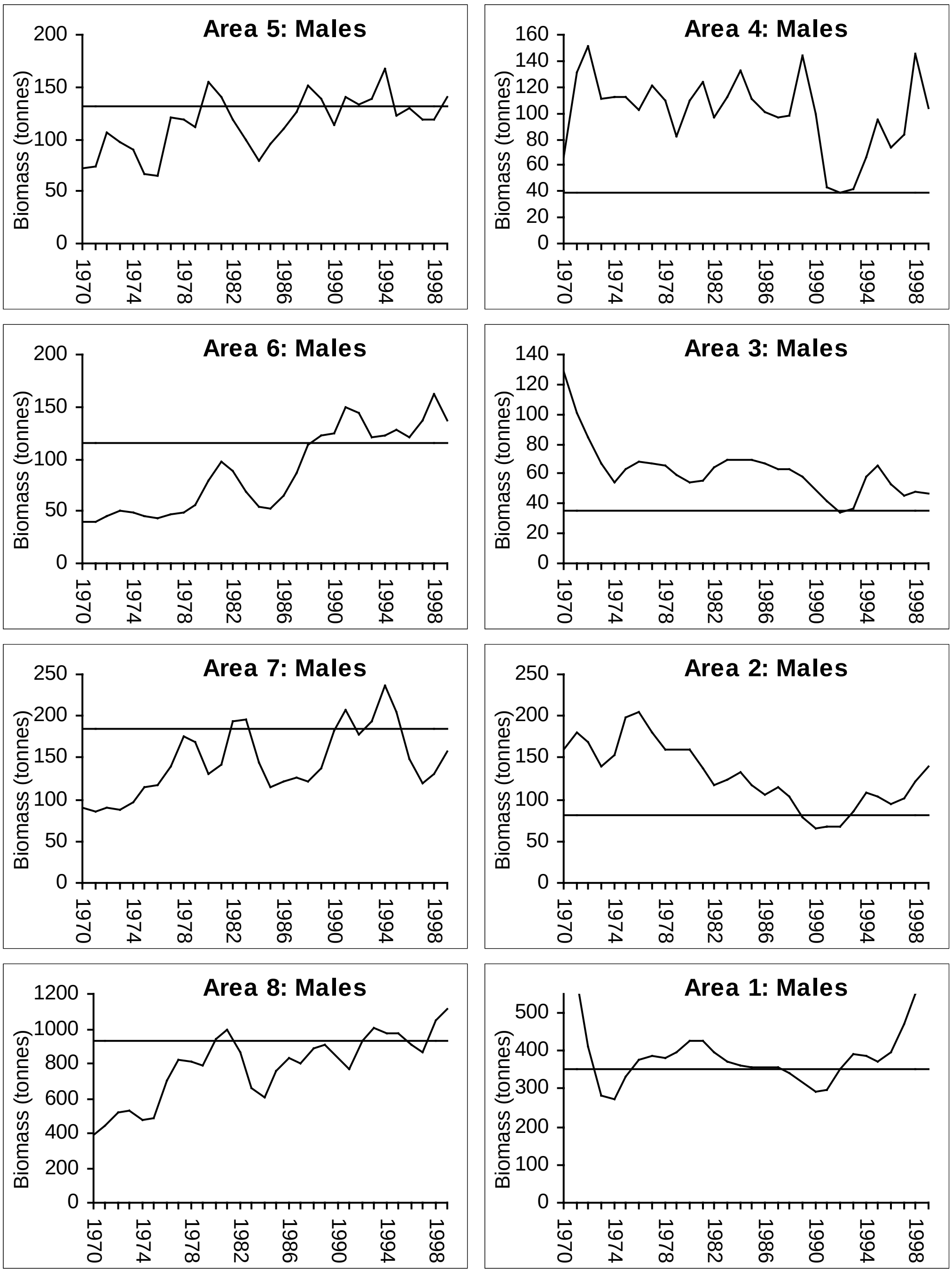


Figure 20. Undersized biomass estimates for male lobsters from 80mmCL to 110mmCL. The horizontal line represents the value of 95% of the reference year. These estimates are back calculated from recruitment estimates of the model.

4.1.6 The total annual catch

The total annual commercial catch (TACC) is constrained by output controls on the fishery. A TACC of 1500 tonnes was introduced for the first time in March 1998 and the management trigger is a catch of 95% or less of this amount (=1425 tonnes). The total catch for the period March 2000 to February 2001 (inclusive) was 1452 tonnes which is greater than the trigger. Several fishers have reported that they retained a small amount of quota unfished, as it was not economically viable to return to sea for this small catch. This implies the TACC shortfall is not a function of lobster abundance.

4.1.7 The size of the rock lobster fleet

Table 8. Changes in the number of licences and vessels in the Tasmanian rock lobster fishery in calendar years from 1993 to 2001. Licenses cannot be created so the 2001 value cannot change although it is based on partial year data. Active licenses are those that recorded catch. It is possible that the number of active licenses in 2001 is an underestimate as it is based on partial year data.

Year	Number of licences	% change	Number of active licenses	% change	Number of active Vessels	% change
1993	337	-	330	-	353	-
1994	334	-0.9	329	-0.3	342	-3
1995	331	-0.9	326	-0.9	348	2
1996	321	-3.0	315	-3.4	332	-5
1997	316	-1.5	309	-1.9	330	-1
1998	314	-0.6	304	-1.6	314	-5
1999	314	0	269	-11.5	270	-14
2000	314	0	259	-3.7	254	-6
2001	314	0	250	-3.5	242	-5

4.1.8 The recreational catch

During the 2000/2001 recreational rock lobster fishing season, a telephone/diary survey of recreational rock lobster licence-holders was undertaken (see Lyle 2000 for methodology). This survey was conducted partly in response to the steady increase in recreational licences issued over the last six fishing seasons (Figure 21).

Since the introduction of the present licensing system in 1995 there has been a 55% increase in the number of rock lobster licence-holders (Figure 22). Fishers are able to hold up to three rock lobster licences, i.e. rock lobster pot, rock lobster dive and rock lobster ring (introduced in 1999), with the total number of licences issued increasing by 89% since 1995 (Figure 22).

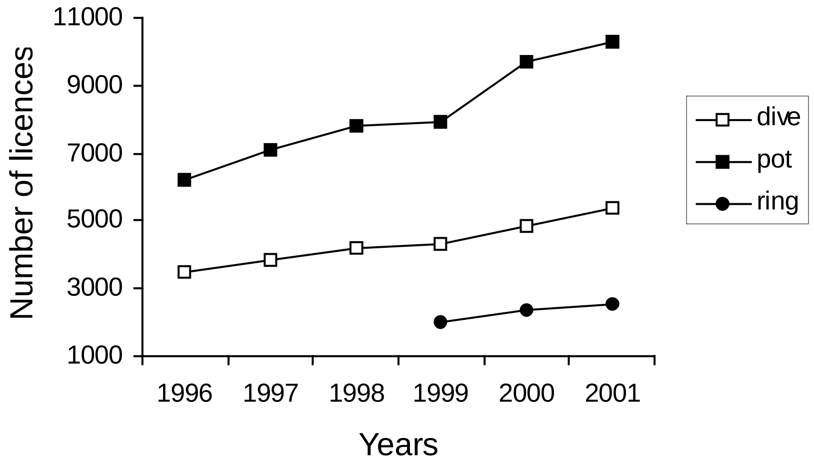


Figure 21. Number of recreational pot, dive and ring licences issued from 1996 to 2001.

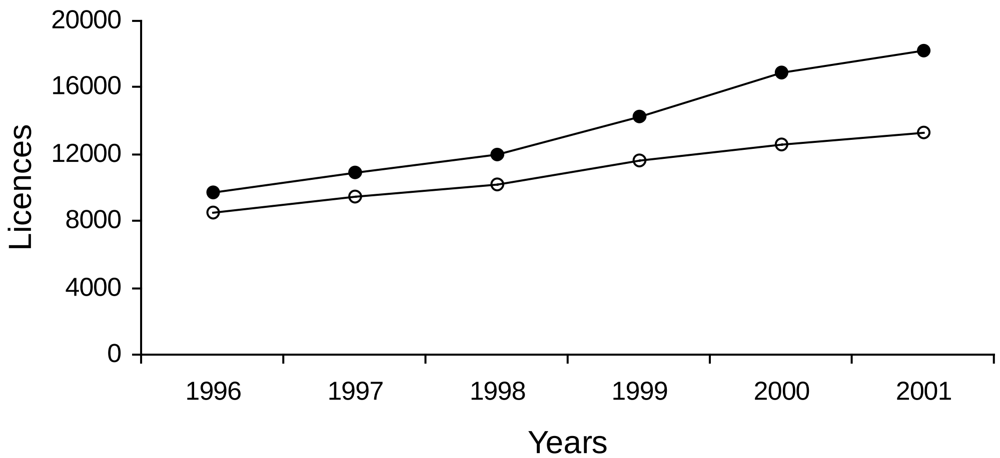


Figure 22. Comparison between the total number of recreational rock lobster licences issued (pots, dive and rings; solid circles) and the number of licence holders (open circles) from 1996 to 2001. No data was available for the number of licence holders in 1999.

Preliminary results from this survey indicate that nearly 130,000 rock lobsters were harvested by recreational licensed fishers in the 2000/2001 fishing season. As in other years, the distribution of the catch is focused around urban and popular holiday regions, with over 44% of the recreational catch coming from south eastern Tasmania adjacent to the capital city Hobart and its associated holiday locations (Figure 23). Although potting is the preferred fishing method (based on catch) in south eastern Tasmania (Assessment area 1), diving is the preferred method in northern regions (Assessment areas 4, 5 and 6).

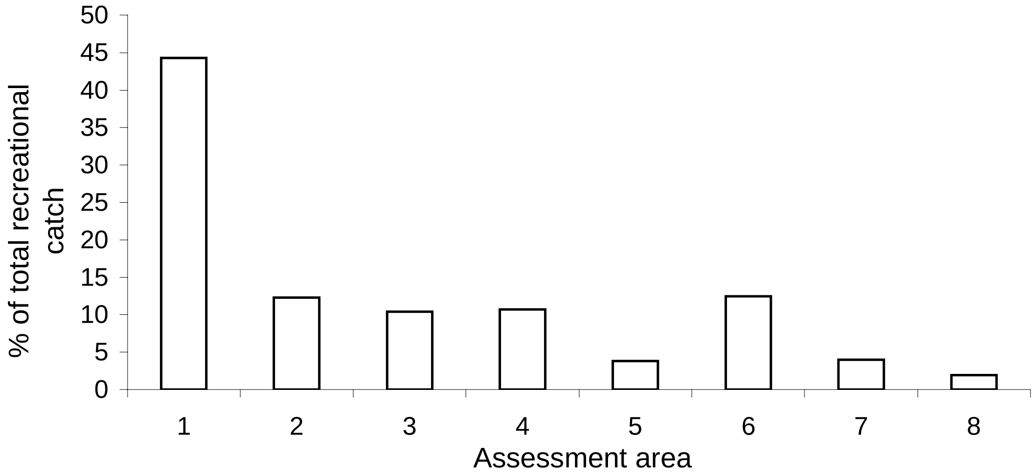


Figure 23. Regional distribution of recreationally caught rock lobsters in Tasmania in 2000/2001. Nearly 45% of the recreational catch comes from south-eastern Tasmanian in assessment area 1.

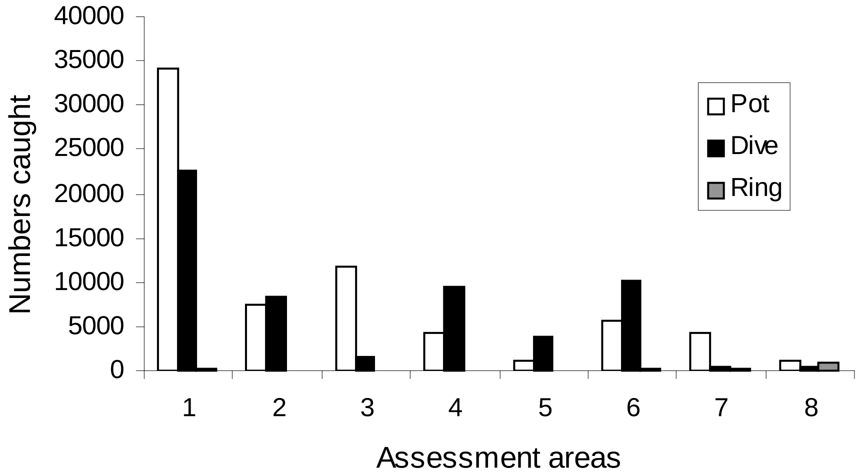


Figure 24. Regional distribution of recreationally caught rock lobsters by fishing method.

Although the 2000/2001 estimated catch equates to approximately 7.5% of the commercial catch in numbers, commercial fishers suggest that this is an under estimate by weight since divers are considered to target larger lobsters than are taken by pots. To explore this concern we estimated the weights of commercially pot caught lobsters from shallow (<15 metres) depths in each of the assessment areas (based on commercial catch returns). These regional weights were applied to the pot proportion of the recreational catch.

To test the sensitivity of the ratio of the recreational to commercial catch in terms of weight based on different assumptions about the average weight of dive caught lobsters, the dive portion of the recreational catch was estimated by using the average pot weight and then increasing this value from 10 to 100%). An estimate was also calculated based on speculative ranges given by a member of the assessment working group (Table 9). The upper 95% confidence limits were obtained by applying the same percentage that was obtained from the bootstrapping procedure of the numbers caught.

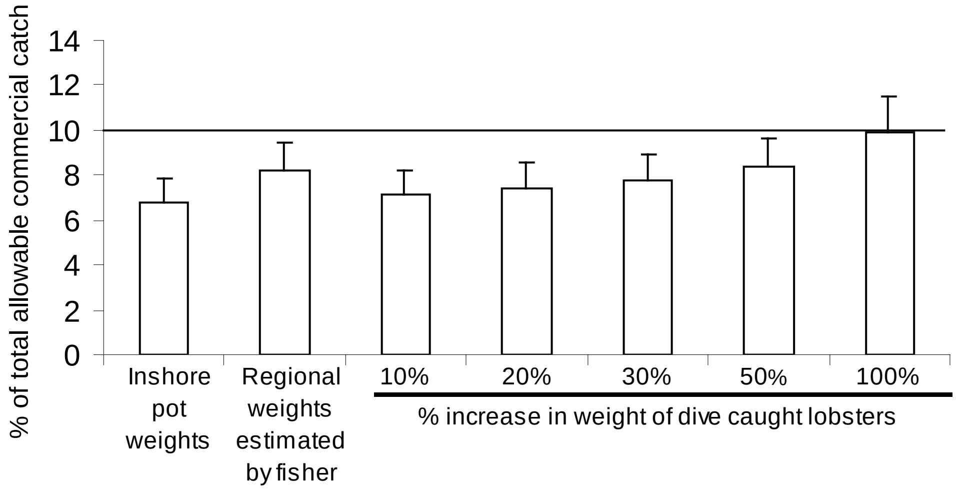


Figure 25. Comparison of the percentage of the recreational catch compared to the commercial catch after a number of different weight conversions (see text for explanation). Error bars are based on the same percentage as obtained for the upper 95% confidence limit for recreational catch in numbers.

Table 9. Annual average regional weights of lobsters caught by the commercial fishery in depths less than 15 meters and potential average weights suggested by the fishing industry for each assessment area. Included also is the percentage of the total commercial catch assumed for recreational fishers for each assessment area

Assessment area	Average weight from commercial pots (<15m) (kg)	Potential weights (from fisher) (kg)	Percentage of total 2000/01 commercial catch (numbers)
1	0.71	0.71	42.2%
2	0.71	0.80	15.3%
3	0.83	1.5	16.1%
4	1.03	2.0	6.5%
5	1.09	2.0	1.8%
6	0.88	1.5	6.0%
7	0.77	0.8	3.6%
8	0.74	0.71	0.6%

Only when the regional weights are doubled for the diving portion of the recreational catch does the recreational catch approach the 10% of TACC trigger (Figure 25). While the performance indicator for the fishery has not been exceeded, future increases in recreational effort, arising from either increased numbers of licensed fishers or improved catches by licensed fishers, are likely to result in an increase in the share of the catch taken by the recreational sector. There is, therefore, a requirement for ongoing monitoring of the recreational rock lobster fishery if the performance indicator is to be assessed, including a need to estimate regional average weights for the dive component of the catch.

4.2 Trends in Commercial Catch Rate Data

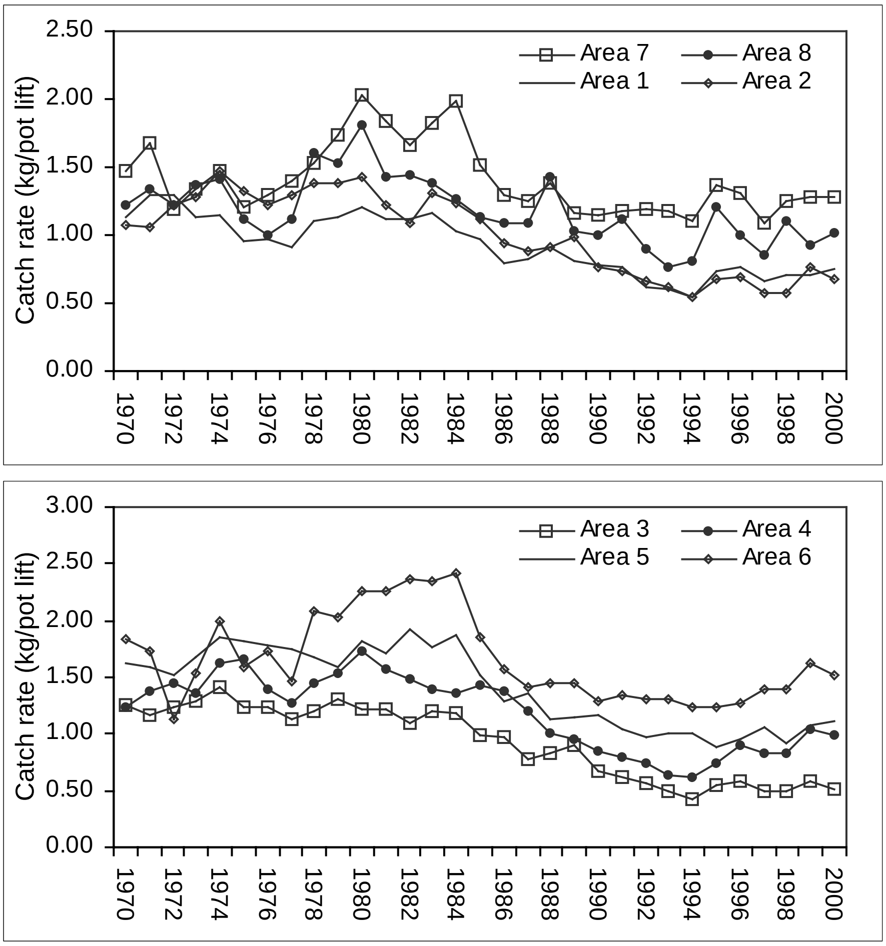


Figure 26. Regional catch rates from southern and northern Tasmania since 1970. Data is presented on a quota year basis (ie March to February) so the last data point is for March 1998 to February 1999 inclusive.

Table 10. Comparison of highest and lowest commercial catch rates (kg/pot lift) regionally around Tasmania from 1970. Comparisons are between years on a quota year basis (i.e. March to February). Included is the regional catch (kg) for the 2000/01 season.

Area	Highest Catch Rate		Lowest Catch Rate		% Difference in Catch Rate	2000/01 Catch Rate	% Difference 1999/00 to 2000/01	Catch 2000/01 (t)
	Year	Catch Rate	Year	Catch Rate				
All	1981/82	1.66	1995/96	0.82	+51%	1.00	-1%	1452
1	1971/72	1.30	1994/95	0.54	+58%	0.75	+6%	98
2	1974/75	1.47	1994/95	0.54	+63%	0.68	-11%	80
3	1974/75	1.40	1994/95	0.43	+69%	0.51	-14%	70
4	1980/81	1.72	1994/95	0.61	+65%	0.99	-4%	233
5	1982/83	1.92	1995/96	0.89	+54%	1.11	+4%	308
6	1984/85	2.43	1972/73	1.14	+53%	1.52	-6%	237
7	1980/81	2.03	1997/98	1.09	+46%	1.28	+0%	110
8	1980/81	1.80	1993/94	0.77	+57%	1.02	+10%	317

Although the catch rates in Table 10 are for different months than those presented in Table 3 (May to February and January to December respectively), the Statewide (All) figure is the same. Although there are differences in regional estimates, the trend of declines on the east coast and improvements on the west coast is similar.

4.3 Trends in fisheries independent abundance indices

4.3.1 East Coast Shallow

Trends for both the commercial and research legal-sized catch rates are relatively similar and flat (Figure 27). Commercial catch rate tends to show greater between year fluctuations than the research catch rates. Research catch rates would be expected to be less variable as they are obtained from the same site whereas commercial catch rates will reflect the commercial distribution of the fishing fleet in this region during November of each year. As noted in Table 3 and Table 4 there has been a decline in commercial and research catch rates over the last year respectively. Further declines in these catch rates are anticipated if the relationship between puerulus settlement and catch rates in Area 2 is maintained (Figure 46, page 51).

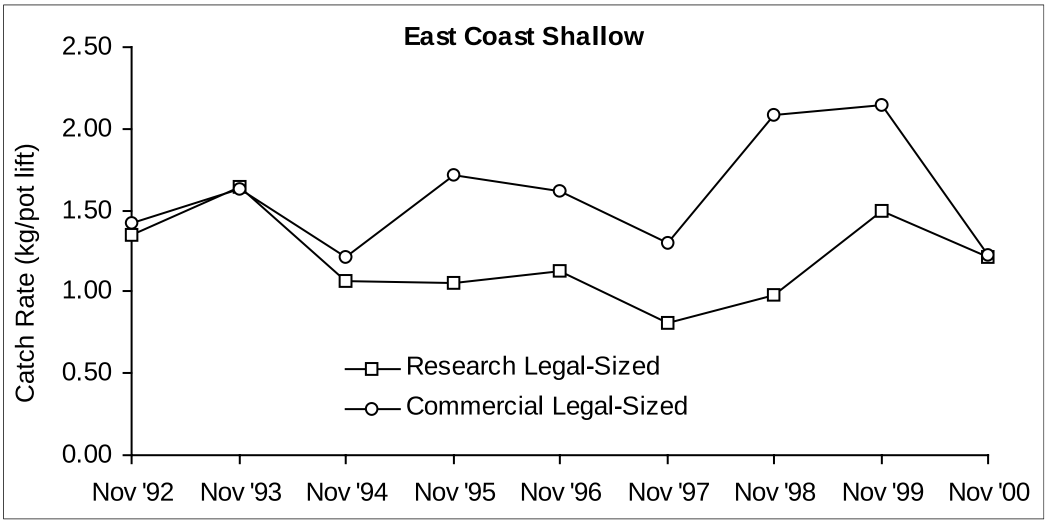


Figure 27. Shallow water catch-rates (<35m) from the east coast of legal-sized lobsters from research surveys and commercial fishing.

The relationship between the catch rate of pre-recruits (males between 102 and 110 mm CL; females between 98 and 105 mm CL) and legal-sized lobster prior to commencement of the following year is weak (Figure 28). This is primarily due to the large catch rate of pre-recruits in November 1997. With the exception of this year, the remaining 8 years show a relatively flat trend in research catch rates of both pre-recruits and legal-sized lobsters.

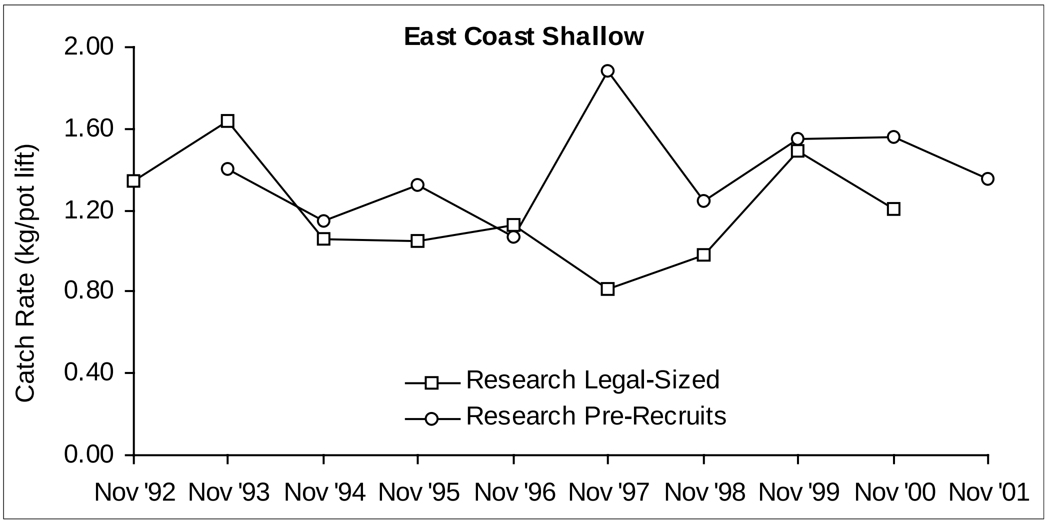


Figure 28. Shallow water catch-rates (<35 m) from the east coast of legal-sized and pre-recruit lobsters from 1992 to 2000 survey periods. The pre-recruit lobsters (males between 102 and 110 mm CL; females between 98 and 105 mm CL) have been advanced by 1 year to simulate growth of undersized lobsters to legal size. Undersize catch rate has been a reasonable predictor of catch rate of legal-sized lobsters the following year, apart from 1996/97. The reason for this deviation is unclear but may have been due to atypical moult timing.

4.3.2 East Coast – Medium Depth

As with the trends in shallow water catch rates on the East Coast (<35 m), the trend in catch rates in medium water depths (35-50 m) is relatively flat for both commercial and research legal-sized lobsters (Figure 29). The relationship between both catch rates is generally close until November 1998. Unlike in shallow water, the commercial catch rate from medium depth water tends to exhibit smaller fluctuations than the research catch rate. There appears to be no relationship between pre-recruit catch rates and catch rates of legal sized lobsters in the following year (Figure 30). In comparison declines in catch rates of pre-recruits match declines in legal-sized lobsters of the same fishing season (Figure 31) suggesting that the fluctuations in catch rates reflect changes in catchability rather than abundance.

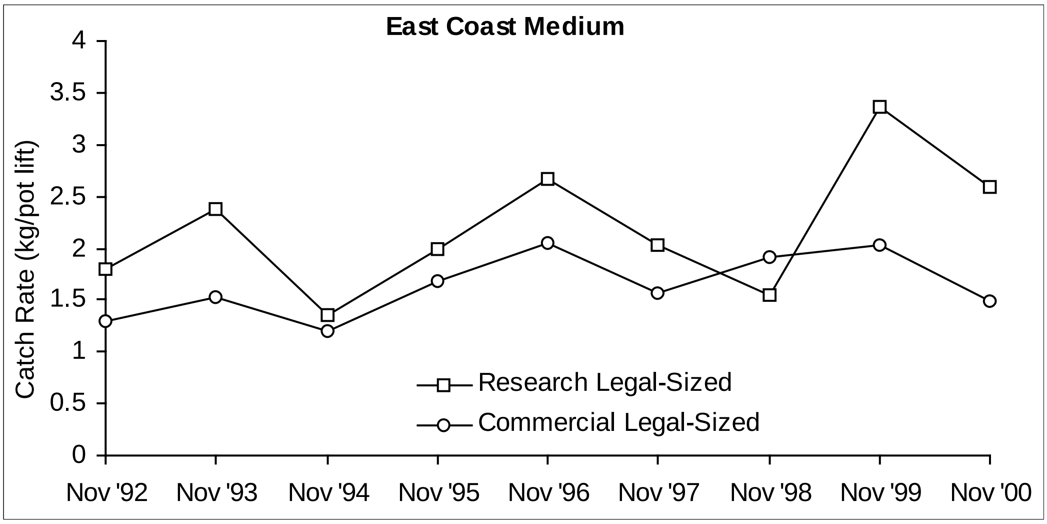


Figure 29. Medium depth (35-50 m) catch rates for the east coast of legal-sized lobsters from research surveys and commercial fishing for the start of the fishing season.

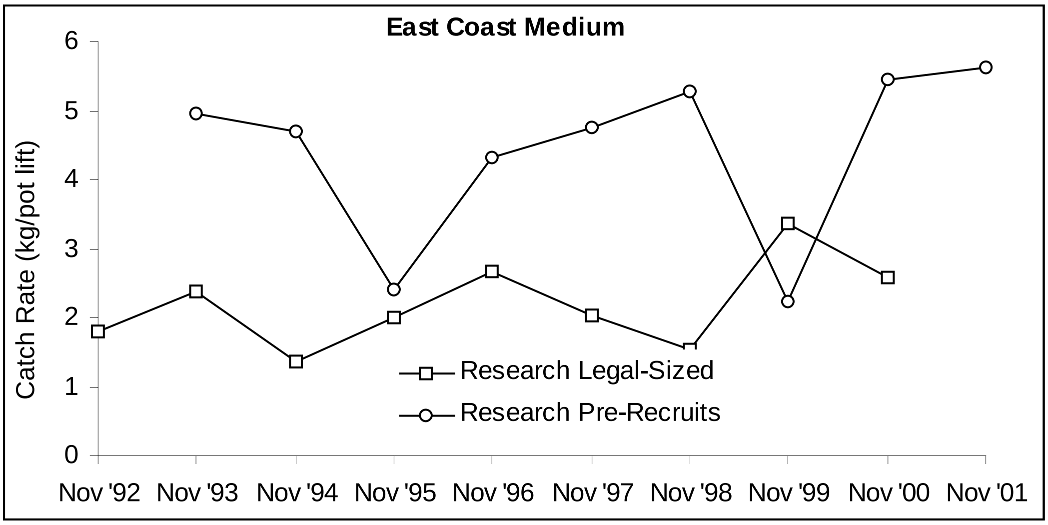


Figure 30. Medium depth (35-50 m) catch rates from the east coast of legal-sized and pre-recruit (males between 102 and 110 mm CL; females between 98 and 105 mm CL) lobsters for the 1992 to 2000 survey periods. The pre-recruit lobsters have been advanced by 1 year to simulate growth of undersized lobsters to legal size.

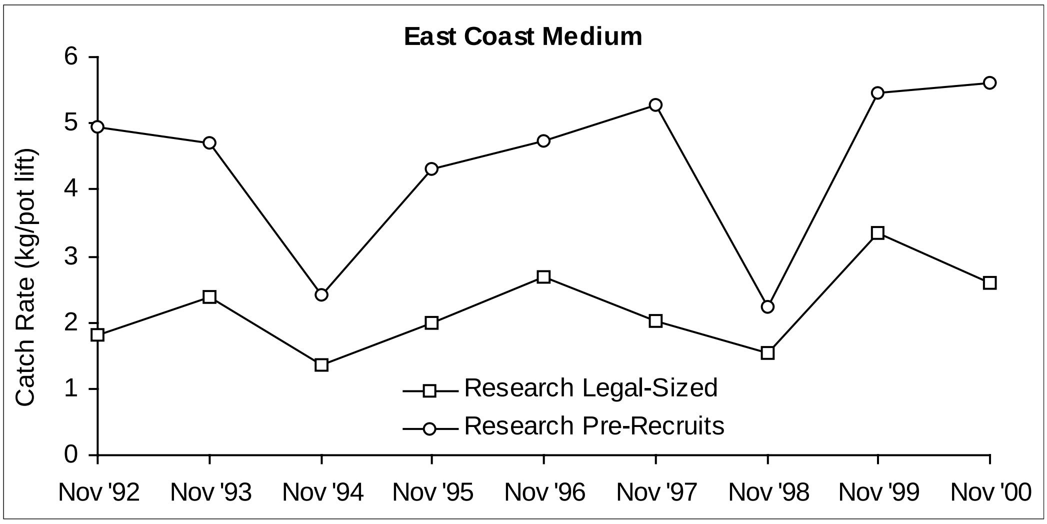


Figure 31. Medium depth (35-50 m) catch rates from the East Coast of legal-sized and pre-recruit lobsters for the 1992 to 2000 survey periods. The pre-recruit and legal-sized lobsters have been plotted on the same time series. The similarity in trends of pre-recruit (males between 102 and 110 mm CL; females between 98 and 105 mm CL) and legal-sized lobsters suggests that the inter-annual fluctuation is more an effect of catchability than recruitment (compare with Figure 30, which shows the same data, only with a time lag of 1 year).

4.3.3 South Coast - Medium to Deep Depths

Both commercial and research catch rates show substantial fluctuation over the 9 years of comparisons (Figure 32).

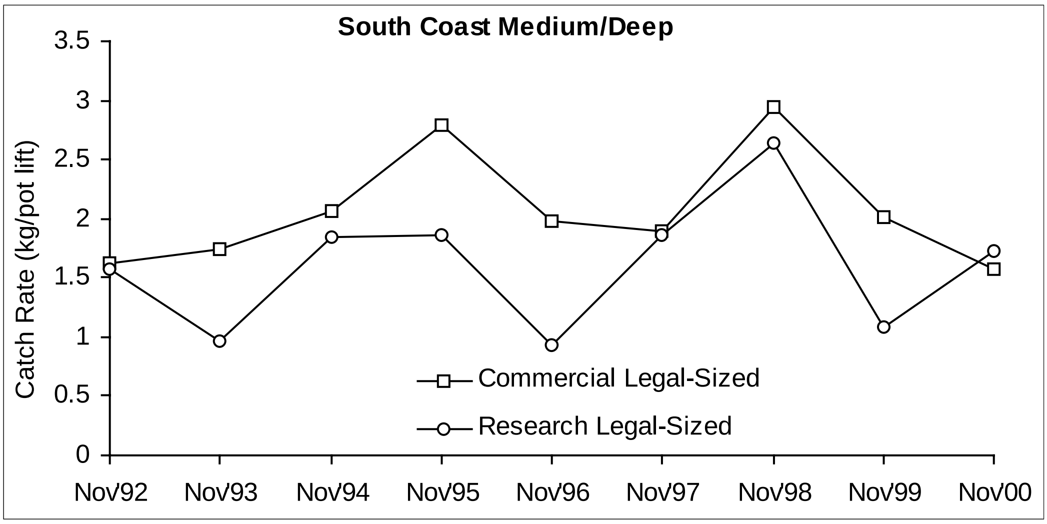


Figure 32. Medium to deep water (45-100 m) catch rates for the south coast of legal-sized lobsters from research surveys and commercial fishing for the start of the fishing season.

There appeared to be general agreement between the pre-recruits (males between 106 and 110 mm CL) and the one-year lagged legal-sized catch rates for the first 6 years (Figure 33). Since this time, the pre-recruit catch rates have steadily increased while the legal-sized catch rates have shown considerable inter-annual variation with no pronounced trend.

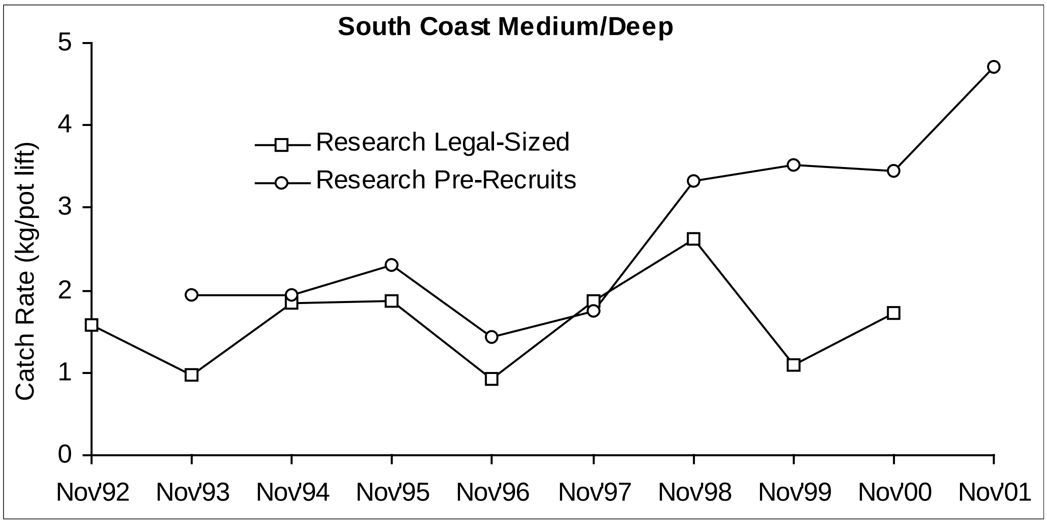


Figure 33. Medium to deep water (45-100 m) catch rates from the south coast of legal-sized and pre-recruit lobsters (males between 106 and 110 mm CL) for the 1992 to 1997 survey periods. The pre-recruit lobsters have been advanced by 1 year to simulate growth of undersized lobsters to legal size. Pre-recruit catch rate has been a reasonable predictor of catch rate of legal-sized lobsters the following year, apart from in 1999/00. The reason for this deviation is unclear but may have been due to atypical moult timing.

4.4 Other analyses including risk assessments

Projections of future biomass and virgin egg production were conducted using one hundred simulations with averages of these simulations shown here. Estimates of error around these averages are estimated by the variation in these different simulations.

Various projection scenarios were tested, based on the industry's request to explore the options of increasing the TACC while still maintaining reasonable probability of stock rebuilding. Scenarios were based on round number increases to the per-pot quota holding (with a total of 10507 pots in Tasmania).

The scenarios tested were:

- the status-quo of 1500 tonnes (142.7 kg/pot);
- TAC of 1523 tonnes (145 kg/pot);
- TAC of 1550 tonnes (147.5 kg/pot);
- TACC of 1576 tonnes (150 kg/pot)

4.4.1 Biomass

Legal-sized biomass projections for the next six years show that there is only minor stock rebuilding with a fixed 1500 tonnes TACC for this period (Figure 34). All TACC scenarios predict stock rebuilding to occur until March 2002 (Figure 35). Beyond this period, the projections suggest that biomass may slightly increase at a TACC of 1500 tonnes, may be stable at a TACC of 1523 tonnes, and be in decline with higher TACC scenarios. Note however that the uncertainty associated with estimates increases with additional years forward, due to recruitment variation (Figure 35).

As noted by Gardner (2000), legal-sized biomass estimates for the southern areas (1 and 8) tend to be slightly positively biased. Removing these areas from the projections results in all scenarios showing relatively stable legal-sized biomass, with the exception of the 1576 TACC scenario, which shows a slight downward trend (Figure 36 and Figure 37). As the bias in legal-sized biomass estimates decline from southern to northern Tasmania, forward projections were undertaken based only on the northern regions (4 and 5). These projections indicated stable legal-sized biomass for TACCs of 1500, 1523 and 1550 tonnes, but a decline at 1576 tonnes (Figure 38 and Figure 39).

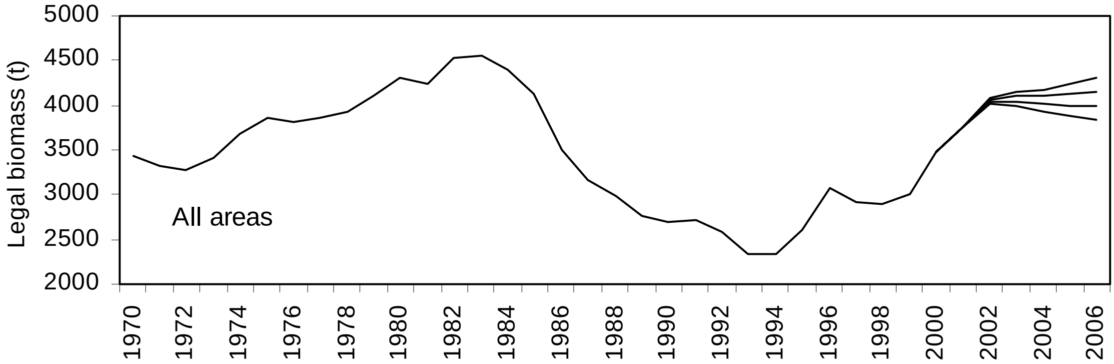


Figure 34. Statewide legal-sized biomass estimates from November 1970 to November 2000 with averaged trajectories to 2006 of biomass for TACCs of 1500 (upper line), 1523 (upper medium line), 1550 (lower medium), and 1576 (lower line). Biomass estimates are for the month of March.

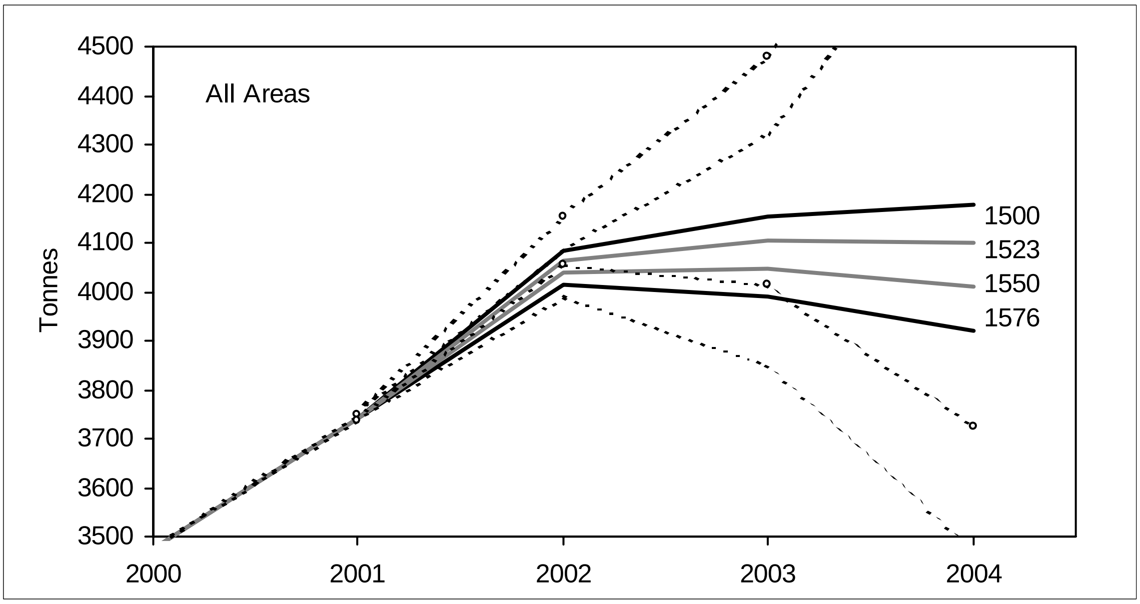


Figure 35. Statewide legal sized biomass projections showing the same data presented in the previous graph (Figure 34) but focused on projections for the next 4 years. Biomass estimates are for March. Maximum and minimum ranges of the 100 simulations are shown for the 1500 and 1576 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

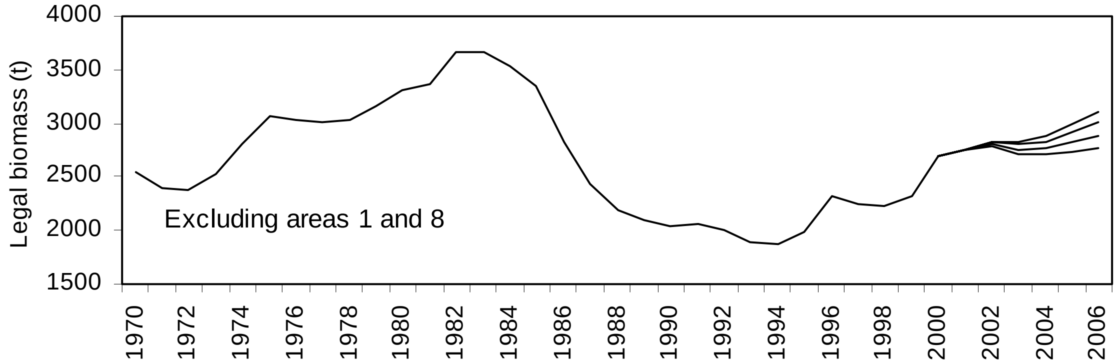


Figure 36. Legal-sized biomass estimates from November 1970 to November 2000 with averaged trajectories to 2006 of biomass for TACCs of 1500 (upper line), 1523 (upper medium line), 1550 (lower medium), and 1576 (lower line) for areas 2 to 7 (that is, with areas 1 and 8 excluded). Biomass estimates are for the month of March. Biomass projections from Areas 1 and 8 are typically most positively biased.

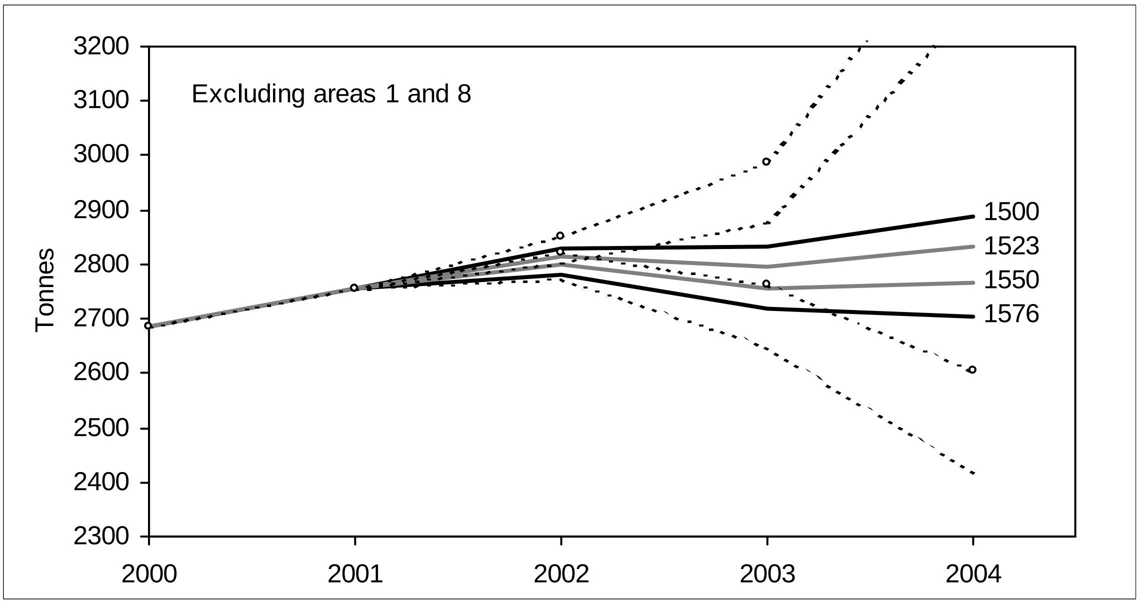


Figure 37. Legal sized biomass projections with areas 1 and 8 excluded showing the same data presented in the previous graph (Figure 36) but focused on projections for the next 4 years. Biomass estimates are for March. Maximum and minimum ranges of the 100 simulations are shown for the 1500 and 1576 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

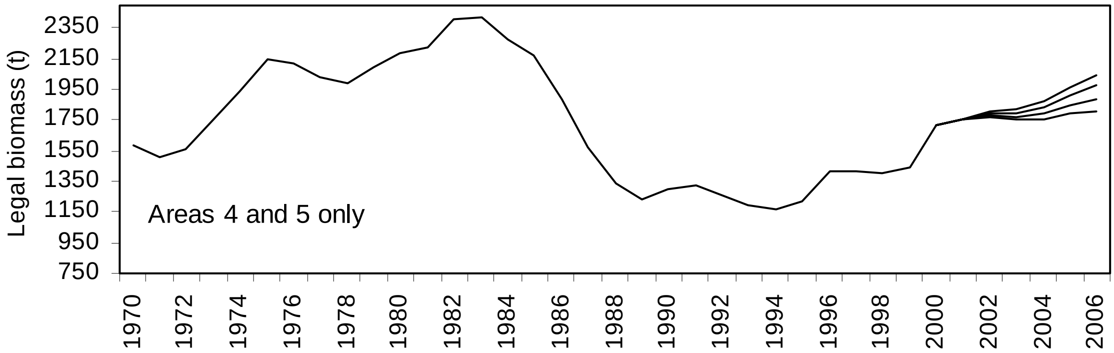


Figure 38. Legal-sized biomass estimates from November 1970 to November 2000 with averaged trajectories to 2006 of biomass for TACCs of 1500 (upper line), 1523 (upper medium line), 1550 (lower medium), and 1576 (lower line) for areas 4 and 5 only (Northern areas). Biomass estimates are for the month of March. Biomass projections from Areas 4 and 5 are typically least biased.

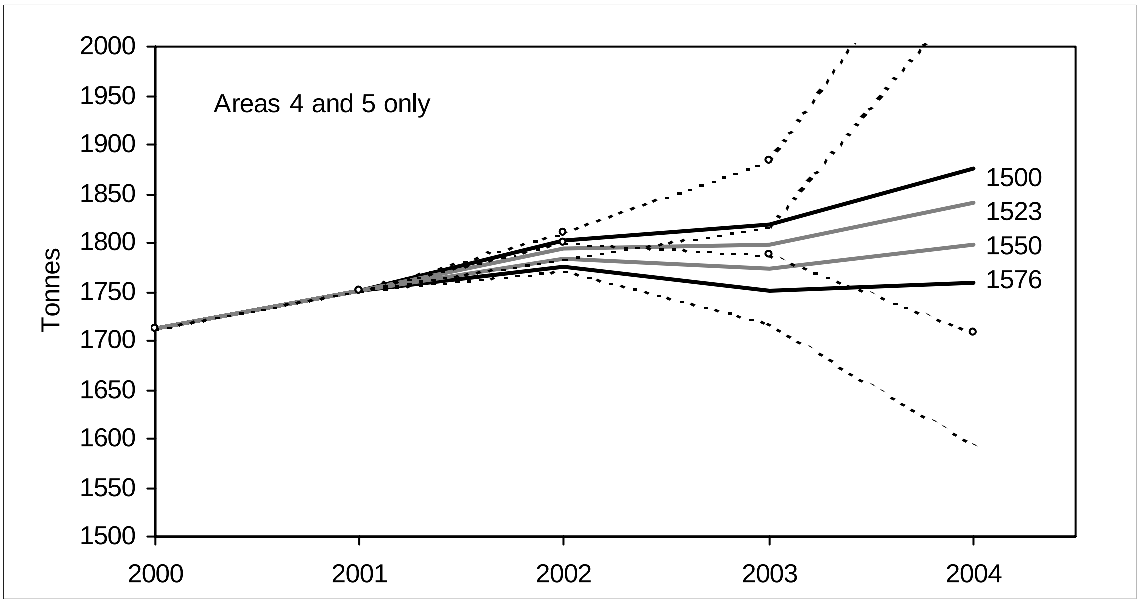


Figure 39. Legal sized biomass projections for areas 4 and 5 only showing the same data presented in the previous graph (Figure 38) but focused on projections for the next 4 years. Biomass estimates are for March. Maximum and minimum ranges of the 100 simulations are shown for the 1500 and 1576 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

Regional projections of legal –sized biomass estimates show increases in biomass in all areas except 4, 6 and 7 between 2001 and 2002 (Figure 40). After 2002 some areas continue to increase (1, 3 and 8), some continue to decline (6 and 7) and the remaining regions show mixed results for different TACC scenarios (5) or are relatively flat (2 and 4). These regional differences highlight the spatially complex nature of the fishery and the need for an accurate fleet dynamic model.

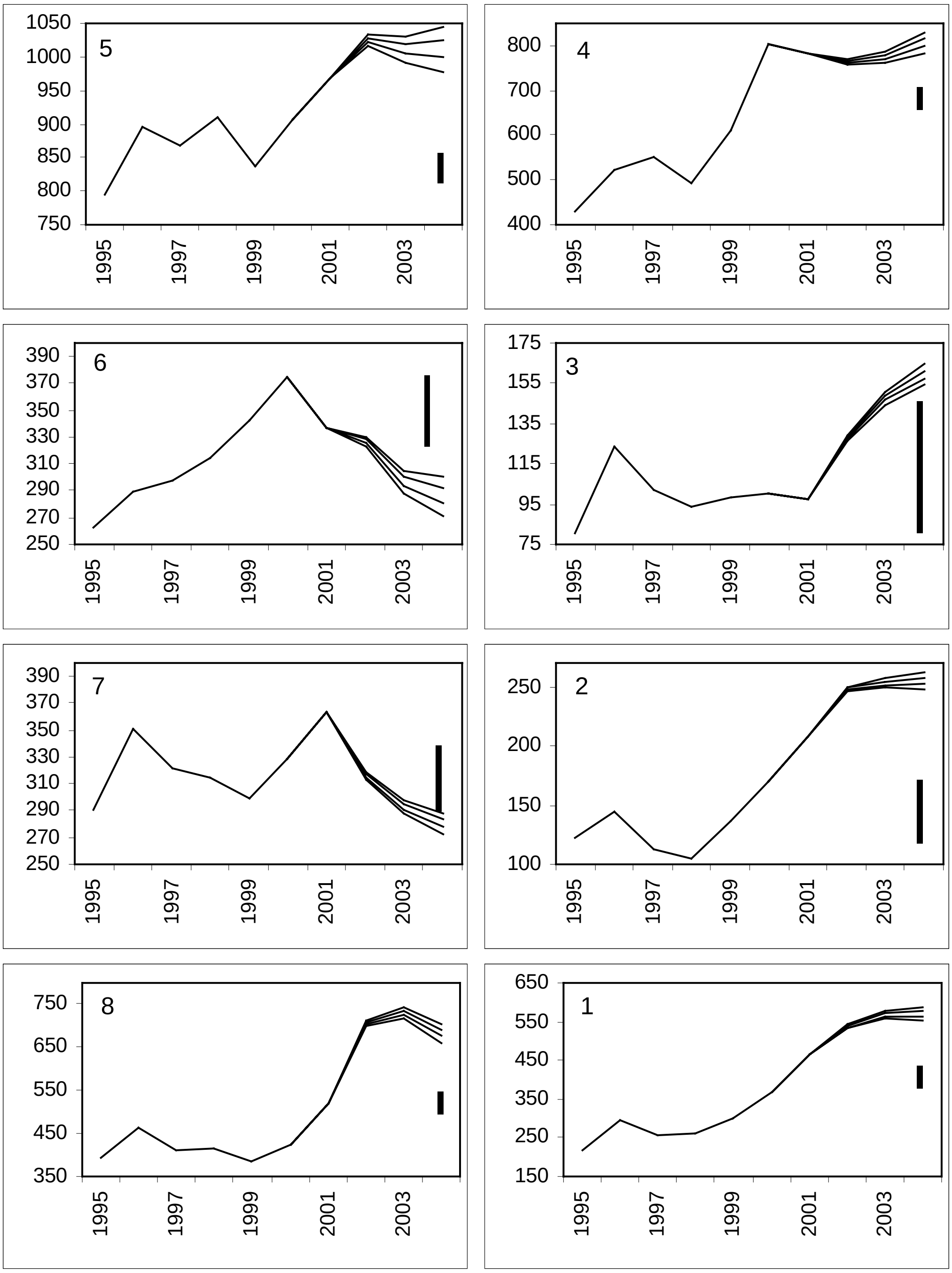


Figure 40. Mean legal-sized biomass projections for TACCs of 1500 (upper line), 1523 (upper medium line), 1550 (lower medium), and 1576 (lower line) for each stock assessment area. Each plot is scaled differently to enable the different projection scenarios to be distinguished. A scale bar is included in each figure equivalent to 50 tonnes to facilitate comparison between areas.

4.4.2 Egg Production

Statewide egg production is expected to increase with all TACC scenarios (Figure 41 and Figure 42). In northern areas where increases in egg production are required, the average trajectory of all scenarios shows an improvement in egg production (Figure 43 and Figure 44). However, none of the scenarios are likely to lead to rebuilding above the level of 25% of virgin production by 2004. In northern areas, the 1576 TACC scenario indicated only a minor increase in egg production would occur. Of the four northern areas that are in need of improved egg production to bring them to 25% of virgin egg production, only areas 3 and 4 are expected to improve under any of the TACC scenarios (Figure 45).

Note that all TACC scenarios have a similar effect on egg production in southern areas, most difference between alternative scenarios happens in the north. This highlights the need to understand fleet dynamics in model projections; these projections indicate that the fleet will respond to an increased TACC by removing proportionally more females from northern areas than southern areas.

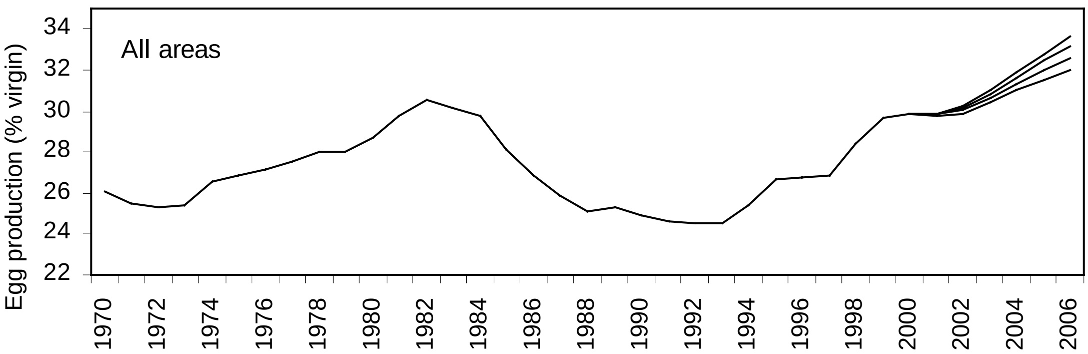


Figure 41. Averaged statewide egg production relative to virgin under 4 TACC scenarios: 1500 (upper line), 1523 (upper medium line), 1550 (lower medium), and 1576 (lower line). All trajectories are the average of 100 simulations.

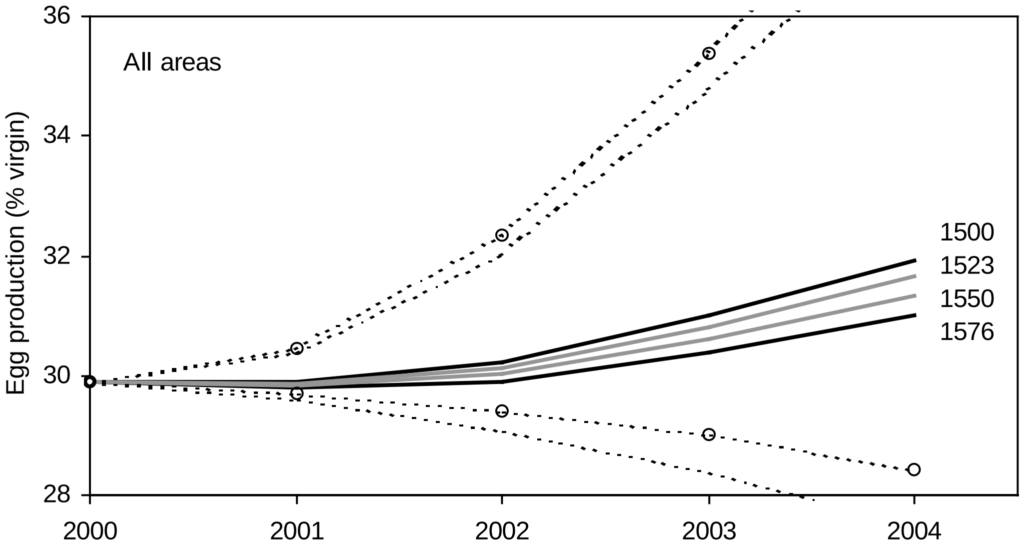


Figure 42. Statewide egg production projections (as % of virgin) showing the same data presented in the previous graph (Figure 41) but focused on projections for the next 4 years. Maximum and minimum ranges of the 100 simulations are shown for the 1500 and 1576 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

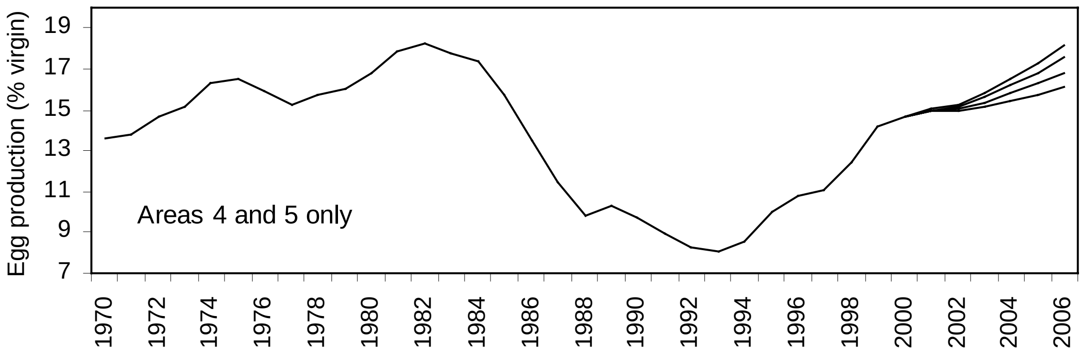


Figure 43. Mean relative egg production in the north of the state (Areas 4 and 5) under 4 TACC scenarios: 1500 (upper line), 1523 (upper medium line), 1550 (lower medium), and 1576 (lower line). Means are drawn from 100 simulations.

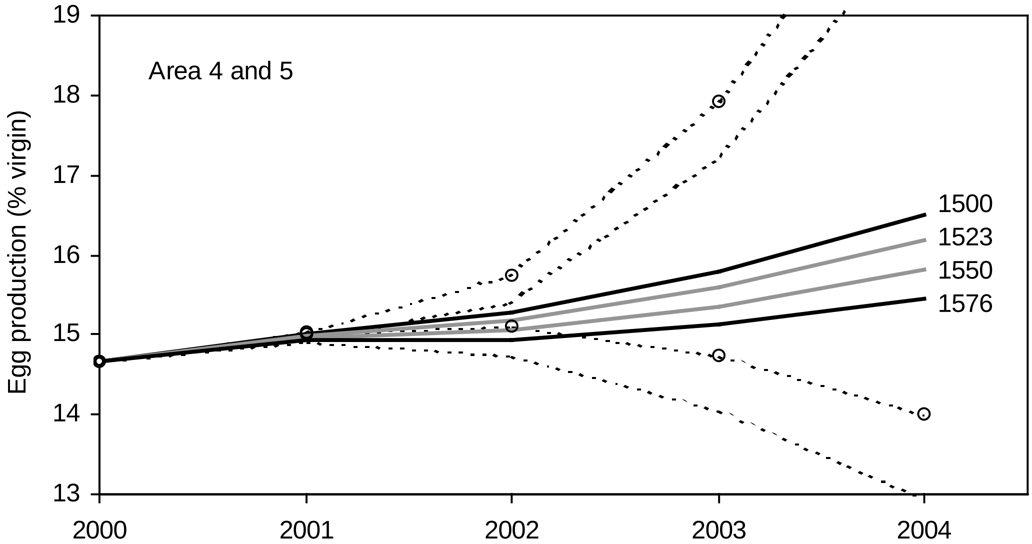


Figure 44. Egg production projections (as % of virgin) from areas 4 and 5 combined showing the same data presented in the previous graph (Figure 43) but focused on projections for the next 4 years. Maximum and minimum ranges of the 100 simulations are shown for the 1500 and 1576 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

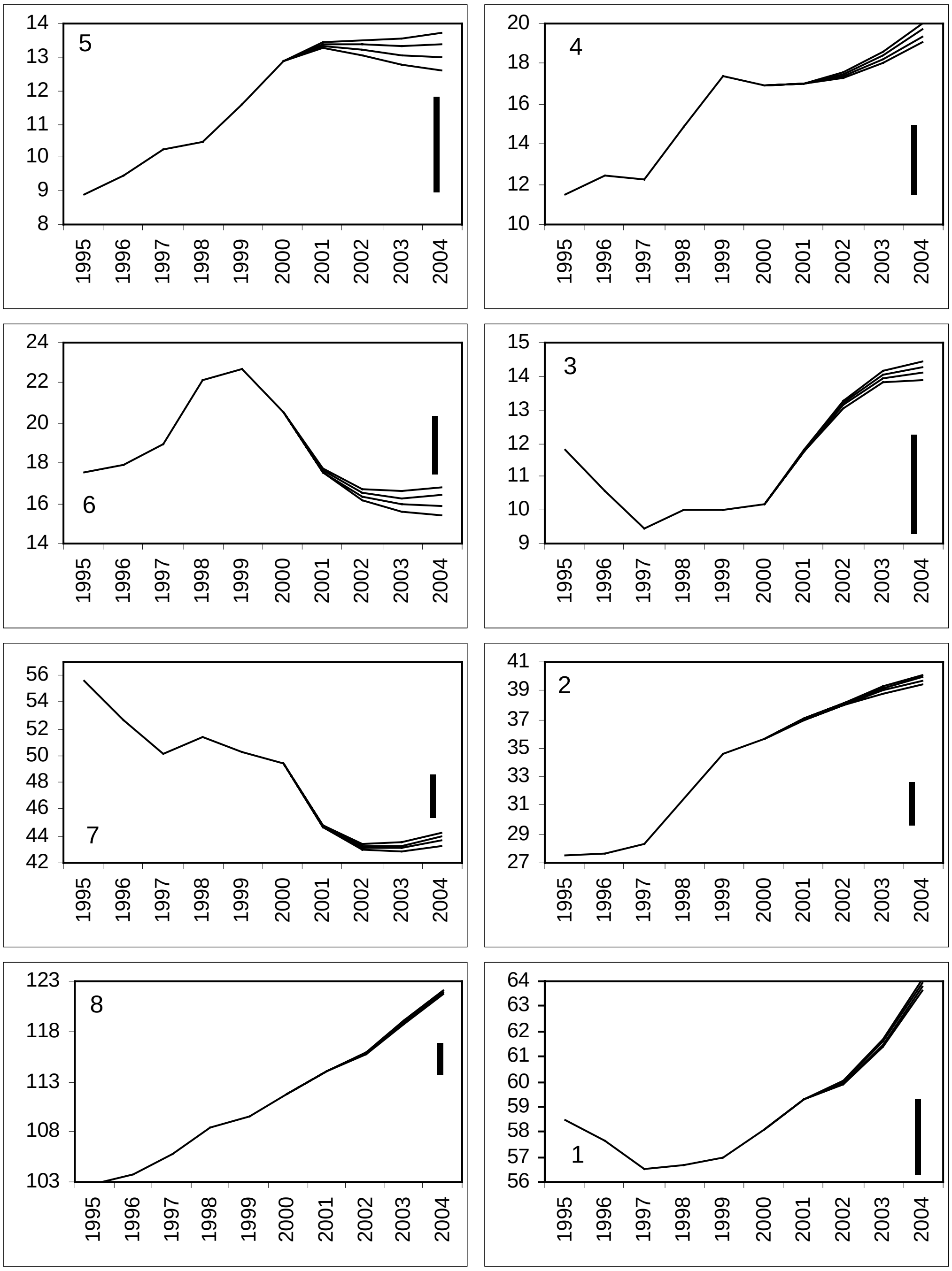


Figure 45. Mean virgin egg production in each of the stock assessment areas under 4 TACC scenarios: 1500 (upper line), 1523 (upper medium line), 1550 (lower medium), and 1576 (lower line). Means are drawn from 100 simulations. Note that each plot is on a different scale. A scale bar equivalent to 3% change in egg production relative to virgin is included in each plot to facilitate comparison.

5. Recruitment

In the previous stock assessment report, it was shown that the puerulus index from Bicheno can predict catch rates in several catch and effort reporting blocks along the east coast. In this report the index is compared to catch rates for stock assessment areas 2 and 3 (Figure 46). This spatial scale is slightly broader and more directly relevant to the stock assessment process. Although correlation is less than for the restricted regions, it remains statistically significant with the puerulus index correctly predicting the spike in catch rates in 1999/00 and the fall in catch rates over the last year - 2000/01.

If this correlation continues to remain strong, we would therefore expect catch rates along the east coast in regions 2 and 3 to remain relatively low for the next 4 or 5 years.

Patterns in the puerulus index from other regions of the coast are shown in Figure 47. Currently, a relationship between puerulus index and recruitment to the fishery has only been demonstrated for the Bicheno region, although King Island puerulus data also appears to correlate with catch rates. We remain cautious with the interpretation of data from King Island due to missing data from some years. An important test of the King Island data set will be in 2003 when a recruitment spike is predicted.

Insufficient data has been collected from the remaining sites to test correlation with catch-rates (ie at Recherche Bay, South Arm and Flinders Island). This is because growth from puerulus to recruitment is slower in southern regions of the state, and because the Flinders Island site was only established in 1996.

Recent collaborative research between CSIRO and TAFI has indicated that puerulus settlement in the southern regions of the state is likely to be relatively consistent from year to year, while occasional spikes in settlement are expected in the north, particularly at Flinders Island (Bruce *et al*., 2000). This may account for the sharp increase in catch-rates from Flinders Island over the last 2 years. The increased catch rate in area 4 impacted on regional fishing trends and overall statewide catch rates in 1999 and 2000 and thus we expect collection of settlement data from Flinders Island to be particularly valuable for management in the future.

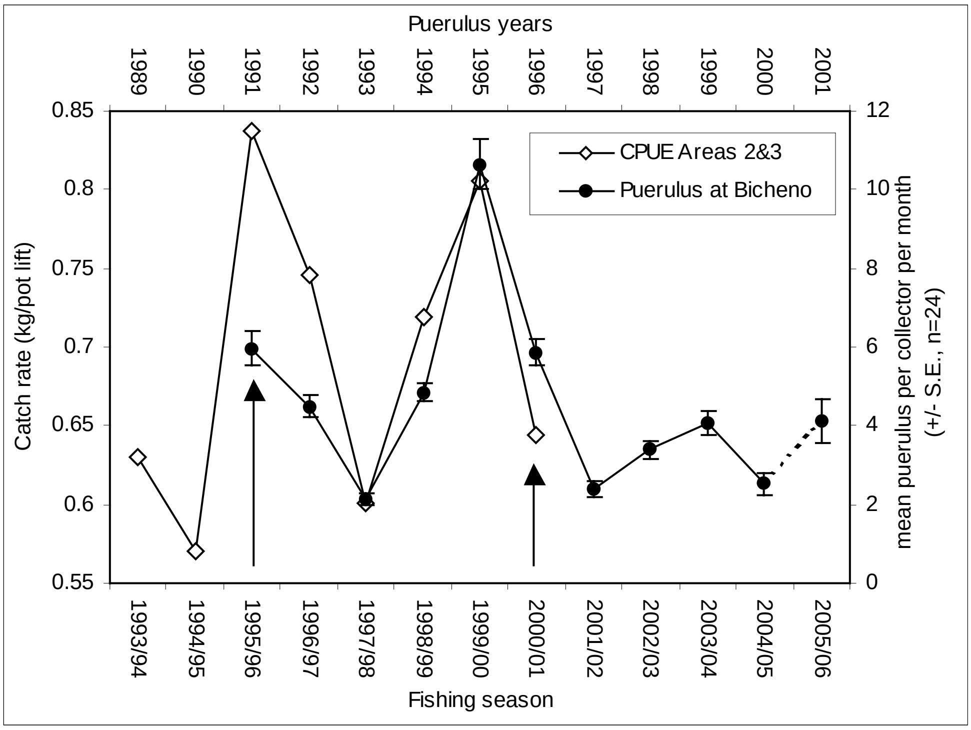


Figure 46. Correlation between inter-annual change in commercial catch rates for eastern Tasmania (areas 2 and 3) and puerulus index from Bicheno. Puerulus index has been shifted forwards 5 years to simulate growth from settlement to legal size. Arrows indicate the extent of the current overlap, which is 6 years. Puerulus settlement data for the most recent year is incomplete.

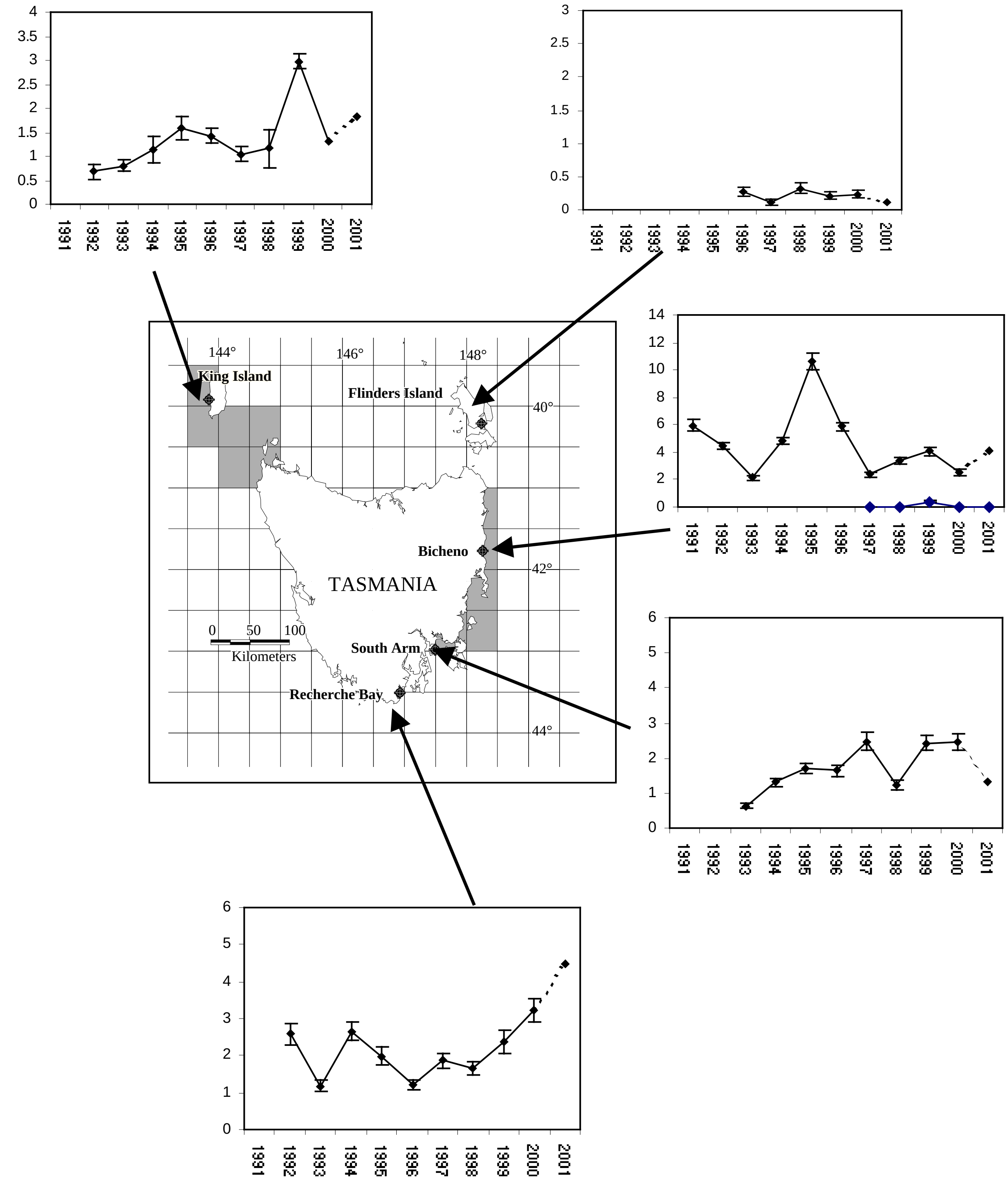


Figure 47. Inter-annual trends in puerulus index from monitoring sites around Tasmania. Scale on y-axis in all plots is the mean number of puerulus per collector per month (+/- S.E.). Quarter degree reporting blocks shaded in grey are those for which puerulus index is currently providing indication of future recruitment to the fishery. Data for 2001 is incomplete. Two lines are shown on the plot for the Bicheno region; these relate to *Jasus edwardsii* (higher catch rates) and *J. verreauxi* (lower catch rates).

6. Changes in the Fleet Dynamics in Response to ITQ.

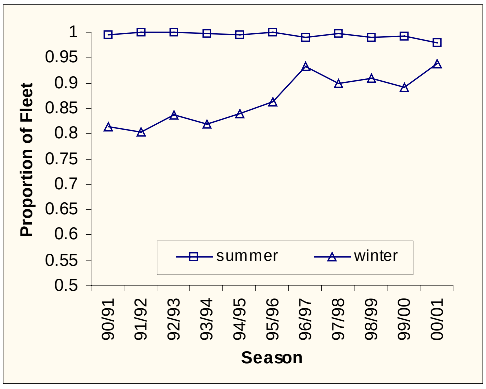
It is believed that there have been two major changes in the fishery since the introduction of the quota management system: a move to an increase in fishing during the winter months, and a tendency for fishers to localise their efforts or favour shallower inshore sites. In this section the commercial catch and effort data collected from the fishery is investigated to see if there is evidence to support these claims.

It will become clear that the amount of catch that has been taken in the winter months has been increasing, not only since the introduction of quota but from the early 1990's. However, the rate of this increase has increased in the last 3 years since quota was introduced.

On the other hand, with the data available there was no clear evidence to support the claim that fishers have localised their efforts in terms of either the area or the depths where fishers are fishing.

6.1 Temporal Allocation of Catch

Historically, fishing effort was concentrated during the summer months of higher catch rates and catches (Gardner et al, 2001). However, during the 1990s the development of the live fish market in Asia saw the price of fish during winter months fetch up to twice that of the summer months. This encouraged fishers to put more effort into the winter months. The proportion of vessels fishing in winter has indeed increased over the last decade while the proportion fishing in summer has slightly fallen (Figure 48).



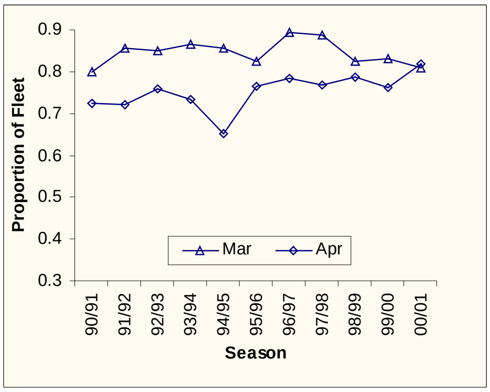


Figure 48 : Proportion of vessels that fished in at least one of the summer months from November to April compared with the winter months of May to September, and in the months of March and April

It was expected that the introduction of quota would further encourage fishers to increase winter fishing. Fishers are under pressure to maintain their return on their now limited catch. As the fishing season now ends in February each year, fishers must ensure their quota has been caught prior to this time. Saving quota for the final months of the season gambles on favourable catch rates, prices and weather during this time. Moreover, trading quota is not profitable at this time as the market value of quota drops considerably because supply exceeds demand as fishers try to obtain some return on quota they cannot feasibly catch before the season end.

No evidence of a change in the trends evident prior to quota introduction is seen in Figure 48. Moreover in Figure 49 it can be seen that that the proportion of boats fishing in any given winter month has continued the increasing trend apparent in the early 1990's. However, it is clear that there has been a drop in the proportion of vessels fishing in each of the summer months from November through February since the introduction of quota with the most marked change occurring in November and February.

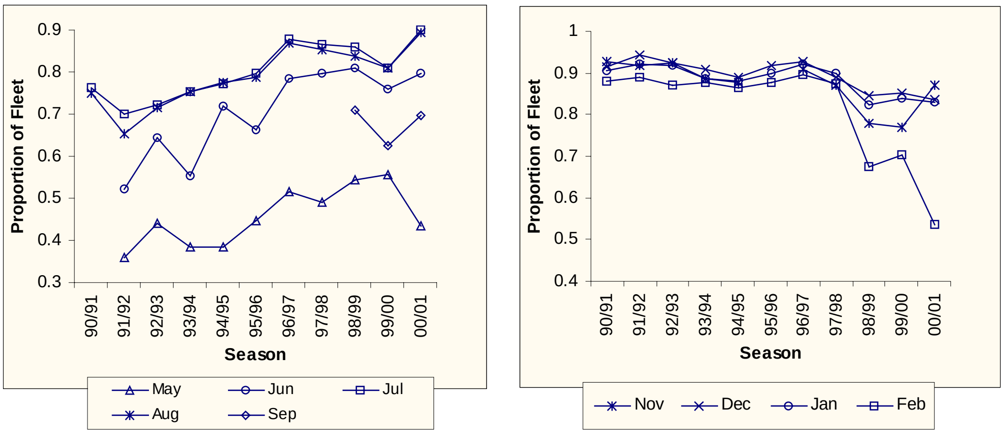


Figure 49 : Proportion of vessels that fished in each of the winter months from May to September, and in each of the summer months from November to February

The above graphs show how many boats were on the water, however, also of relevance is how much catch was taken during each season. In Figure 50 we see that prior to the introduction of quota management in the 98/99 season, the average proportion of a vessel's yearly catch that was taken during winter followed a linear trend as fishers moved toward greater winter fishing. When quota was introduced there was a clear shift in behaviour and the increase in proportion of catch taken in winter can no longer be explained by the trend already in place.

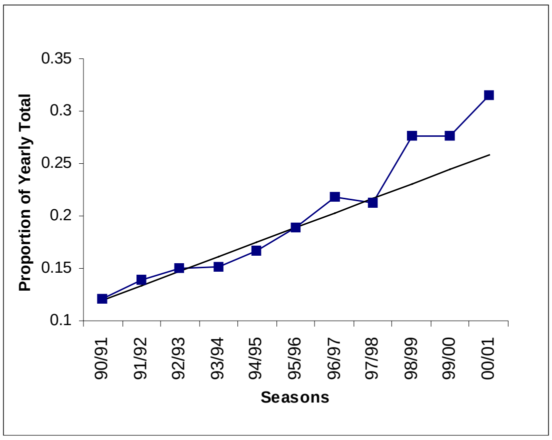


Figure 50 : The average of the proportion of a vessels yearly catch taken during the winter months of May through to September. A linear trend line is fitted to the average values from 90/91 until 97/98, which correspond to the year prior to quota.

In Figure 51 the average of the *logs of catch per unit effort* (lnCPUE) and *return per unit effort* (lnRPUE) are plotted. The return on catch was estimated by multiplying each vessel's monthly catch by the average beach price recorded for that month (indexed for inflation). This figure shows how the change to winter fishing has influenced the economics of the fishery. Although catch rates were falling during the early 1990's, the large differential between summer and winter price for lobster made winter fishing profitable so that fishers have maintained a steady increase in lnRPUE.

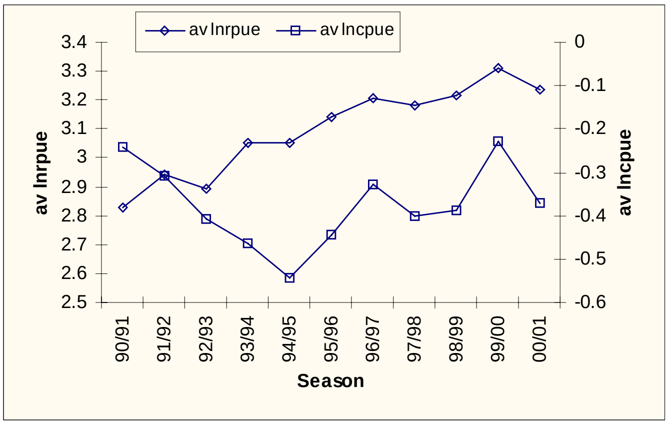


Figure 51 : Averages of yearly average of a vessels logs of the monthly catch per unit effort (lnCPUE) and return per unit effort (lnRPUE).

6.2 Spatial Allocation of Catch

It is believed by management and many industry participants that as the fishery is less competitive fishers have less need to travel large distances for their catch and choose to fish in more convenient locations. If this were true, we would expect to see evidence of this in the number of different regions in which a fisher chooses to fish within a year, with fewer regions being fished now, assuming they are fishing more locally.

However, as can be seen in Figure 52 the average number of (half-degree) blocks in which a fisher fishes over the year has been slightly increasing over the last few years which does not support the claim that fishers are localising.

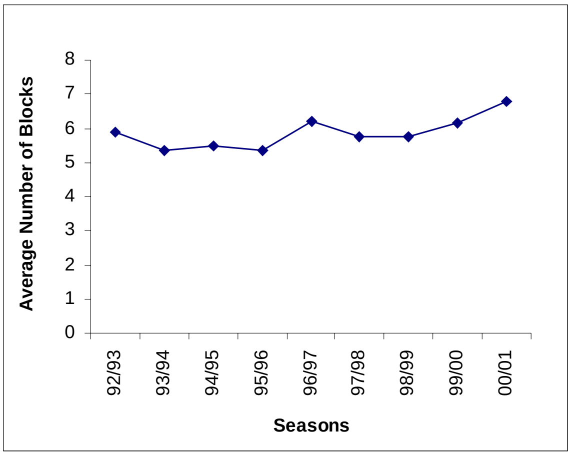


Figure 52 : The average of the number of ½ degree blocks fished by a vessel during a season.

Even though they may fish in roughly the same number of regions, it is possible that the fishers are now taking more of their yearly catch from their "favoured" fishing regions. However, it is clear from Figure 53 that this is not the case. In this figure the average proportion of a vessels catch that is taken from their primary fishing block (the one where they do the most fishing) is plotted.

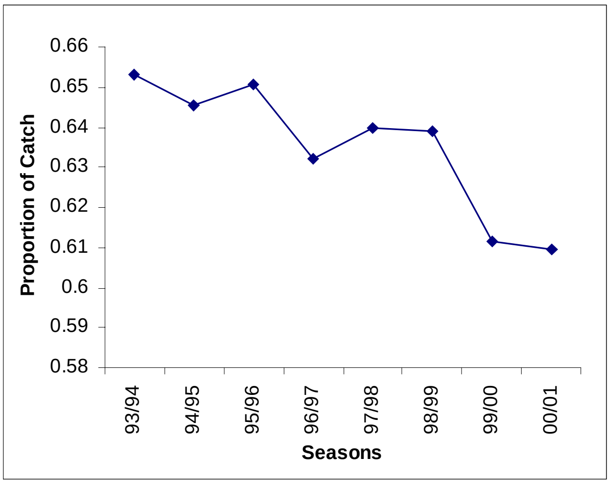


Figure 53 : The average of the proportion of catch caught in primary fishing block.

Although no evidence is apparent to support the claim of localisation of effort there has been some change in the amount of catch taken from shallower sites since the introduction of quota. The change can be seen in
Figure 54 where the relative frequency distributions of the proportion of a fisher's catch that is taken in shallow water are plotted as time series, along with the averages of these distributions. Any depth of 10 fathoms or less is considered as a shallow water site. In the last three years it appears that a lower proportion of the fleet take under 20% of their catch from shallow sights. At the same time, a lower proportion is taking over 80% of their catch from shallower sights. Although the spread of the distributions has changed,

the effect on the average is less apparent. Thus from these graphs there is no clear evidence to point towards an overall increase in shallow water fishing but there is evidence to suggest a change in the depth allocation of fishers is occurring.

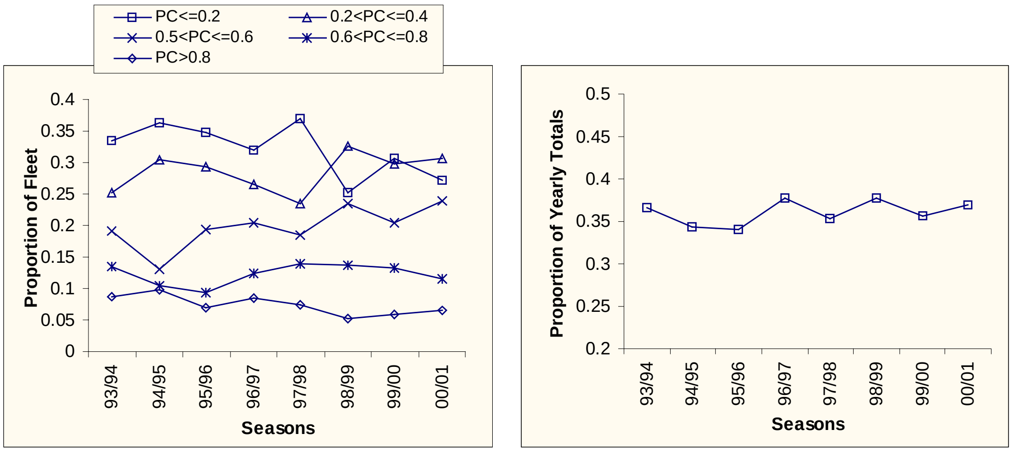


Figure 54 : (a) Time series of the relative frequency distributions of the proportion of catch caught in shallow water and (b) the average of these distributions. PC = proportion of catch.

Finally, in Figure 55 we consider if the distribution of the total commercial catch amongst depths has altered through time. A visual comparison of the proportion of the yearly catch taken from shallow water for the last three years suggests that the proportion taken in shallow water has been stable over the last three years and at a higher level than in the past. However, given the variability of the data, an 8-year history (which covers all depth data available) is not enough to draw firm conclusions. This is apparent from the low R^2 value of 0.0825 for the trend line fitted to data for the years between 93/94 and 97/98. Under the linear model the 80% prediction interval for the 98/99 average value, calculated from a t-distribution with 3 degrees of freedom, is (0.186,0.415). The observed value of 0.320 falls easily within these bounds. Thus there is no evidence to support a claim that since the introduction of quota there has been an increase in the proportion of commercial catch taken from shallower sites.

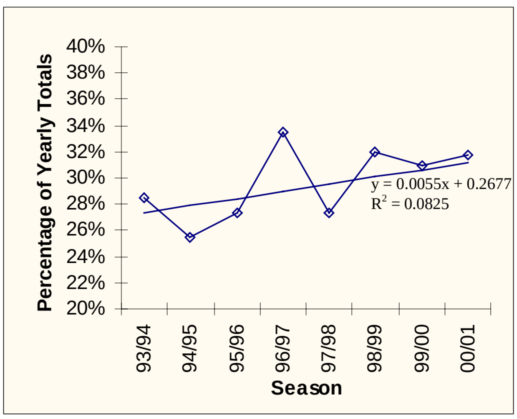


Figure 55 : Proportion of total years catch caught in shallow water with linear trend fitted to data from 93/94 until 97/98

7. Socio-economics of the Tasmanian rock lobster fishery.

Over 250 formal interviews were conducted with participants from all sectors of the industry in 2000/2001 as part of an FRDC funded project 'Impact of management change to an ITQ system in the Tasmanian rock lobster fishery' (1999/140). Researchers spoke with approximately 200 commercial Tasmanian rock lobster license holders. Over 150 interviews were tape recorded with participants from all sectors of the industry. In addition, over 70 interviews were conducted without being tape recorded. Given that many interviews included more than one participant, as well as that many informal conversations were conducted, a total of approximately 350 people were involved in the research. The response was so overwhelming that a full quota year was required to interview all those in the industry who wished to participate in the study.

The large volume of interview data has been converted into a data matrix in SPSS.

To convey, in short, the scope of the matrix, information is entered under the categories of personal information, circumstances of interview, participant type, history in the fishery, changes in fishing dynamics, uptake and use of technology, changes in relations with crew, positives from the introduction of quota, negatives from the introduction of quota, intentions, opinions regarding possible changes in fishery regulations, relations with buyers, impacts on the community, and so on. Interviews are grouped by type of participant including Tasmanian owner-operators, Tasmanian owner-operators leasing in, Tasmanian owner-operators leasing out, mainland owner-operators, mainland owner-operators leasing in, mainland owner-operators leasing out, fathers and sons, mothers and sons, Tasmanian lessees, deck hands, skippers, Tasmanian owner-fishers fishing something else and leasing out, mainland owner-fishers fishing something else and leasing out, Tasmanian retired fisher-owners, processors, leavers, miscellaneous participants, retirees, community participants, brokers, mainland retired fisher-owners, investors and so on. Information from the matrix – descriptive statistics, cross-tabulations and qualitative information, will inform the bulk of forthcoming reports.

As noted, it is possible with the matrix to group participants into 'like' entities or types. This possibility will be used as the basis for a new funding application to build participant types into the fishery assessment process. The effects of proposed management changes on fishery participants could then be considered. Such an agent based modelling approach is an ideal way of combining biological and socioeconomic information for assessment of a fishery. Although these models have been identified as the emerging 'new era' in ESD assessment approaches, they are still largely theoretical due to the lack of empirical data. Data forthcoming from this project places the Tasmanian rock lobster fishery in a unique position of being able to develop such an agent-based model and evaluate its effectiveness.

The following reports are in progress: First, a report detailing the uptake and use of GPS and plotters by fishers in the Tasmanian commercial rock lobster industry; second, a report discussing changes in fleet dynamics, based on interviews with fishers, as part of the move to quota management; and, third, a social impact assessment of the introduction of quota management in the Tasmanian commercial rock lobster fishery.

Three issues have clearly emerged from the research, namely: financial difficulties experienced by those attempting to buy into the industry; the need for a clear and broadly-based longer-term vision for the industry; and the requirement to develop socioeconomic performance indicators for the fishery. On the basis of these issues, arising from this work, a set of performance indicators has been prepared by the Department of Primary Industries, Water and Environment. These indicators will be included in the rock lobster fishery management plan for 2001-2006. This plan is still in draft and has not been released.

8. Ecosystem Impacts

8.1 Bycatch

Bycatch composition in the rock lobster fishery was described in detail in the previous stock assessment report (Gardner *et al.*, 2001). Although the bycatch caught per pot is low, there was approximately 1.45 million pots lifts undertaken in Tasmania in the 1999/00 fishing season. However, the use of escape gaps, which are mandatory in the Tasmanian fishery, reduce bycatch by over 80% (Frusher and Gibson 1998). It was also noted that the majority of bycatch is returned alive and apparently unharmed. It was concluded that the impact of lobster potting on bycatch species appears to be low.

Monitoring of bycatch has continued since that report with bycatch from approximately 3500 pot-hauls recorded since the previous stock assessment report. No change in bycatch has been noted. This work is ongoing to enable the tracking of change in bycatch composition.

In addition to monitoring of bycatch composition, additional research has been initiated on the tagging of bycatch species to investigate abundances and ecological interaction with rock lobsters. Species include various leather jacket species, purple- and blue throat wrasse, draughtboard sharks, conger eels and octopus. These were the main species that were found to influence lobster catch rates (Brickhill et al., submitted). This sampling has only been conducted for 2 years so no results are available as yet, although numerous recaptures have already been obtained. Sampling has been conducted in both fished populations and also in two protected areas (Crayfish Point scientific reserve and Maria Island MPA).

8.2 Interactions with endangered species

Interactions with endangered and threatened species were discussed in detail in the previous stock assessment report (Gardner *et al.*, 2001). No verified interactions with endangered or threatened species have been detected since that report, although some fishers have reported seabirds flying into their boat lights at night. These birds were not killed, but there appeared to be potential for damage. The fishers were uncertain of the species involved but are currently attempting to note if any of the listed threatened species are involved.

8.3 Decline in beds of string kelp

Giant kelp (Macrocystis pyrifera) is one of the fastest growing plants in the world and has been measured at growing 11cm/day in Tasmanian waters. It is highly productive, and the amount of biomass it can generate on one reef in a short amount of time has led to speculation it is an important component of reef ecology.

Many areas of reef which once supported large communities of *M. pyrifera* are altering due to anthropogenic, biological and physical reasons. Large areas of our coast that were once kelp forest have declined with up to 90% loss of cover along areas of eastern Tasmania. These areas are now dominated by 'urchin barrens' or by introduced species. There is potential for this broadscale alteration in community structure to impact upon puerulus settlement and survival. Research undertaken in the mid 1990's demonstrates that *M. pyrifera* provides habitat and food for early benthic stage lobsters (M. Edmunds PhD thesis).

In an attempt to broaden the knowledge base about lobster interactions with other species, and to strengthen the links between fisheries management and ecosystem studies, TAFI has recently commenced a study investigating the interactions between *M. pyrifera* and *J. edwardsii.*

A series of experiments have recently been instigated to test the null hypothesis that the presence of *M. pyrifera* has no impact on the settlement rate or subsequent survival of *J. edwardsii* puerulus. In undertaking these experiments we also hope to gain a greater understanding of the processes affecting settlement selection and habitat utilisation of early benthic stage lobsters. Settlement of juvenile lobsters is being monitored inside and outside kelp forests and on collectors with and without attached *M. pyrifera*.

8.4 Urchin Barrens

The long-spined sea urchin (*Centrostephanus rodgersii*) is well known for its capacity to overgraze algae, and therefore underpin a shift in shallow reef ecosystems from productive and diverse seaweed beds to urchin-dominated ‘barrens’ devoid of macroalgae (Andrew 1991,1993, 1994; Andrew and Underwood 1993; Andrew and O’Neil 2000). Primary production of urchin barrens is *ca*. 100-fold less than the alternative configuration of dense algal beds (Chapman 1981), and with flow-on effects to secondary production and loss of physical heterogeneity, it is unsurprising that urchins barrens do not support viable fisheries of abalone or rock lobster. Accordingly, the advent of the long-spined urchin in Bass Strait and east coast of Tasmania in recent decades, and formation of large barrens in part of this range is cause for concern by Tasmanian abalone and rock lobster fisheries. This issue is a research focus for Prof Craig Johnson of TAFI; a summary of the issues and progress on this topic are described below.

An informed management response to the formation of *C. rodgersii* barrens in Tasmania requires knowledge of the factors that trigger destructive grazing of algae in the first place. Observations in Bass Strait and Tasmania (C. Johnson, pers. obs.), and experimental manipulations in NSW (Andrew 1993), indicate that habitat with shelter for urchins (e.g. boulder bottom) is a necessary condition for barrens formation.

However, beyond this, the mechanisms that enable (1) urchin densities to increase, and (2) urchin behaviours to change, so that destructive grazing of seaweeds begins, are unknown. Two candidate hypotheses are that overfishing of major predators (rock lobsters [*Jasus edwardsii*] and possibly scale fish) and competitors (abalone [*Haliotis rubra*]) facilitates both the increase in density and change in urchin behaviour necessary for destructive grazing to occur. Research is proposed to test these hypotheses and, if proven correct, estimate minimum standing stocks or appropriate size ranges of legal-sized lobsters and/or abalone necessary to lower the risk of barrens formation.

8.4.1 Effects of overfishing of predators of urchins

Considerable attention has been given to the effects of fishing down predators on marine ecosystems in general (Jackson *et al.* 2001) and on kelp ecosystems in particular (Steneck 1997, 1998; Sala *et al.* 1998; Tegner and Dayton 2000). While mechanisms and dynamics are complex and often peculiar to particular systems, the general conclusion of this work is that overfishing of predators of sea urchins often results in increases in urchin populations with subsequent formation of urchin barrens. Urchin barrens are a well-documented feature of many temperate algal-based systems (Lawrence 1975; Chapman and Johnson 1990).

Depending on the system, either rock lobsters or fishes, or both, emerge as important predators of sea urchins. Lobster predation has been shown to exert an important influence on urchins in South Africa, despite that they are not the most preferred prey (Tarr *et al.* 1996; Mayfield *et al.* 2001). Similarly, experimental and correlative evidence suggests a potentially important role of lobsters in limiting urchin populations in New Zealand (Andrew and MacDiarmid 1991; Babcock *et al.* 1999) and California (Tegner and Levin 1983). Recent experiments in Tasmania has shown that predation by legal-sized rock lobsters (*Jasus edwardsii*) in the field is sufficient to prevent the urchin *Heliocidaris erythrogramma* from attaining densities sufficient to create barrens (Pederson and Johnson, in prep). In all of these examples, the effect of lobsters on urchins is size-specific, with all lobsters preferring small urchins, while only large lobsters are able to consume large urchins. However, in some cases very small urchins find refuge from lobsters under the spine canopy of adult conspecifics (Tegner and Levin 1983), although there is no evidence of this in Australia.

In Tasmania, only larger lobsters around the size of transition to legal-size have significant predatory impact on *H. erythrogramma* (Pederson and Johnson, in prep). Consequently, changes to legal-sized biomass through fishing may influence barren formation and thus lobster recruitment.

Overfishing of lobsters has also been postulated as a principal cause of formation of extensive urchin barrens in Nova Scotia (Mann and Breen 1972; Breen and Mann 1976a,b), although the idea has been controversial given poor and conflicting evidence (Chapman and Johnson 1990; Elner and Vadas 1990; Vadas and Steneck 1995). Just to the south in the Gulf of Maine, there is a stronger case that overfishing of demersal scalefish has enabled urchin populations to increase and create extensive barrens (Witman and Sebens 1992; Vadas and Steneck 1995). Similarly, fish predation is sufficient to regulate urchin populations in California (Cowen 1983), and may have a role in New Zealand (Babcock *et al.* 1999). Wrasse are a key predator of invertebrates in the kelp-bed systems of southern Australia, but in studies with *H. erythrogramma*, only large fish preyed on the urchins, and urchins were a poorly preferred prey (Shepherd and Clarkson 2001). Recent experiments and large-scale surveys in southeast Tasmania suggest that lobsters are far more important as predators of *H. erythrogramma* on rocky reefs than are fishes (Pederson and Johnson, in prep).

8.4.2 Effects of overfishing of competitors of urchins

In southern Australia, the largest and most abundant herbivores on inshore reefs are sea urchins and abalone. Interactions between these species are complex. In several parts of the world, juvenile abalone obtain shelter from predators beneath the spine canopy of sea urchins (Tegner and Dayton 1981; Tarr *et al.* 1996; Mayfield and Branch 2000). In this situation densities of urchins and abalone are positively correlated. Thus, if predation on urchins increases there are concomitant declines in abalone populations (Mayfield *et al.* 2001), and if urchins are protected then abalone populations increase (Rogers-Bennett and Pearse 2001). However, there is no evidence of this mechanism operating in temperate Australasian waters. *C. rodgersii* in Australia (Shepherd 1973; Andrew and Underwood 1992) and *Evechinus chloroticus* in New Zealand (Naylor and Gerring 2001) are negatively correlated with abalone (*Haliotis* spp) abundances. Experimental removals of *C. rodgersii* in NSW realised a 10-fold increase in abalone (Andrew *et al.* 1998), and similar results have been obtained with other species in California (Tegner and Dayton 2000). In New Zealand, addition of urchins (*E. chloroticus*) to kelp-beds realised dramatic reductions in abalone (*Haliotis iris*) while urchin removal resulted in small but significant increases in abalone (Naylor and Gerring 2001). These results suggest that *C. rodgersii* and *Haliotis* species may be strong competitors.

8.4.3 Testing the effects of predators and competitors on abundance of the long spined urchin.

Quantifying changes in ecosystem state and identifying the underlying mechanisms of change are difficult because of the lack of an adequate baseline (e.g. see Dayton *et al.* 1998). The best estimates of some form of 'baseline state' is arguably obtained from marine reserves where abundances of both fished and unfished species may be different to those in nearby fished areas (Babcock *et al.* 1999; Edgar and Barrett 1999; Wallace 1999; Tegner and Dayton 2000). In the proposed research, experiments in marine reserves will be the principal means to test the overall hypothesis that overfishing of key predators (southern rock lobster and scale fish) and/or competitors (black lip abalone) of the long-spined sea urchin facilitates increased densities of the urchin, which leads to barrens formation and a major shift in the state of the nearshore rocky reef ecosystem. Results of these experiments in combination with demographic models parameterised by observations on urchins outside reserves will be used to identify target standing stocks of legal-sized lobsters and abalone necessary to ensure a low risk of barrens formation.

8.5 Physical impacts of trapping

Another potential effect of rock lobster fishing is the physical impact of traps on rocky reef. This issue was the subject of a recent study in South Australia (Casement and Svane, 1999).

Conclusions were that the physical impact of pots was not strongly influenced by trap design. Impacts were of a similar magnitude between study sites. Overall, physical impact appear trivial, even when scaled by the number of pots in use across the fishery.

8.6 Lobster predation by *Octopus maorum.*

The Maori octopus, *Octopus maorum* is a large (up to 10 kg) temperate, shallow water species, which is common in southern Australian and New Zealand waters and a significant predator of pot-caught rock lobsters throughout its distribution. Despite its impact on lobster fisheries, however, we know virtually nothing of the patterns or dynamics of its predation on rock lobsters.

To address this lack of understanding, a research project examining rock lobsters at an ecosystem level, in particular the predator-prey relationships between octopus and lobsters commenced at the Tasmanian Aquaculture and Fisheries Institute (TAFI) in April 2001. This project is a collaboration between TAFI, the Tasmanian Department of Primary Industries, Water and Environment (DPIWE) and the Tasmanian Rock Lobster Fisherman's Association (TRLFA).

This project aims to document and evaluate rock lobster predation patterns and dynamics for *O. maorum* to assist lobster fishers in reducing kills by octopus. The project will also examine factors influencing mortality of 'discarded' undersized and buried female rock lobsters during fishing operations through predation by octopus, to further assist fishers in developing strategies to reduce the problem.

Both octopus and catch data have been collected from rock lobster fishers across the state and publication of results should commence in 2002, along with further study.

8.7 Marine reserve monitoring

Several marine protected areas (MPAs) or marine reserves were declared in Tasmania in the early 1990's and proposals for further reserved areas are currently pending. Fishing is prohibited in those marine reserves with the highest conservation objectives.

The primary stated objective for the declaration of these areas is the protection of biodiversity, with fishery management only listed as a secondary objective (Anon, 2000), although the system of reserves currently planned is not intended to cover the range of all species or habitats. The establishment of highly protected marine reserves may have an impact on the distribution of fishing, depending on the size and location of each reserve. It will be important to monitor any changes in the spatial distribution of lobster catches to ensure that the introduction of MPAs does not have a negative effect upon the fishery.

Modelling of the effects of these area closures on exploited species in Tasmania, such as rock lobster and abalone, show that the effects of area closure are mixed (Gardner *et al.*, 2000; Buxton, *et al.*, 2001). Under quota management of commercial fisheries, MPAs have little effect on the total legal sized biomass. However, they do displace fishing effort so that it becomes increased in open areas. The magnitude of the effects of increased fishing pressure in open areas varies depending on the size of the reserve, with small reserves having a proportionally small effect, possibly negligible, on displaced effort. The biological characteristics of the populations in the regions where effort is reduced and also the regions where effort is subsequently concentrated will also affect the level of impact that introducing an MPA would have on the fishery.

MPAs provide valuable research sites for assessing the effect of change to marine community structure and productivity as a result of fishing activities. Two projects have been running for over 3 years and are examining the community structure inside MPAs.

The first is conducted in the Crayfish Point scientific reserve and is focussed on rock lobsters with tagging of a range of other species to establish population sizes. Additional species include several wrasse species, draughtboard sharks, leather jackets, conger eels and octopus. Expected outcomes from this study for rock lobster are revised growth estimates taken from an unexploited population plus an indication of the unfished size distribution within the area. Any effects of fishing on the rock lobster population will be determined by comparing results obtained from adjacent fished populations.

The second project is monitoring the community changes inside reserves at Maria Island, Tinderbox, Ninepin Point and Governor Island with funding from FRDC "Evaluating the effectiveness of MPAs as a fisheries management tool".

Both projects have shown increased biomass of exploited species, particularly rock lobster, within the reserves., Industry Issues

The commercial sector of the rock lobster fishery has highlighted the following issues that are of concern and should be considered before the preparation of the next stock assessment report, which will cover the 2001/2002 season.

- Given the increase in recreational licenses (approximately 60% increase over the last three years) the need to obtain accurate estimates of the recreational catch on an ongoing basis for stock assessment purposes should be given a high priority. This is of particular importance for area 1 (southeast coast) as 40% of the recreational catch is taken from this area. Any further significant increase in the number of recreational fishers may have implications for resource sustainability, particularly in the easily accessible areas of the east coast. The commercial fishery believes that it is important that the government commits to the long term monitoring of the recreational catch.

- In relation to the recreational catch, the ability to have an estimate of weight for assessment purposes instead of just an estimate of numbers caught is another essential prerequisite of an accurate stock assessment.

- The commercial fishery recognises the need to closely monitor trends in CPUE. It is important to standardise CPUE to account for changes in fishers behaviour that may have been precipitated by the introduction of the quota management system. The changes in fisher behaviour may have introduced a bias in the assessment that has not been accounted for at the present time. The introduction of an improved fleet dynamics model for assessment purposes is an important tool that can assist in explaining fisher behaviour and its affect on CPUE. Again it is important that this work is ongoing.

- For future assessments, industry believe that a review of current data collection methods, both fishery dependent and fishery independent together with an overall review of the current suite of research projects should be conducted. This is to ensure that data that is essential for the stock assessment process is (1) accurate and (2) obtained in the most cost-effective manner.

- Industry considers the recommendation by the FAC to the minister requesting an increase in the TAC by 23 tonnes (2 kg per pot) to be an appropriate response to the trends in biomass and egg production provided by both the current and previous stock assessments. The commercial fishery recognises the need to continue the process of rebuilding the legal size biomass, however industry also believes that fishers currently operating in the fishery should gain some benefit from the increase in biomass that has occurred since the introduction of the quota management system.

9. Aquaculture

Permits for the collection of puerulus and early stage juveniles for the purpose of ongrowing for aquaculture were issued for the first time during the period of this assessment report. Seven permits were issued each for the collection of 50,000 puerulus and early stage juveniles (<15mm CL equivalent to puerulus and the first 2 or 3 instars post settlement). Puerulus are to be collected using artificial collectors deployed over sand in areas 1, 2, 7 or 8 only.

While this appears to represent additional removals from the resource, the exercise is intended to be either biologically neutral or positive for stock abundance. The aim of enhancement or biological neutrality is achieved by the release of juveniles after one year in culture. Natural mortality during this period would normally be high so it is theoretically possible to compensate or enhance the natural stocks while also providing animals for commercial culture.

Although this exercise can lead to the outcomes of both provision of animals for aquaculture (which is not possible through hatchery production) and enhancement of the wild fishery, there are several issues critical to the exercise that require further research. These issues are:

1) assessment of the survival of those animals released after 1 year in captivity. This research is underway in the FRDC funded project “Rock lobster enhancement and aquaculture subprogram: evaluating the release and survival of juvenile lobsters released for enhancement purposes”.

2) Estimation of the natural survival of juveniles during their first year. This research is underway through the FRDC funded project “Can production in the southern rock lobster fishery be improved? Linking juvenile growth, survival and density dependence to sustainable yield.”

3) Assurance that diseases will not be transmitted from aquaculture operations. This issue requires the development of the tools for monitoring the health of cultured animals and will be addressed in the FRDC funded project “Rock lobster enhancement and aquaculture subprogram: health assurance for southern rock lobsters”.

10. Appendix 1: List of Management Objectives and Strategies

There are eight policy objectives and associated strategies in the current rock lobster fishery policy document (Anon, 1997). Note that while this plan remains current, opinion has shifted in some aspects and these are highlighted throughout by footnotes. A new policy document is due in 2002.

Policy objectives listed in the plan are:

10.1 Maintaining biomass and fish recruitment.

To maintain fish stocks at sustainable levels by constraining the total catch and size of individual rock lobster taken by the commercial and recreational sectors. In particular, to ensure that:

- Rock Lobster are harvested at sustainable levels.
- Biomass and egg production do not decrease and that reasonable levels of egg production are maintained in all regions of the fishery.
- Biomass levels are increasing over time to the level required for producing the maximum yield from the fishery.

10.1.1 Strategies

- Limiting the commercial catch through setting a total allowable commercial catch (TACC) and using individual transferable quotas to allocate proportions of the TACC.
- To minimise the opportunity for illegal activity through a monitoring, compliance and enforcement strategy.
- Limiting the recreational catch through the use of daily bag limits and possession limits, requiring fishers to be licensed and limiting fishers to one rock lobster pot per person or other specified fishing gear or methods.
- Conserving egg production and constraining fishing mortality on spawning female lobster by the use of minimum size limits and the closure of the fishery for female lobster during the peak spawning period[3].

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[3] The use of seasonal closures as a management strategy is under review at the time of preparation of this assessment report. This is an industry initiative and initial steps involve a polling of industry opinion, research sampling during an extended season opening in September 2000 and 2001 and model simulations(Gardner, C. and Frusher, S. 2000).

10.2 Sustaining yield and reducing incidental fishing mortality

To take fish at a size likely to result in the best use of the yield from the fishery. To provide measures to protect undersized lobster. To minimise incidental fishing mortality as a result of fishing operations.

10.2.1 Strategies

- Maintenance of size limits.
- Restriction of size at first capture by requiring rock lobster pots to have escape gaps and to conform to size specifications.
- To reduce incidental mortality by limiting the set duration for rock lobster pots.
- Require rock lobster fishing vessels to be able to carry all pots on the vessel at any one time.

10.3 Managing commercial fishing interactions

To mitigate any conflict that results from competition between different fishing methods for access to shared fishing grounds.

10.3.1 Strategies

- Restrict the number of rock lobster pots that can be used from individual fishing vessels.
- Restrict the number of rock lobster fishing vessels in the fishery.

10.4 Ensuring access to fish stocks by recreational fishers

To maintain or provide reasonable access to rock lobster stocks for recreational fishers.

10.4.1 Strategies

- Encourage communication between the commercial and recreational sectors.
- Promote the development of a Code of Practice for recreational fishing for rock lobster.
- Maintain existing recreational fishing areas where no commercial rock lobster fishing will be permitted.

10.5 Providing marine farming opportunities for rock lobster

To provide for the development of a rock lobster aquaculture industry through the limited and controlled harvest of puerulus (juvenile rock lobster)[4].

10.5.1 Strategies

- Ensure that any harvest of puerulus is biologically neutral.
- Develop appropriate conversion ratios between puerulus and kilograms of quota[5].
- Ensure that the future development potential for the marine farming of rock lobster is achieved with no significant additional net mortality from the wild fishery.
- Ensure that any change in the TACC, and therefore the pot allocation, is matched with a corresponding change to the conversion ratio between puerulus and kilograms quota.
- Develop appropriate compliance mechanisms to ensure illegally taken undersized wild rock lobster do not enter the market.
- Identify methods of collecting puerulus that result in minimal incidental mortality and minimal damage to puerulus.
- Undertake research to assess possible impacts on the wild rock lobster fishery through the harvesting of puerulus
- Investigate opportunities to undertake research into growing puerulus from the egg stage[6].

10.6 Providing socio-economic benefits to the community

To recover a financial contribution from both commercial and recreational rock lobster fishers to contribute to the real costs of management, compliance and research. To ensure the rock lobster fishing fleet continues to provide employment and an economic return to coastal communities of Tasmania.

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[4] The Government position on this objective has changed since the completion of the current management plan. Although the current plan implies that puerulus harvest is to be undertaken for the development of a permanent industry, the current minister has stated that puerulus harvest is intended to be an interim activity until the viability of hatchery production can be more fully evaluated.

[5] Points 2 and 4 assume a quota buy-back option is implemented. Subsequent to the publishing of the rock lobster fishery policy document (Anon, 1997), concerns were expressed at the limited ability of this option to achieve biological neutrality due to a) loss of egg production from sub-legal females and b) effective shift of effort towards the east coast. Consequently, a reseeding option was proposed to overcome these problems.

[6] Research into phyllosoma culture has subsequently commenced (at TAFI. in 1997). Larvae have survived to 400 days of age although there has been no survival to the first juvenile stage or puerulus.

10.6.1 Strategies

- Determine the real costs of management, compliance and necessary research costs for the rock lobster fishery.

- Equitably pass on management and research costs to participants in the rock lobster fishery, sufficient to achieve cost recovery over time. Full cost recovery will not be achieved during the term of this plan.

- Provide mechanisms to ensure that the rock lobster fleet continues to provide economic and social benefits to the Tasmanian community.

10.7 Accounting for environmental interactions.

To minimise the environmental impact of rock lobster fishing methods particularly on areas of special ecological significance and reduce bycatch of juveniles and non-target species.

10.7.1 Strategies

- Establish marine protected areas for the protection of valuable coastal habitats and to maintain biodiversity[7].

- Require rock lobster pots to be fitted with escape gaps.

10.8 Providing high quality produce

To promote and maintain handling and processing practices which ensure the highest quality rock lobster product for human consumption.

10.8.1 Strategies

- Promote quality carrying, handling and storage practices for rock lobster on board fishing vessels and by fish processors, through the use of codes of practice and industry initiatives.

- Undertake research to identify the differences between wild harvested rock lobster and rock lobster reared in an aquaculture facility.

[7] This strategy assumes no harm to biodiversity through the use of MPAs in conjunction with QMS in the rock lobster fishery. FRDC funding has been obtained to research the implications of MPAs for fisheries management and that study has not yet been completed.

11. Appendix 2: List of Performance Indicators and Trigger Point Strategies

11.1 Performance Indicators

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

11.1.1 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.

11.1.2 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, spatial 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.

11.1.3 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 against which egg production in future years will be compared.

11.1.4 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 represent annual growth increments, 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.

11.1.5 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.

11.1.6 The size of the rock lobster fleet

- As the restructuring process occurs it is likely that the number of 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 rock lobster fishing is an important industry.

11.1.7 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.

11.2 Trigger Points

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

11.2.1 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 (ie. 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 region 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 region 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.

11.2.2 Legal-sized biomass

- The estimate of global (state-wide) 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 region 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.

11.2.3 Egg Production

- The estimate of global (state-wide) 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 regions have egg production levels which exceed 40% of that of the estimated unfished stock.

- For regions 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.

11.2.4 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 region 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.[8]

11.2.5 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.

11.2.6 The size of the rock lobster fleet

- The number of 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.

11.2.7 The recreational catch

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

12. Appendix 3: Fishery Description

12.1 General Overview

A detailed description of the Tasmanian rock lobster fishery follows below. For the purposes of this report the following points are especially important to understand:

(i) The fishery adopted an individual transferable quota system (ITQ) in March 1998

(ii) This assessment report contains information available up to the end of the third quota year in February 2001.

[8] 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.

A summary of the main regulations that govern the commercial and recreational sectors are presented in Table 11. More detailed information is available in the rock lobster fishery policy document (Anon, 1997).

A recent initiative undertaken by the Tasmanian government was to investigate the potential for rock lobster aquaculture. While some consider there is potential for development of lobster aquaculture through ‘closing the life cycle’ and thus operating independently of the fishery, the initial development plans to source puerulus from the wild. Seven permits were issued in 2001 for collection of up to 50,000 puerulus per permit. As any quantities either extracted from or returned to the resource will impact on the resource, a chapter on aquaculture has been added to this report.

Table 11. Summary of rules for the Tasmanian Rock Lobster Fishery.

COMMERCIAL

Management zone	one management zone for the State
Limited entry	314 licenses
Limited seasons	In 2000: closed season 24-49th February (both sexes); 1st October-14th November (both sexes); 1st May-1st October (females).
Limits of pots on vessels	minimum of 15 pots, maximum of 50 pots
Quota	Total allowable catch of 1502.5 tonnes
Restrictions on setting pots	pots cannot be set, or pulled, between two hours after sunset and two hours before sunrise
	pots must be hauled no longer than X days after being set
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 lobster diving licence, rock lobster ring license – 4 rings per person.
Daily limit	5 per recreational license holder
Limited seasons	In 2000: closed season 1st May-10th November (females); 1st September-10th November (males).
Restrictions on setting pots	as per commercial fishers
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.

12.2 History of Tasmanian Commercial Rock Lobster Fishing

The rock lobster commercial fishery dates back to the period of early European settlement in Hobart in 1804 and its early history is described by Winstanley (1973). Management restrictions were first imposed in the 1889 Fisheries Act after a Royal Commission on the Fisheries of Tasmania found "*the destruction of crayfish [rock lobster] is so serious in some localities as to threaten extermination at no distant date*".

These first restrictions included a size limit, the ban on taking berried lobsters and a ban on the possession or sale of soft shelled lobsters. These regulations essentially still apply today although closed seasons on females and males supplement the berried and soft shelled regulations. Possession of soft shelled lobster is no longer banned. Closed seasons were first implemented in 1926 and have been adjusted on numerous occasions since (Gardner and Frusher 2000).

In the 1950's licences for commercial fishers (pots allocated according to vessel size with a maximum pot holding) were restricted to participants principally dependent on the sale of rock lobster for a livelihood. At the same time, recreational fishers were restricted to use of a single pot. In 1967 a policy of licence limitation was adopted and this was followed in 1972 by fixing the number of pots in the fishery to 10,993 (Winstanley, 1973).

In the mid to late 1980's concern over the resource was again expressed by fishers as catch rates declined (Figure 56). A working group of fishers and government representatives was formed in the early 1990's to evaluate options to stem this decline (Anon, 1993). The working group clearly identified increased effort as the major problem and expressed concern at the potential for further increases as latent effort was considerable. The lack of consensus on the appropriate management method to adopt resulted in a number of Industry polls. This culminated in a poll in 1996, which resulted in a marginal preference for quota management. In March, 1998 an individual transferable quota (ITQ) management system commenced.

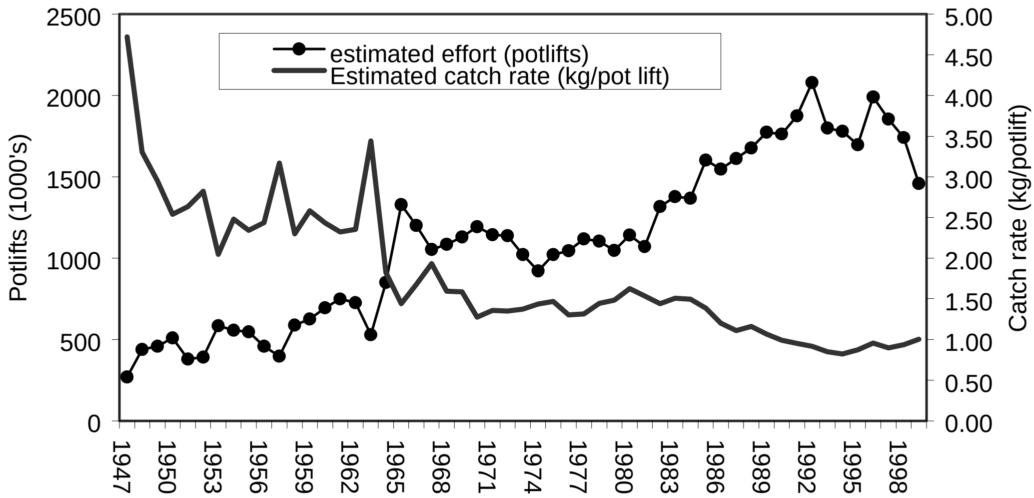


Figure 56. Historical patterns in statewide lobster fishing effort and catch rate.

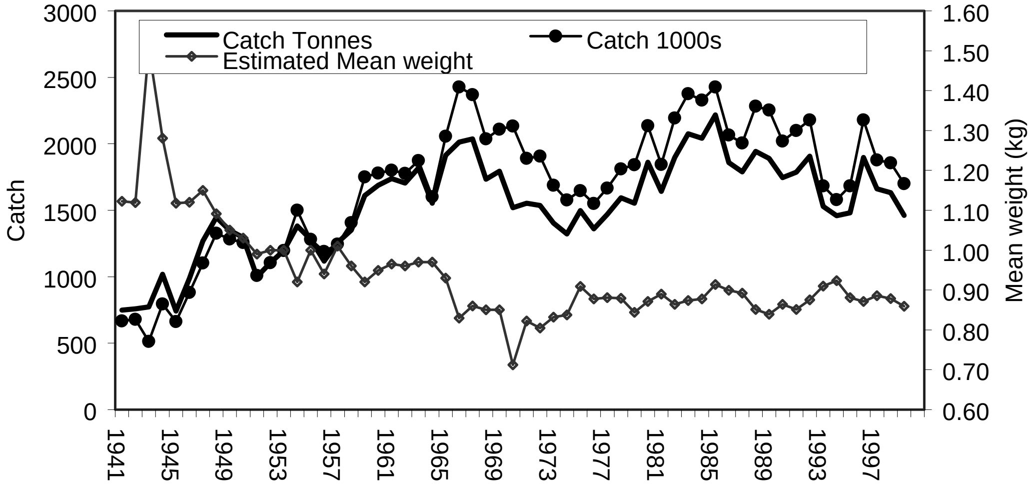
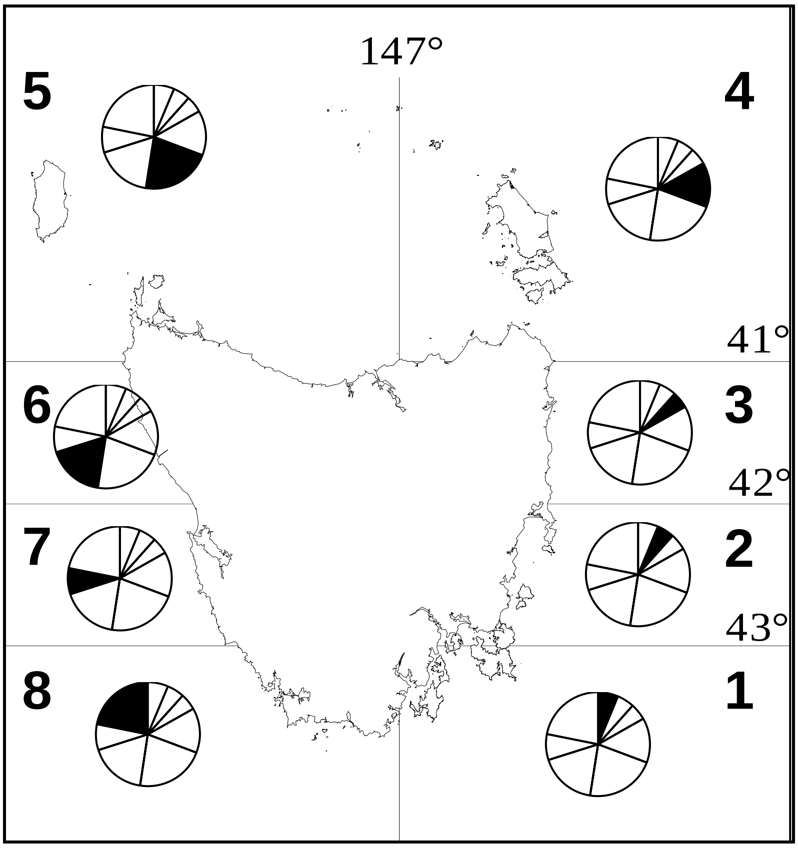


Figure 57. Historical patterns in statewide catch.

12.3 Commercial Rock Lobster Fishery

The Tasmanian rock lobster fishery targets the southern rock lobster (*Jasus edwardsii*) in the waters adjacent to Tasmania. Tasmania has jurisdiction for the fishery in waters generally south of 39 12', and out to 200 nautical miles from the coastline. This jurisdiction is provided to Tasmania by way of the Offshore Constitutional Settlement agreement of 1996, for invertebrates (see Commonwealth Gazette 31/12/1996 No. S531 for full details).

Since 1970 fishers have recorded their daily catch in degree blocks around Tasmania which has allowed for regional trends to be documented. In 1992 reporting blocks were further reduced in size to quarter degree blocks (30 nm X 30 nm). These blocks are aggregated into 8 stock assessment areas which are used in the current rock lobster stock assessment model(Punt and Kennedy, 1997; Figure 58).



Region	% of catch
1	6.7
2	5.5
3	4.8
4	16.0
5	21.2
6	16.3
7	7.6
8	21.8

Figure 58. Location of the eight regions used in this report and their percentage contribution to the 2000/01 commercial catch (March to February inclusive).

The distribution of the catch clearly shows the current importance of the west coast, particularly areas 5 and 8.

Although lobsters have been recorded from depths greater than 200m, few lobster are caught in depths below 125m (Figure 59). With the exception of area 6 where over 40% of the catch comes from waters deeper than 62m, most of the catch comes from waters less than 62 m. Shallow water grounds less than 18 m are especially important in areas 2 and 3 with greater than 30% of the catch from this depth range.

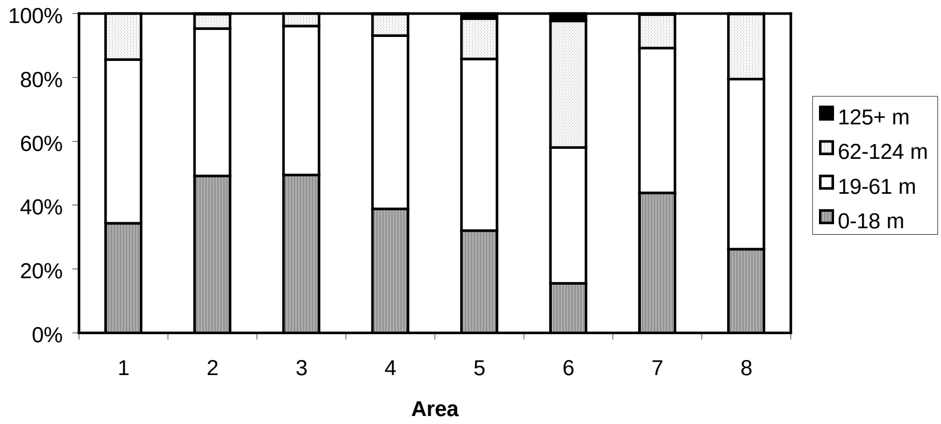


Figure 59. Regional depth distribution of catch from March 1998 to February 1999.

12.3.1 Fishing methods

The only commercial fishing method for rock lobster is the use of rock lobster pots. These are generally made from steel and mesh netting or from wooden "sticks" and steel mesh. Similar pots are used by recreational fishers. Recreational fishers can also dive for lobster or use hoop style lift nets (rock lobster rings).

Lobster pots are baited, usually with fish, such as jack mackerel, barracouta or Australian salmon. Pots are set for a number of hours, normally overnight or from dawn to dusk. The rock lobster are attracted by the bait and crawl into the pots. The neck of the pot is designed in such a way that it is difficult for the lobster to get out of the pot. Pots are required to have escape gaps to allow undersized rock lobster to escape from the pot.

Commercial pots are hauled by hydraulic lifters which is one factor contributing to the ability of commercial vessels to operate in deeper water than recreational fishers. After lobsters have been removed and checked against size restrictions, the pots are re-baited and either reset or stored on the vessel to be set later in the day.

The commercial sector uses colour echo sounders, radar and global positioning systems to assist them in locating suitable areas to set their pots.

12.3.2 Catching sector

In January 1997 the rock lobster fishing fleet comprised 321 vessels and this had reduced to 314 vessels in February 1999, and further reduced to 270 for the period November 1998 to September 1999. Vessels range in size from 6-26 metres in length. The majority of vessels are used primarily for rock lobster fishing but have the capacity to diversify into other fisheries on a seasonal basis. The vessels are a mixture of wooden and steel hulls with a few fibreglass vessels. The majority of the fleet is of the displacement hull style with a small number of planing hull vessels. The average age of the fleet exceeds 15 years, with very few new vessels operating.

Each licence has a quota allocation ranging from 5 to 100 rock lobster quota units. Each vessel has a rock lobster pot allocation based on either the length or tonnage of the vessel. The pot allocation varies between a minimum of 15 and a maximum of 50 pots. A total of 10,507 pots were able to be used throughout the fleet in February 2001, however under quota less pots than this are being used. The majority of vessels are owner operated, but there is a trend toward the leasing of vessels and licences.

The market value of vessels participating in the fishery varies between approximately $15,000 to $750,000. Licences vary in price according to the number of pots and the types of fishing licenses on the package.

All rock lobster are landed live from the catching vessel and are generally purchased by a processor at the wharf, with most product destined for live export.

13. Appendix 4: Biology of the southern rock lobster

While it is beyond the scope of this report to go into any detail of the biology of rock lobsters there are aspects of the biology that will make interpretation of this report easier. The most important points are:

(i) Lobsters grow by a process known as moulting, where the external skeleton or shell is shed.

(ii) Mature female lobsters moult in autumn and males in spring.

(iii) Females incubate eggs under the tail for 3 to 5 months from May/June to September/ October.

(iv) Growth rates and size at onset of sexual maturity vary regionally in Tasmania. Fastest growth rates and largest size at onset of sexual maturity are found in northern Tasmanian waters and the slowest growth rates and smallest size at onset of sexual maturity are found in southern Tasmanian waters.

13.1 Reproduction

Development of the ovaries of the females commences almost immediately after the previous egg mass is extruded - so reproductive processes are virtually continuous year round. Female rock lobsters moult in autumn and are receptive to males for mating for the following few weeks. During mating males deposit a sperm mass known as a spermatophore underneath the body and between the walking legs. Within hours/minutes after deposition of the spermatophore the eggs are extruded from the ovaries, passed across the spermatophore where they are fertilised, and then attached to the pleopods (swimmerets) under the tail. The eggs are incubated under the tail for the next 3 to 5 months before the first larval stage hatches and swims to the surface. During the incubation period, lobsters are commonly referred to as being ‘berried’. The number of eggs a lobster incubates relates to her size with larger females carrying over 600,000 eggs compared with 35,000 for smaller females.

13.2 Larval Period

In spring the eggs hatch into the first larval stage called a naupliosoma. In a matter of minutes, this stage moults to the second stage (phyllosoma) and moves to the surface layers of the sea. Over the following months phyllosoma larvae grow and are carried away from coastal areas to the adjacent oceans. During their larval development they pass through 11 stages and have been recorded from depths greater than 200 metres and over a thousand kilometres from land. The duration of the phyllosoma stage is extremely protracted and ranges from 12 to 24 months

Recent work by CSIRO with support from fisheries organisations in Tasmania, South Australia and Victoria has shown that most rock lobster larvae are found in the upper 100m of water within a limited temperature range (around 12.2-15°C).

Most larvae tend to be found around the convergence zone of major currents which is thought to be a factor influencing the variation in recruitment between years. The predominantly west to east current flow around Tasmania suggest that there is ample opportunity for larvae to be carried from the West Coast. Oceanographic information from satellites and drifters have shown that the movement of currents around Tasmania is complex. It appears that it is also possible for rock lobster larvae to be carried from the east coast to the west or to recruit back to the area where they originated from. This implies that the traditional strategy of managing egg production on a regional basis is appropriate on a precautionary basis.

The final larval stage is known as the puerulus stage and this is the first time that the shape of the larvae resembles that of the adult lobster. The puerulus swims from ocean waters across the continental shelf and settles on coastal reefs. At this stage the lobster is approximately 25mm long with a carapace length of 10-12mm.

Because of the dispersed distribution of larvae, the puerulus settling stage is the first point where future levels of recruitment to regional populations can be estimated. TAFI. (formerly DPIF) has been running a puerulus settlement monitoring project since 1990. There has been considerable variation in puerulus catches during the ten years that this project has been running which is useful for evaluating the link with future catch.

Annual trends in puerulus index and implications for future recruitment are discussed in detail elsewhere in this assessment (Section 5, page 50).

13.3 Growth

Rock lobsters grow by a process called moulting. Like most crustaceans (which includes crabs), rock lobsters have an external skeleton or shell. For a lobster to grow, the shell has to be shed which is followed by the expansion and hardening of the new soft shell over a period of weeks.

In terms of this stock assessment report, the moulting process has some important points. Firstly, during the moulting process the lobster is very vulnerable until the shell (its body armour) has hardened. As such, lobsters will not leave their refuge during moulting and are not catchable by pots. Also, the appetite of lobsters decreases prior to moulting so they are less attracted to baits. However, once the shell has hardened at the completion of the moult, the tissues within the lobster contain a large proportion of water. This causes the lobster to become extremely hungry and vulnerable to being caught in pots (Figure 60).

Moulting is relatively synchronised in rock lobsters with similar sized lobster moulting at approximately the same time in the same region. Male lobsters moult from August to November in southern Tasmanian and a little later in northern Tasmania. Because of this, the opening of the rock lobster season in November[9] just after the majority of male

[9] Prior to quota implementation in March 1998, the fishing season was from November to August of the following year. The season now runs from March to February of the following year with a closure from September to November. The exact dates of the closure vary from year to year although fishers still target

lobsters have moulted, is often classified by fishers as the ‘run of new shellers’. Female lobster generally moult in April and May after which mature female lobsters carry eggs. The season for female lobsters is closed from the 1st of April to mid November of each year. Because of the male moult prior to the start of each season, catchability of lobsters is highest during November. These changes in catchability implies that some estimates of abundances such as catch per unit effort will vary seasonally. The problem is overcome in the stock assessment model by incorporating this effect as a “catchability coefficient” which varies between months.

Recent research undertaken by TAFI has attempted to improve our understanding of these monthly changes by directly measuring the catchability of lobsters in an un-fished population (Figure 60). Catchability was best described as a function of the water temperature, moulting and mating (Ziegler *et al.*, submitted). The use of an unfished region or reserve for this research allowed catch rate changes to be related directly to catchability changes. This direct link between catch rate and catchability cannot be made in fished regions, where catch rates also change during the season through depletion.

The greatest change in catchability was during the spring peak for males which is associated with post moult and increasing water temperatures. Females, which moult in autumn, have lower catchability in spring. Female catch rates have a small peak in autumn, which is related to moulting and reproduction. The peak in males in June is considered to be due to post-reproductive activity. Both sexes have low catchability in winter when water temperature is at its lowest.

‘new shellers’ after the moult either in the extended opening of the fishery in September (see Cheshuk 2000, Cheshuk and Philips 2001) or when the fishery re-opens in November.

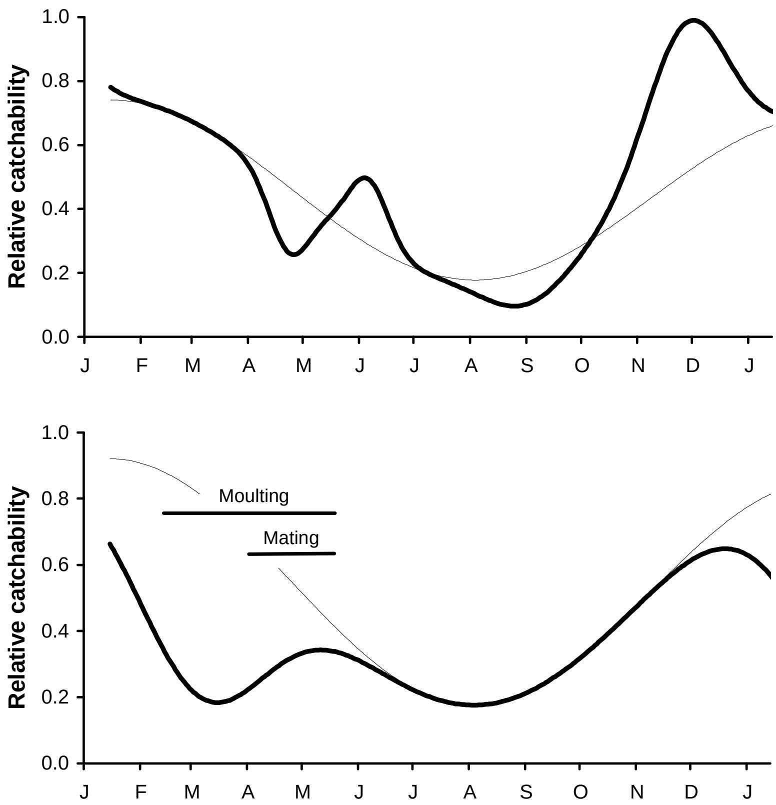


Figure 60. Monthly patterns of catchability of male (upper) and female (lower) rock lobsters from an unfished population at Crayfish Point. "Catchability" is a measure of how vulnerable lobsters are to being caught in pots. Heavy lines represent relative catchability, while thin lines represent change in water temperature. Catchability is influenced by temperature, with overlying affects from biological processes of moulting and mating. Mating reduces catchability of both sexes in April/May, which is followed by heightened catchability afterwards. Likewise, the male moult in September leads to reduced catchability, followed by heightened catchability in November, presumably due to compensatory feeding. While these general patterns are well known to fishers, the research shown here is important as it allows the seasonal changes in catchability to be quantified.

The second point of note in relation to the moulting process is that the process is physiologically stressful and recently moulted lobsters are fragile. Due to this fragility, fewer lobsters are acceptable for live shipment as the added stress of shipping (airfreight) lobsters often results in increased mortality.

Growth of lobsters is normally expressed in terms of an increase in their carapace length. The carapace is the hard shell, which extends from the base of the antennae to the start of the tail. As the carapace is a solid structure its measurement is fixed. This is the reason that the carapace length is the official minimum legal size limit measurement. The term used in this document as 'mm CL' refers to the length of the carapace in millimetres.

Growth rates of lobsters show substantial differences around the State with growth rates fastest in the north. At the legal size limit, male and female lobsters in the north undertake two moults annually compared to a single moult for lobsters in southern waters. The growth increment (change in the length of the carapace with each moult) is also substantially different with northern males at approximately the legal size limit increasing their carapace length by 11 to 13mm whereas their southern counterparts grow less than 6mm. Thus on an annual basis northern lobsters are growing up to 4 times faster than southern lobsters. Lobsters also grow faster in shallower waters than deeper waters. The main factors considered to influence lobster growth are water temperature (lobster grow faster in warmer waters) and food availability.

The size at which lobsters become mature appears to be related to age rather than size and thus faster growing lobsters mature at a larger size than slower growing lobsters. In southern waters greater than 40m in depth, female lobsters mature at 60 to 65mmCL. In contrast, in shallower (<40m) water in northern regions of the fishery, female lobsters mature at sizes greater than 110mmCL (Figure 61).

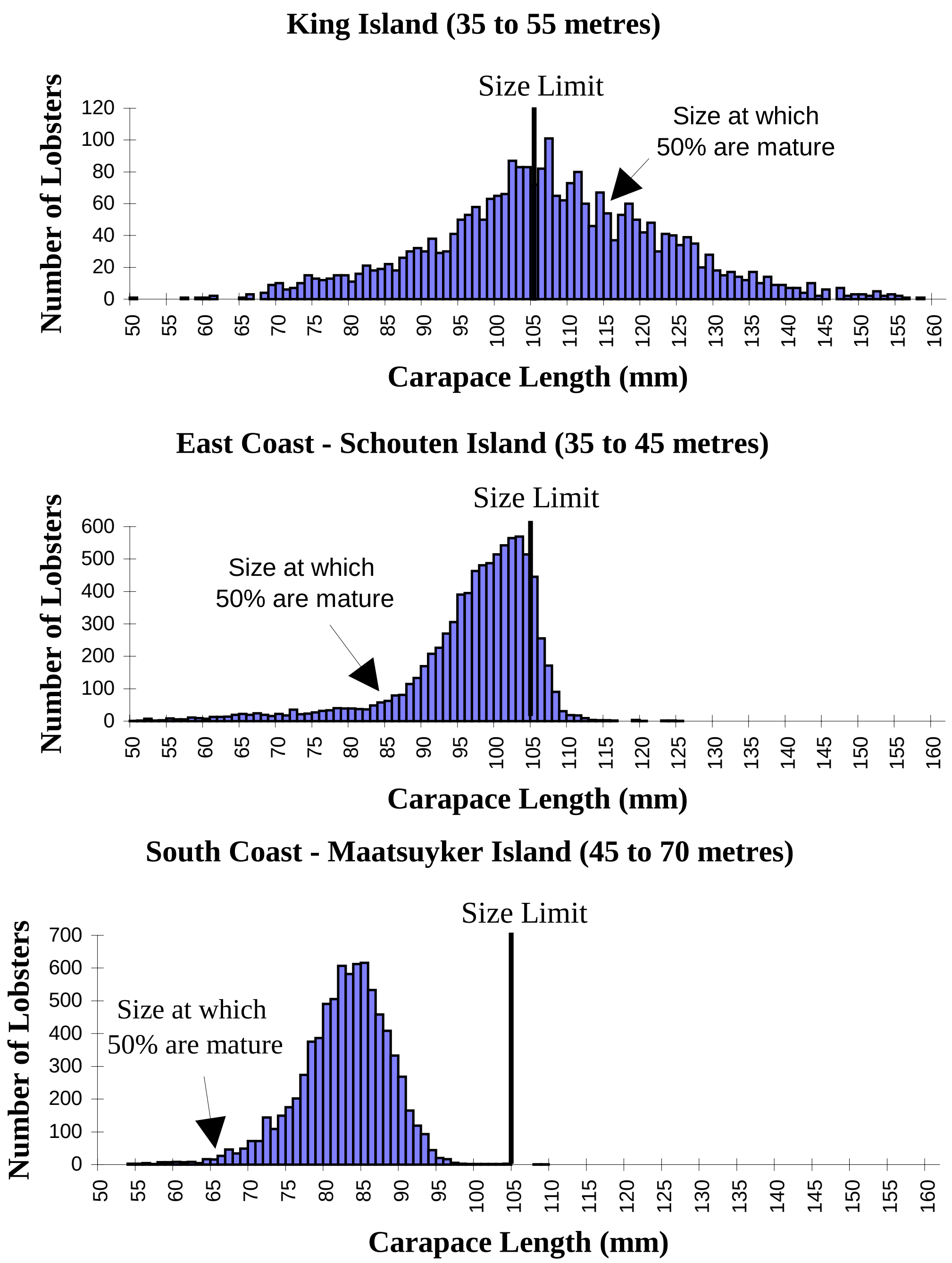


Figure 61. Size structure and size at maturity of female lobsters caught at three locations in Tasmania.

14. Appendix 5: Length frequency data

Length frequency data of lobsters measured for research catch sampling are included here for the first time in response to a request by industry. Data is split by stock assessment area and sex. Displayed for each area and sex are three time periods; a) late 1980's (1987, 88 and 89), b) mid 1990's (1993, 94 and 95) and c) post quota (1998, 99 and 2000). The number of animals in samples is variable, but is indicated in each plot by the y-axis. Carapace length is shown on the x-axis, with the size limits represented by a vertical line. Caution needs to be exercised in interpreting changes associated with these size frequency plots. Firstly, changes in fishing gear have occurred. For instance, in the 1980's, size data was obtained from observers on commercial vessels. Commercial pots were predominantly 'stick' pots and gaps between sticks varied between pots and thus the number of undersized lobsters retained by a pot would vary for each pot. In contrast, fishery independent surveys commenced in 1992 with the use of standardised steel pots covered in mesh of identical mesh size. These surveys resulted in the size structures in areas 1, 2, 7 and 8. Secondly, regions that are sampled in one period may not be the same as other periods. For instance, greater effort may have focused on inshore rather than offshore regions and there are often substantial differences in growth rates and densities of lobsters in different depth ranges in the same region.

During 2002, a review of catch sampling methodology is being undertaken and a new series of surveys which account for gear type and location is being considered.

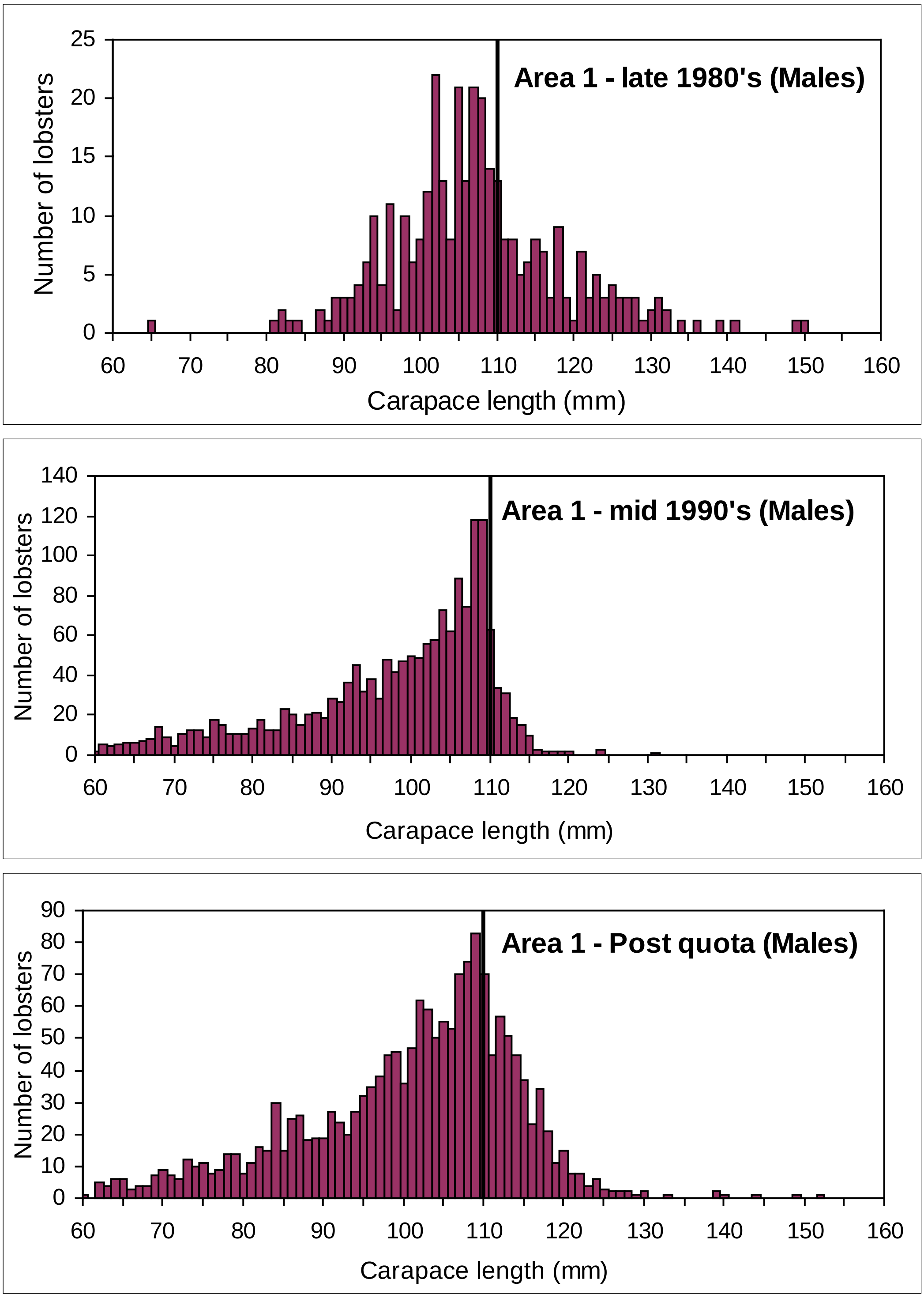
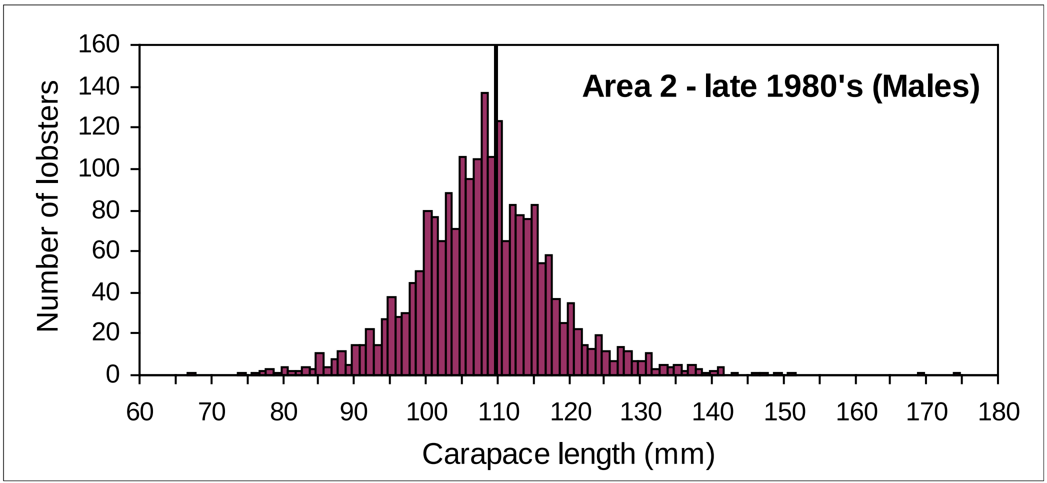
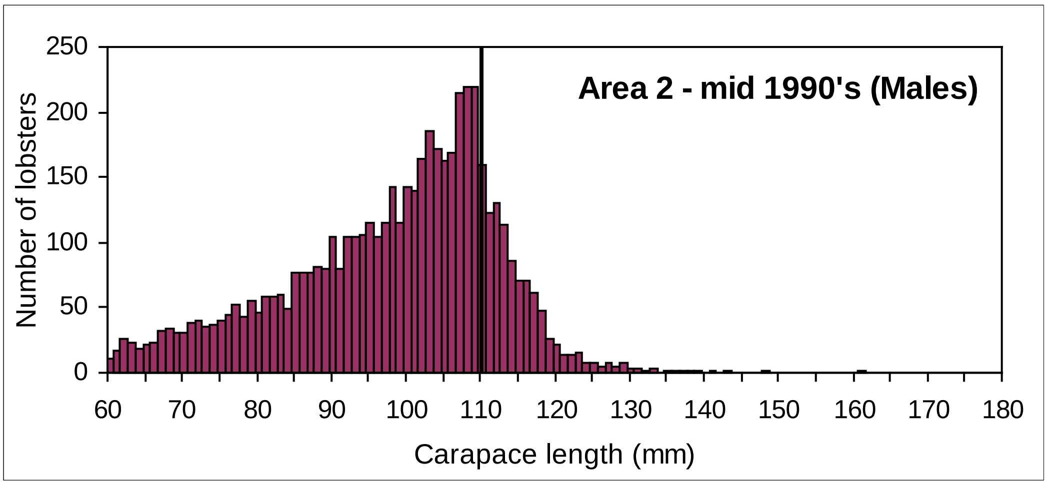


Figure 62. Area 1 –Males.





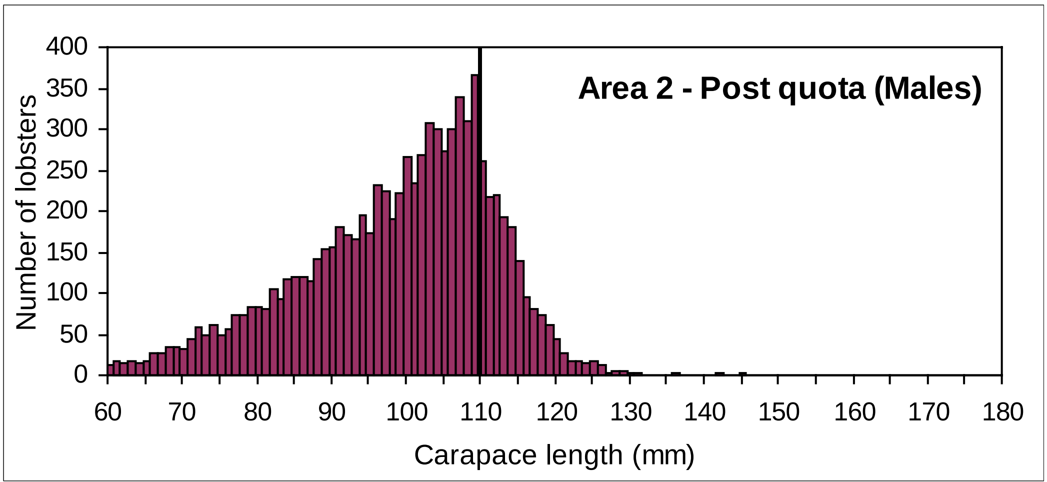


Figure 63. Area 2 –Males.

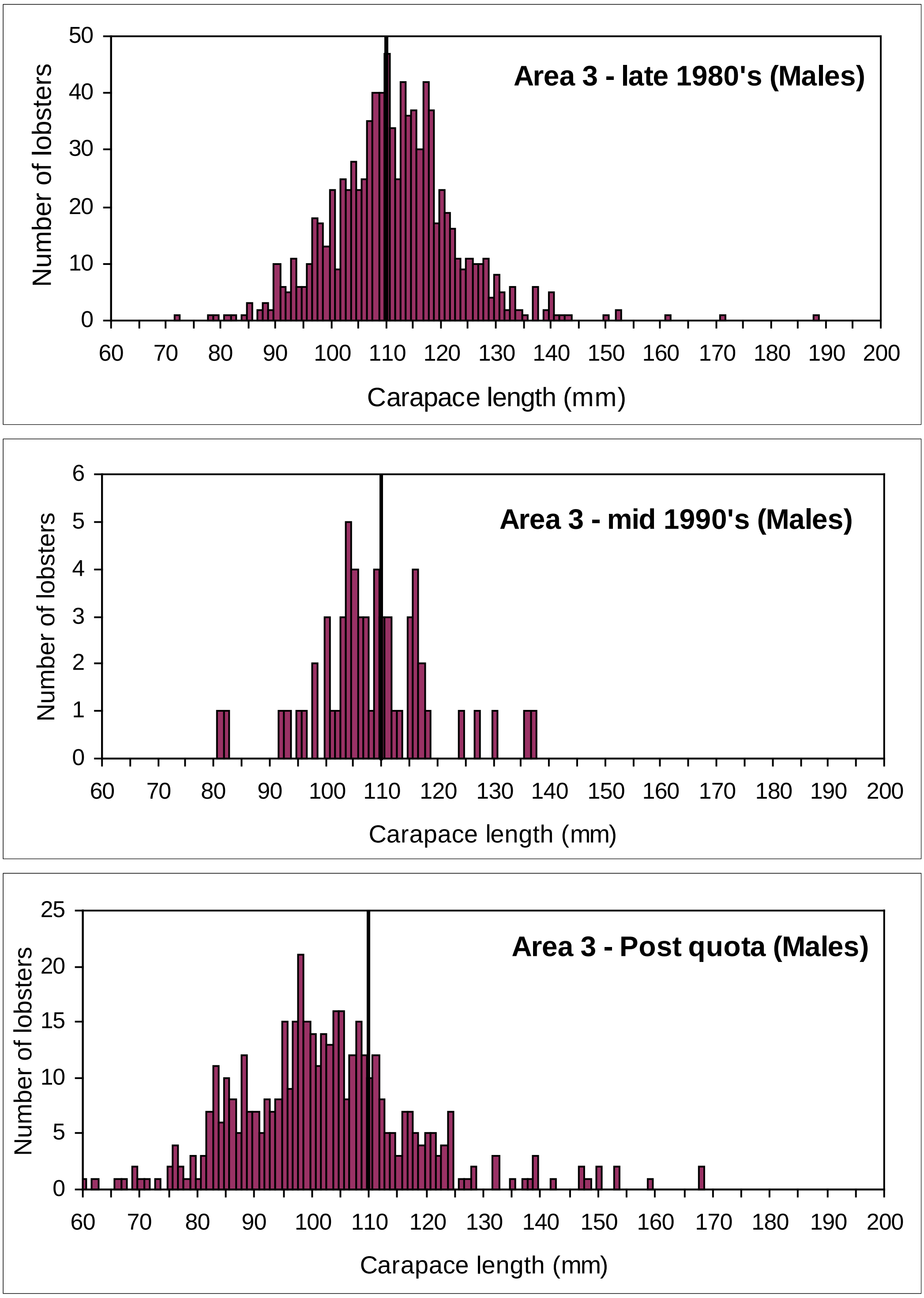


Figure 64. Area 3 – Males.

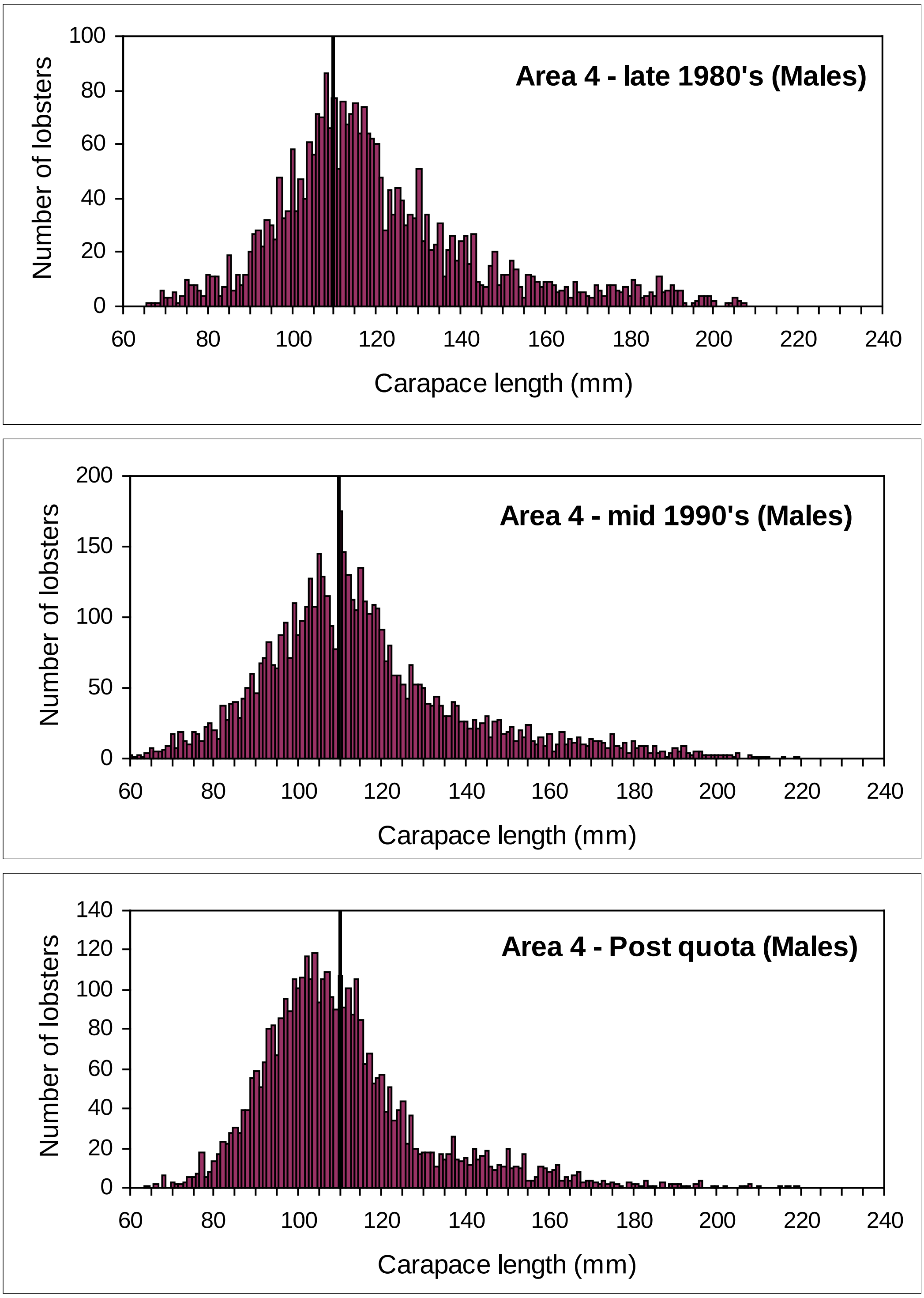


Figure 65. Area 4 – Males.

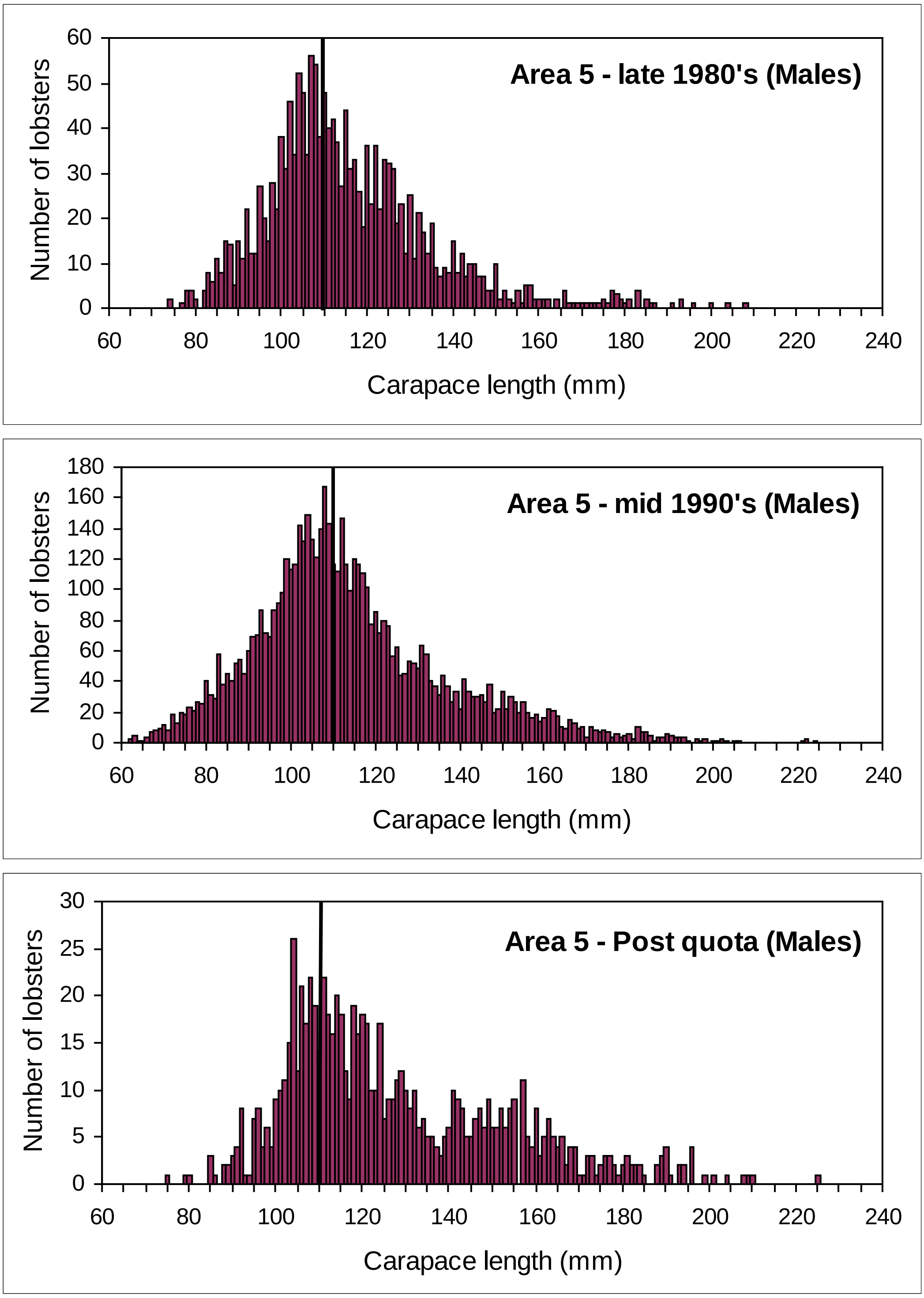
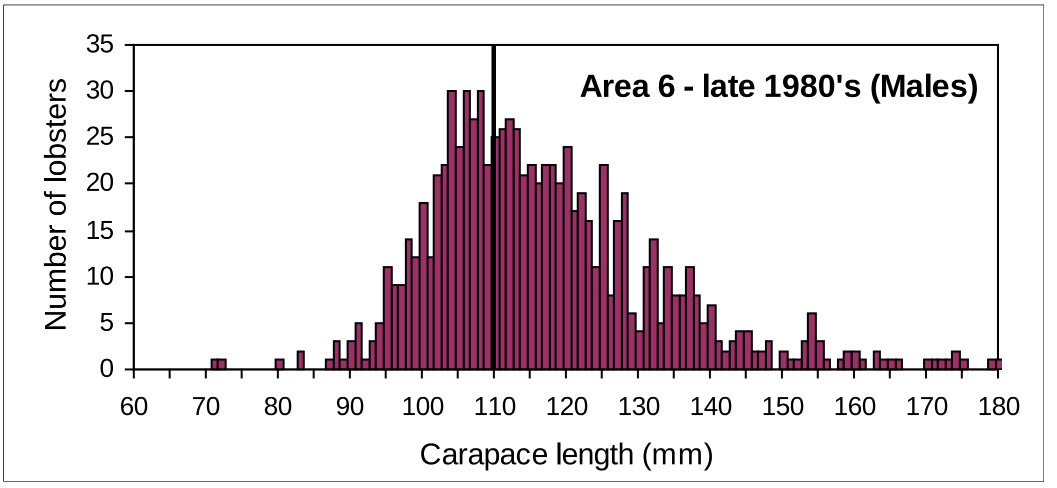
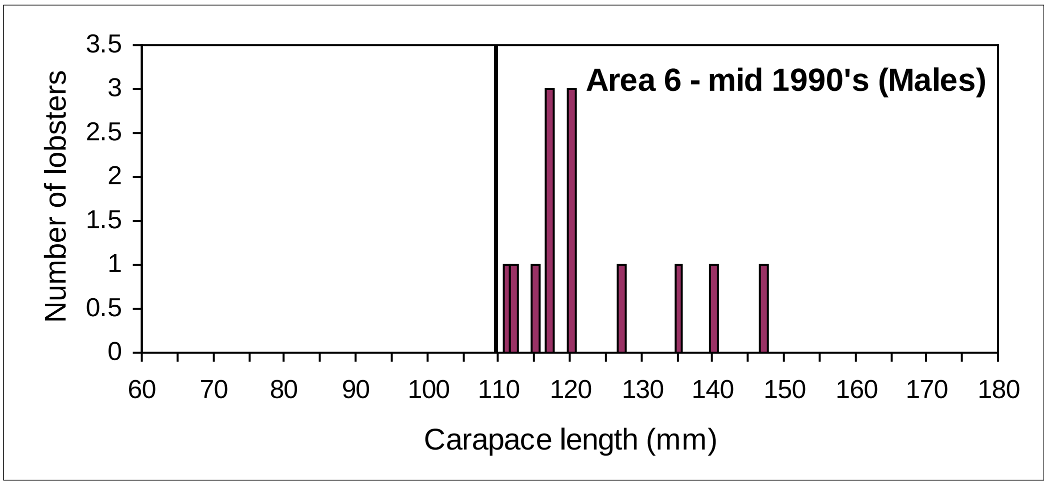


Figure 66. Area 5 – Males.





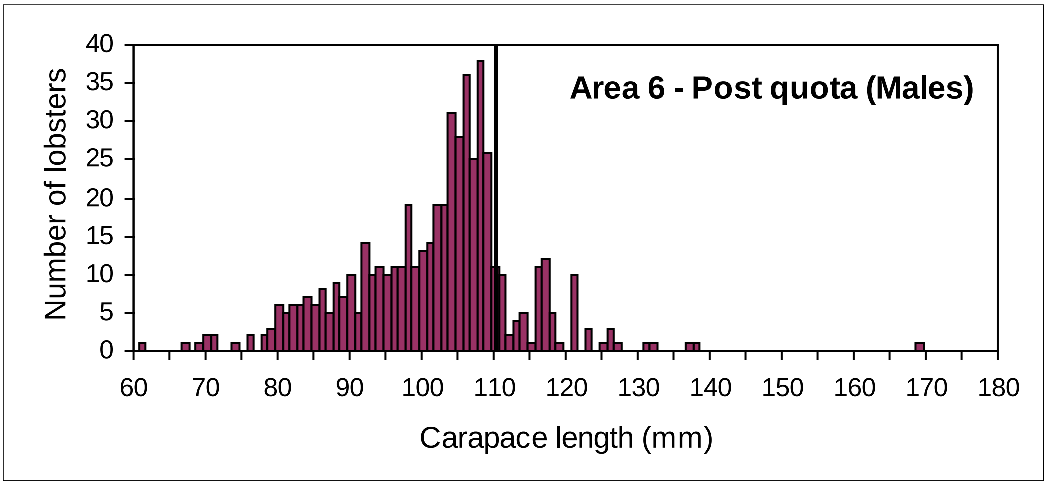
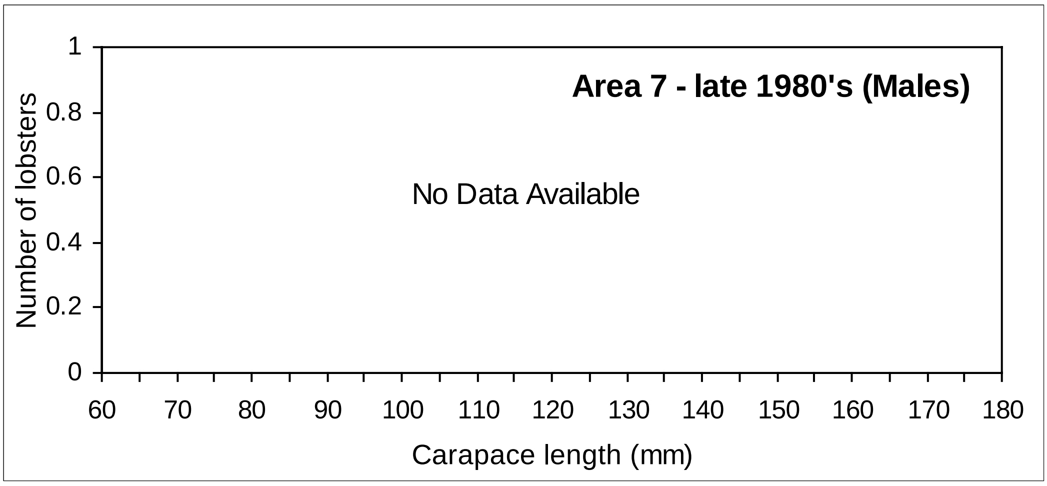
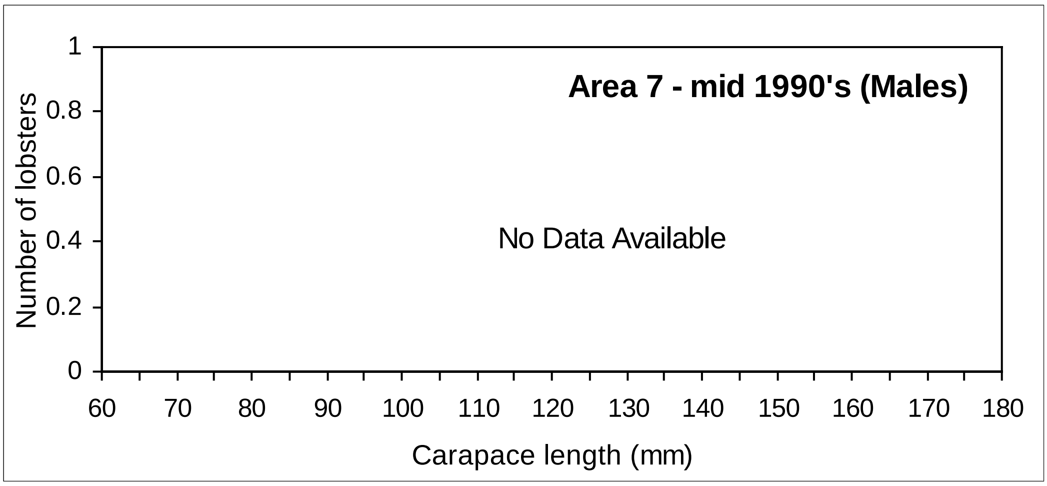


Figure 67. Area 6 – Males.





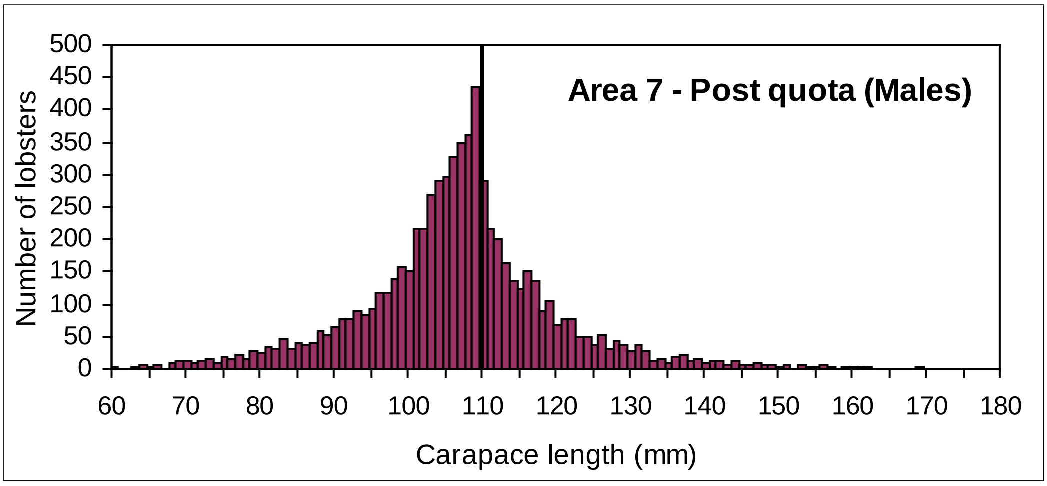


Figure 68. Area 7 – Males

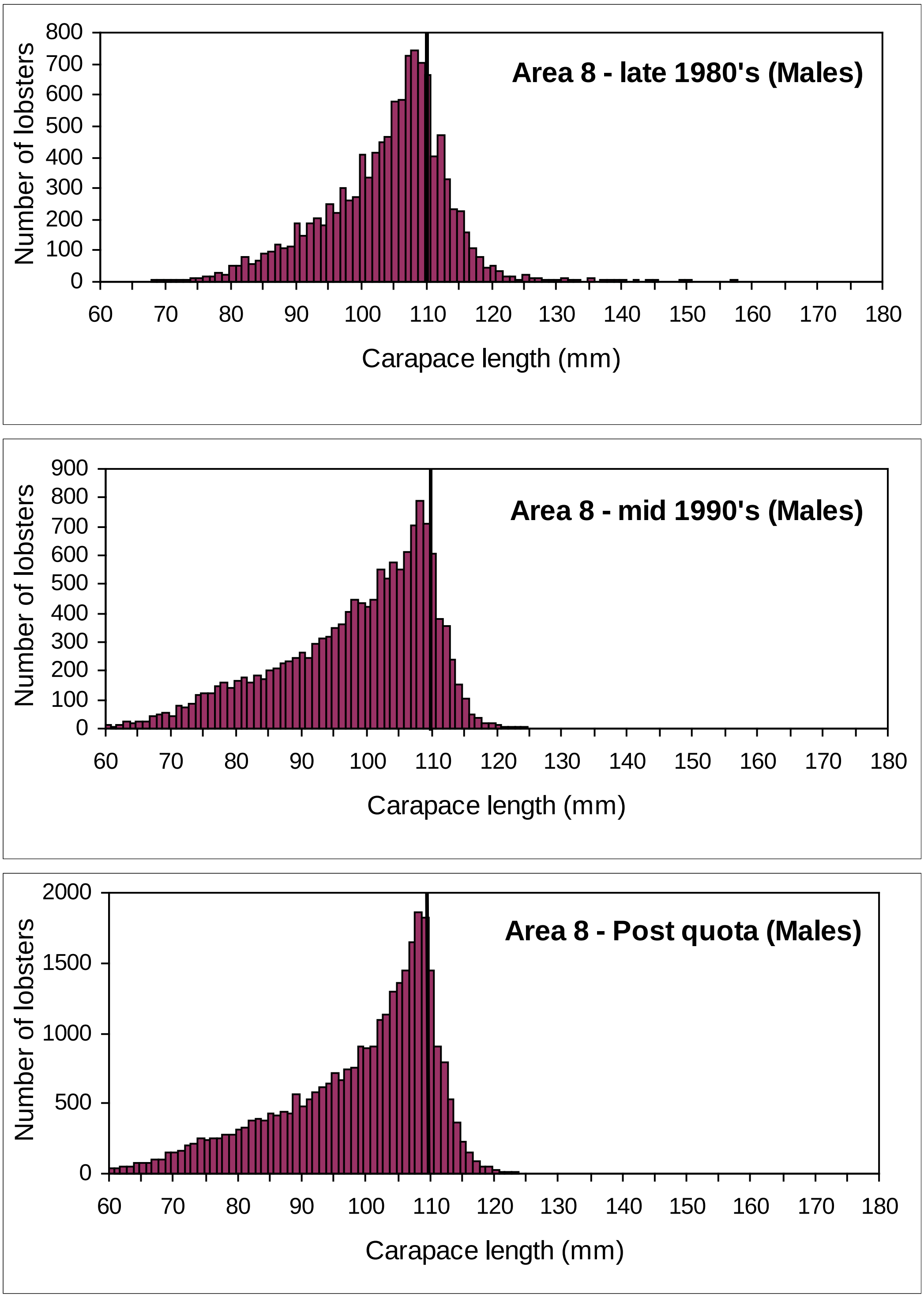
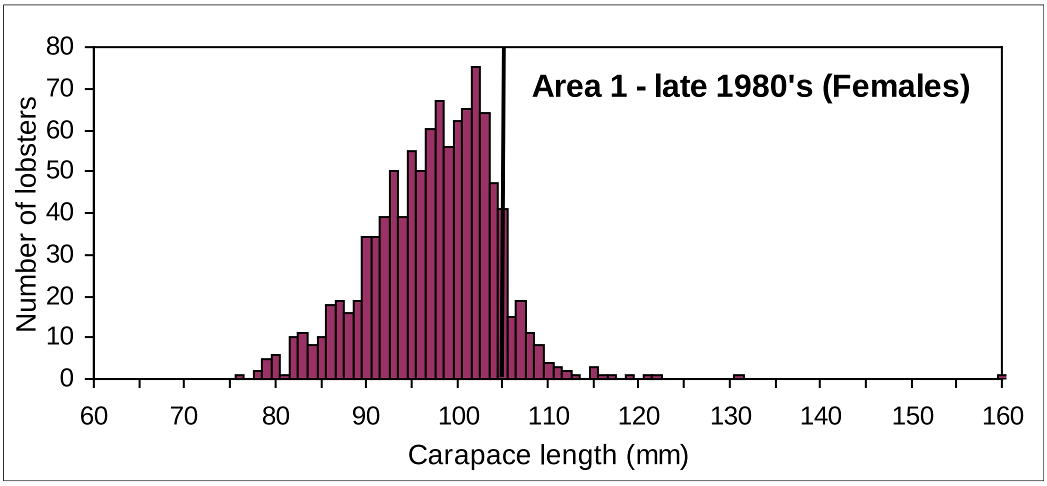
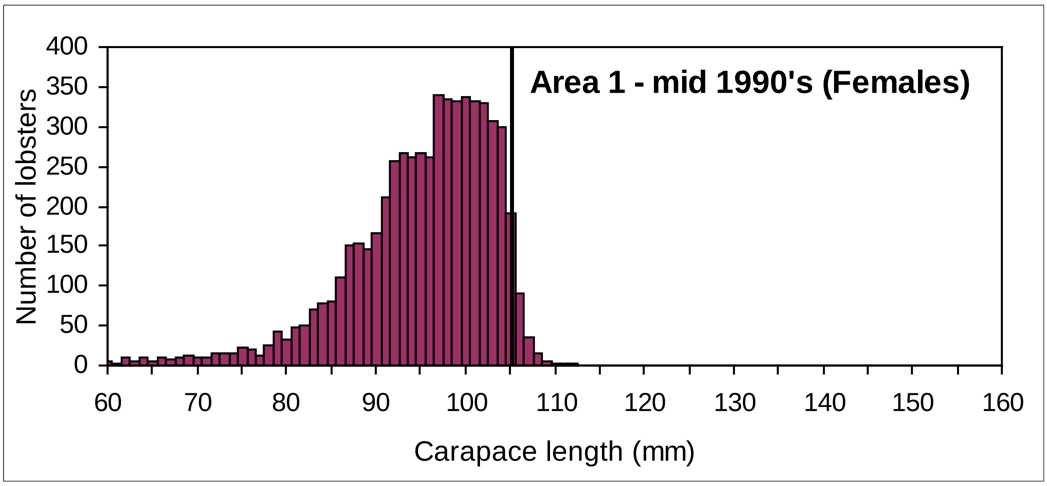


Figure 69. Area 8 – Males.





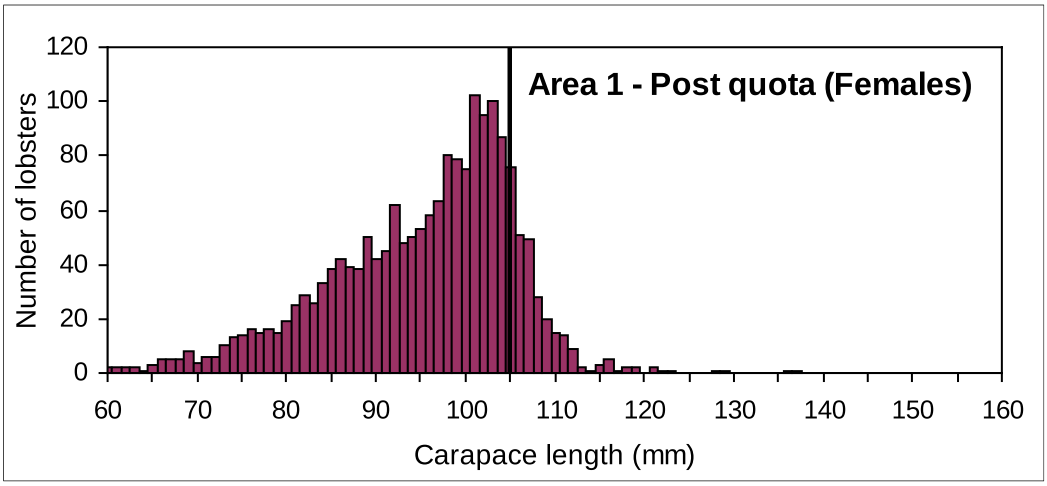


Figure 70. Area 1 – Females.

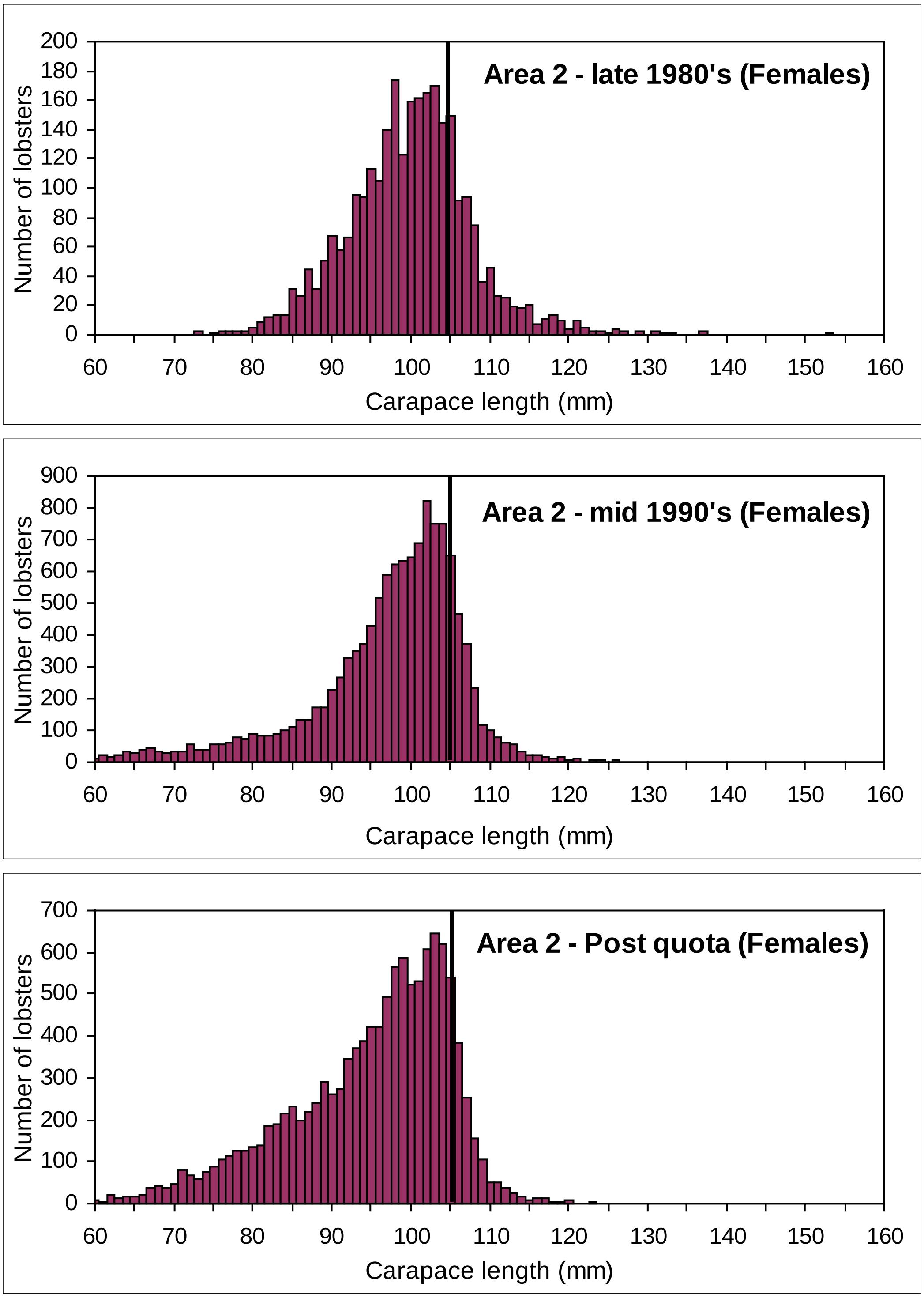
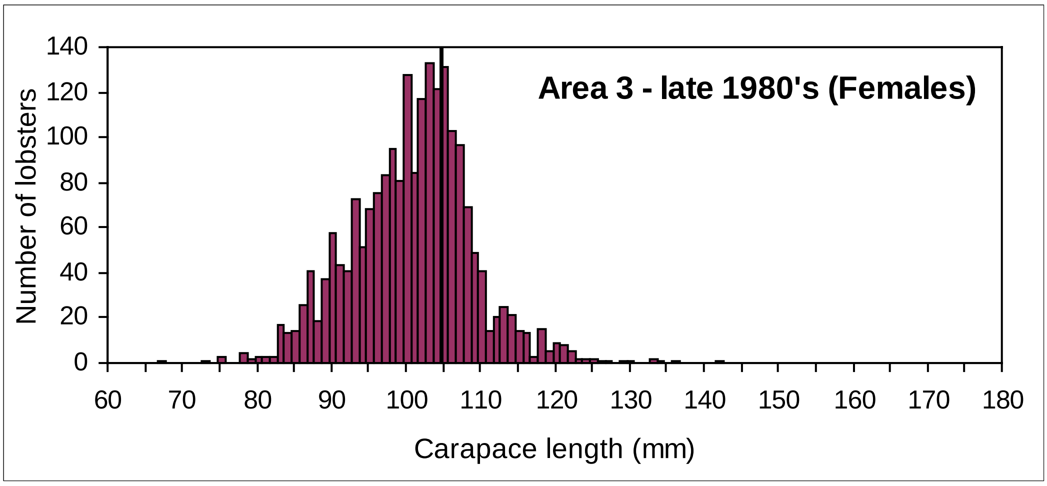
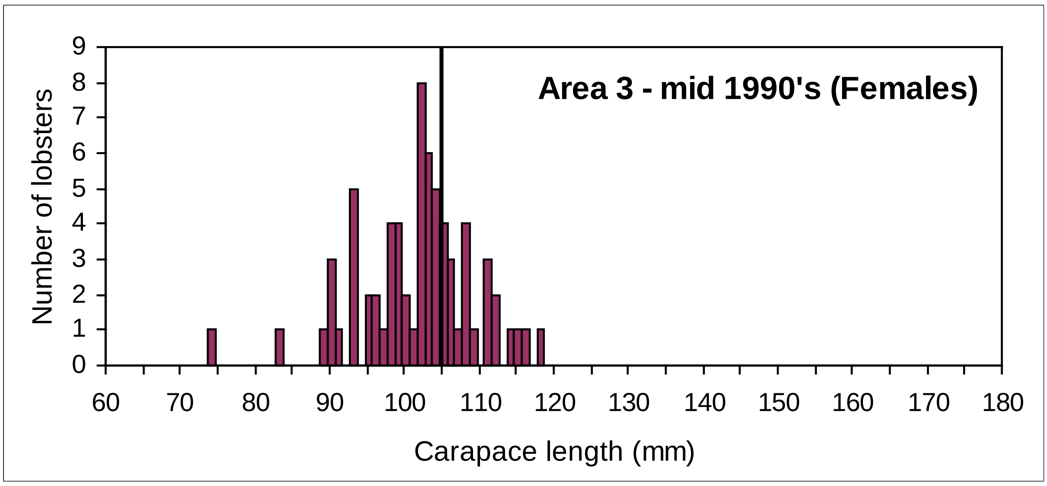


Figure 71. Area 2 – Females.





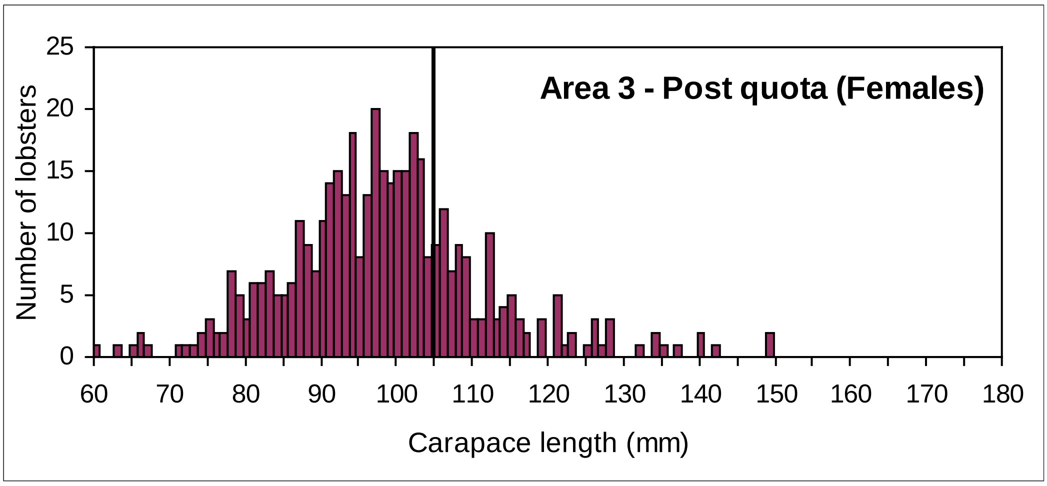


Figure 72. Area 3 – Females.

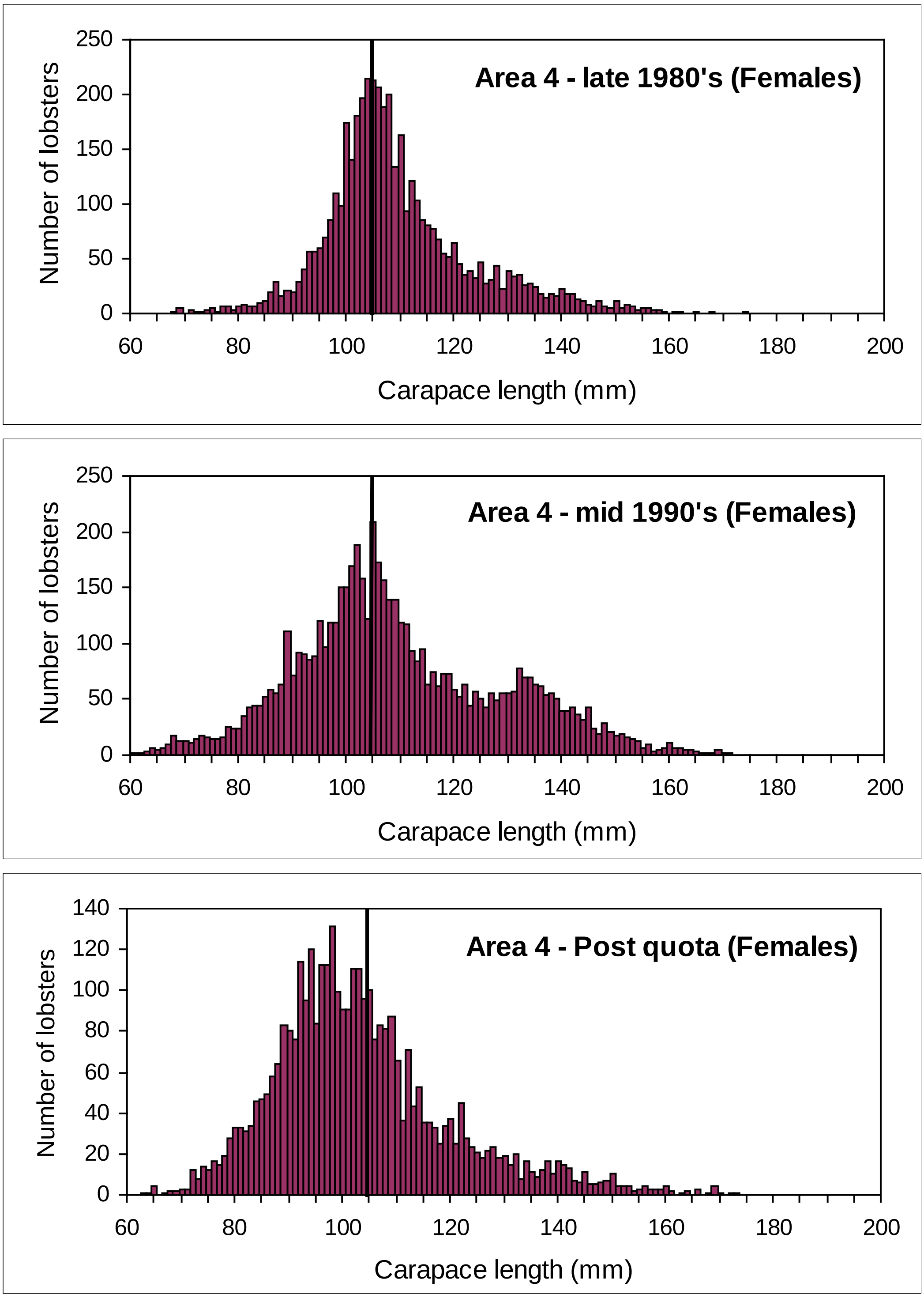


Figure 73. Area 4 – Females.

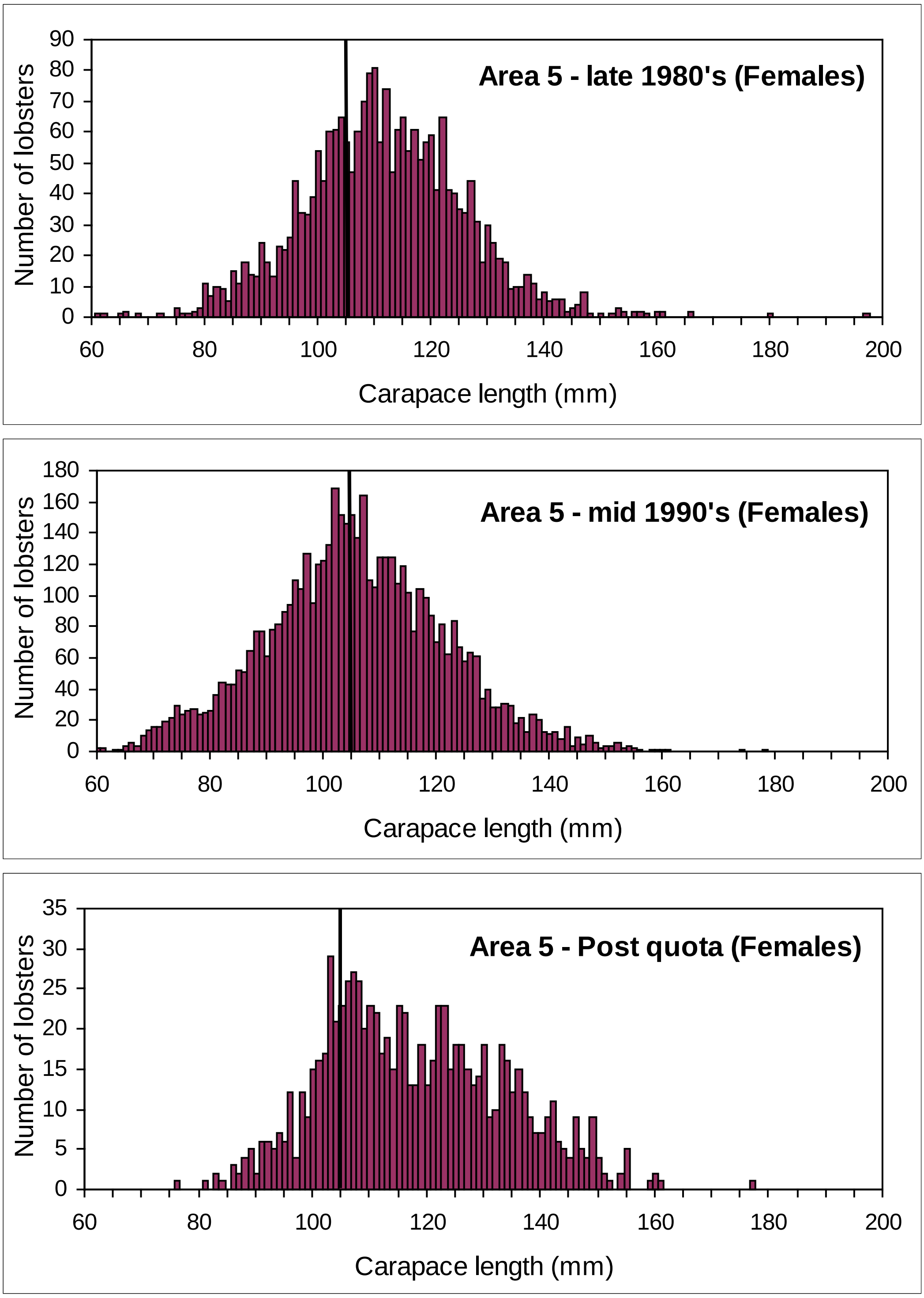


Figure 74. Area 5 – Females.

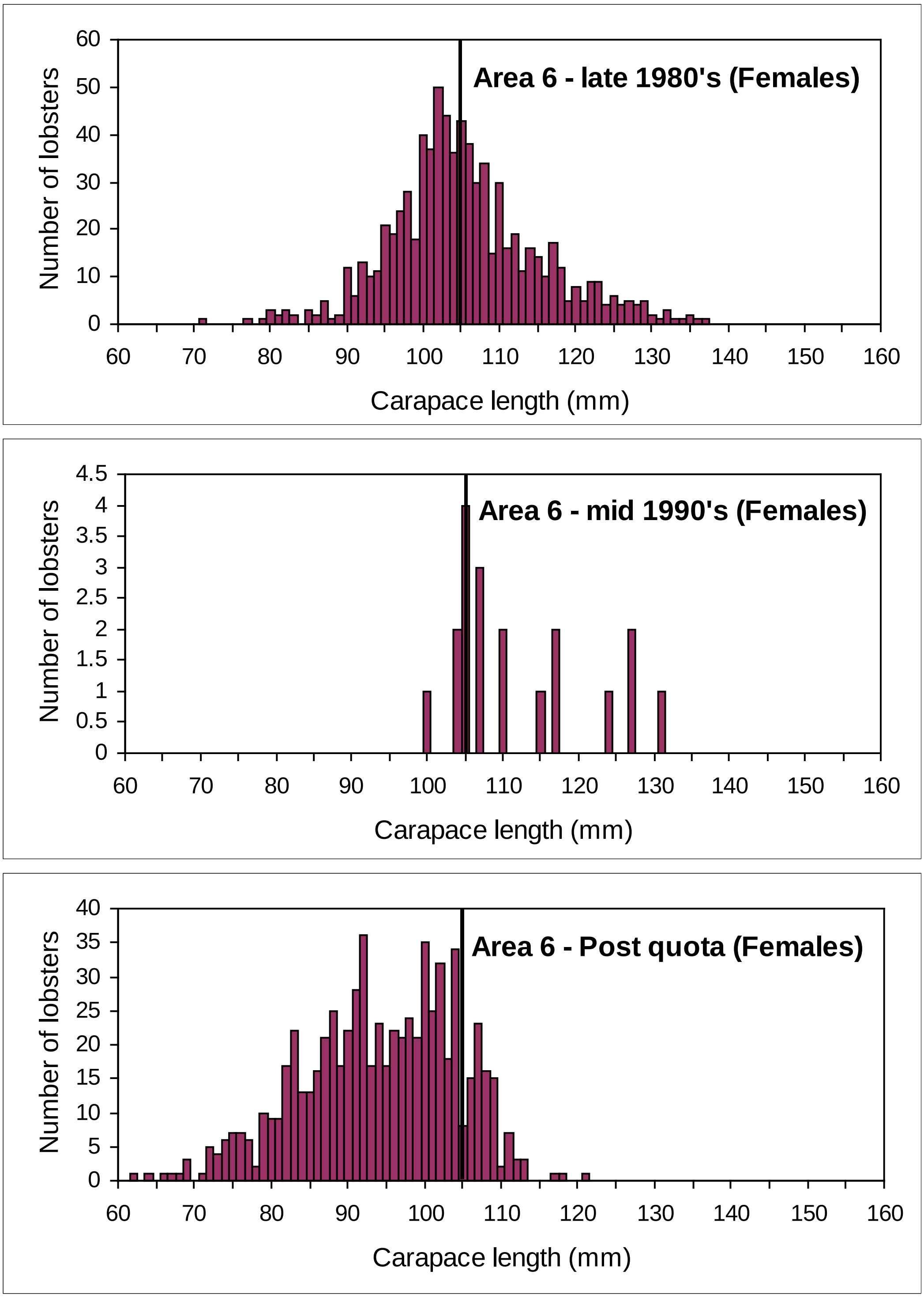


Figure 75. Area 6 – Females.

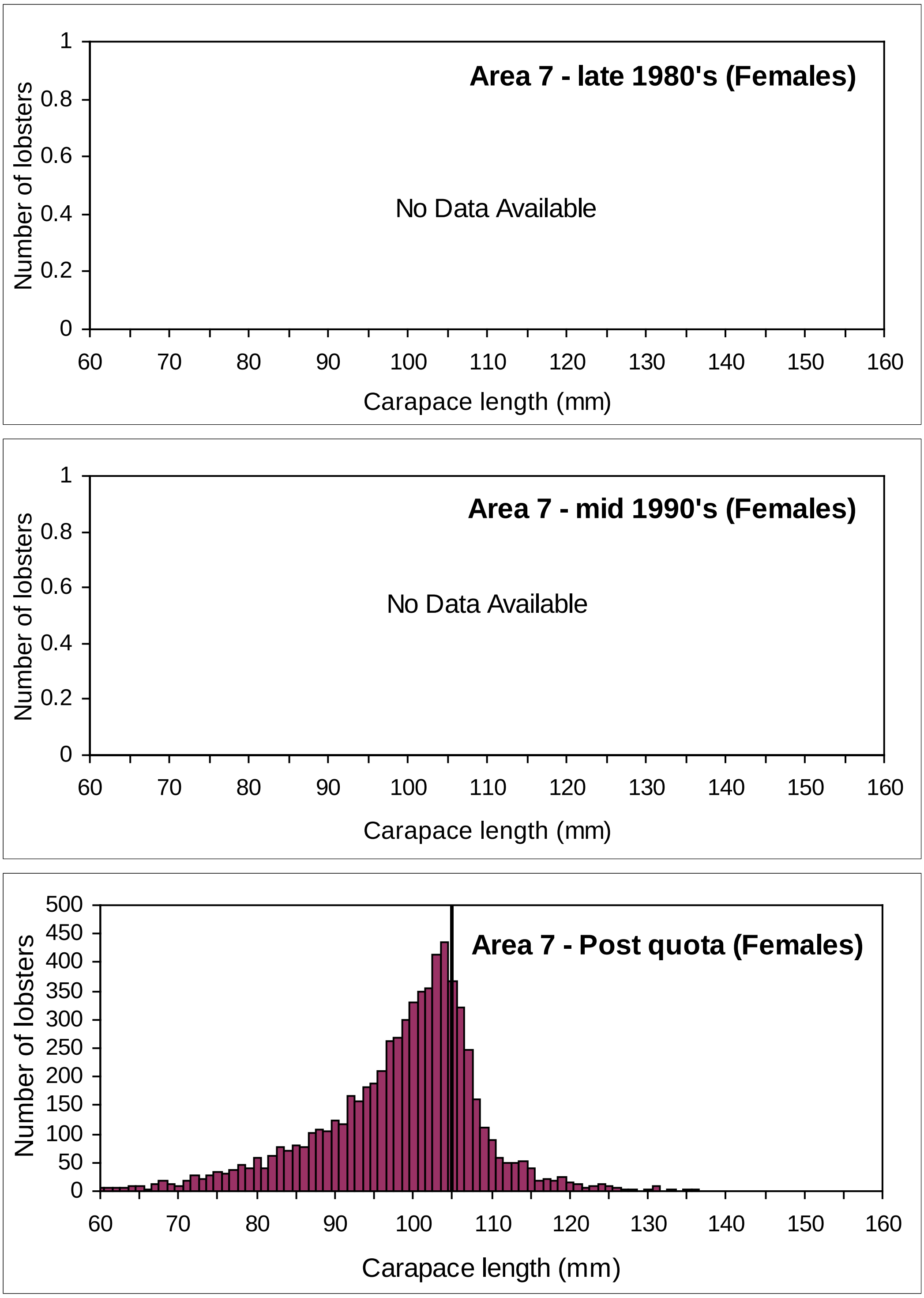


Figure 76. Area 7 – Females.

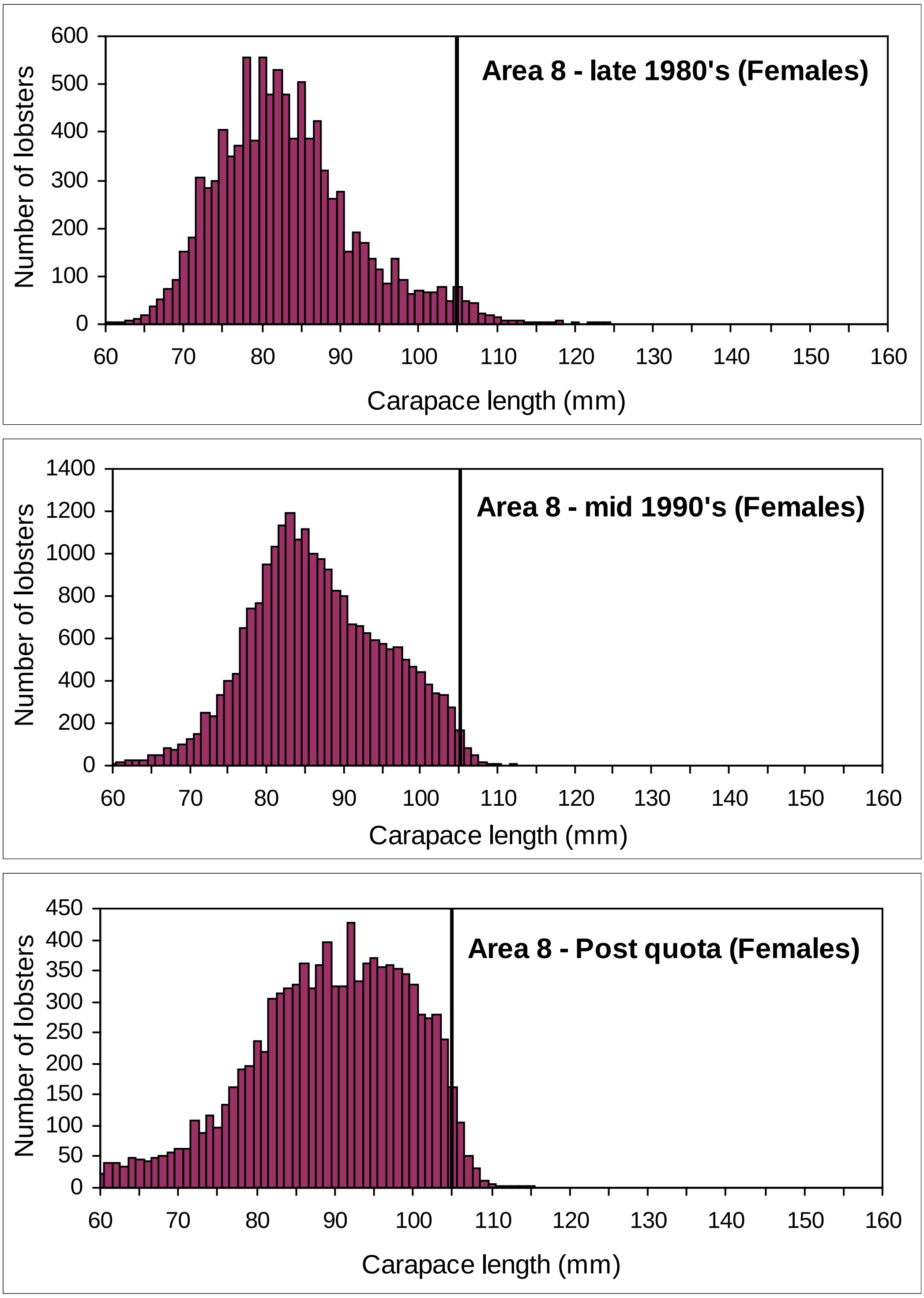


Figure 77. Area 8 – Females

15. Appendix 6: Length frequency data with model fit

Length frequency data of lobsters measured for research catch sampling. Data is split by stock assessment area and sex. Each plot also shows the length-frequency function fitted by the stock assessment model. Only data since 1967 is shown as earlier data is not included in the stock assessment model. The number of animals in samples is variable, but is indicated in each plot by the y-axis. Carapace length is shown on the x-axis.

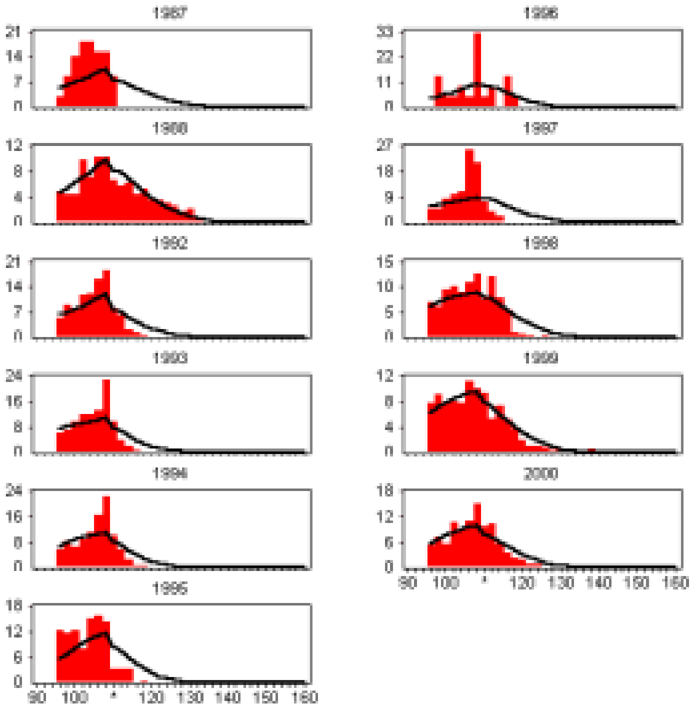


Figure 70. Area 1 – Males

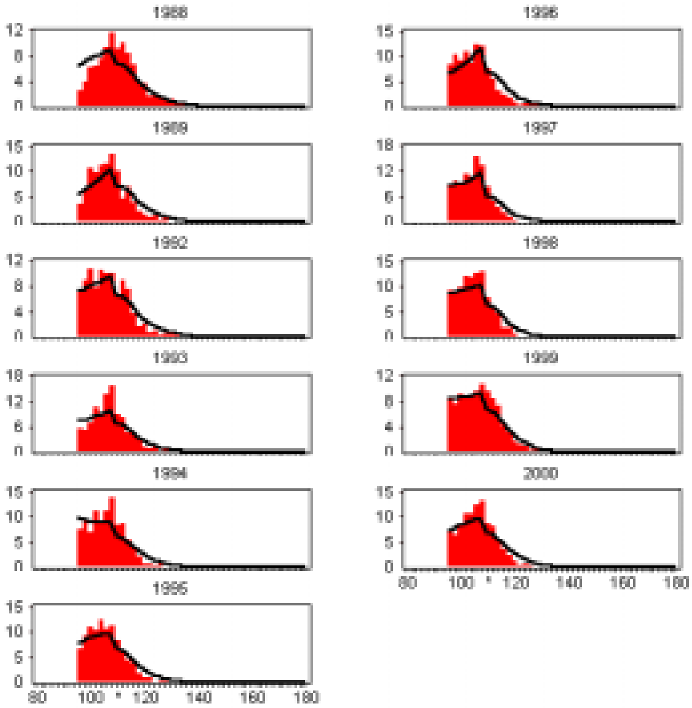


Figure 71. Area 2 – Males

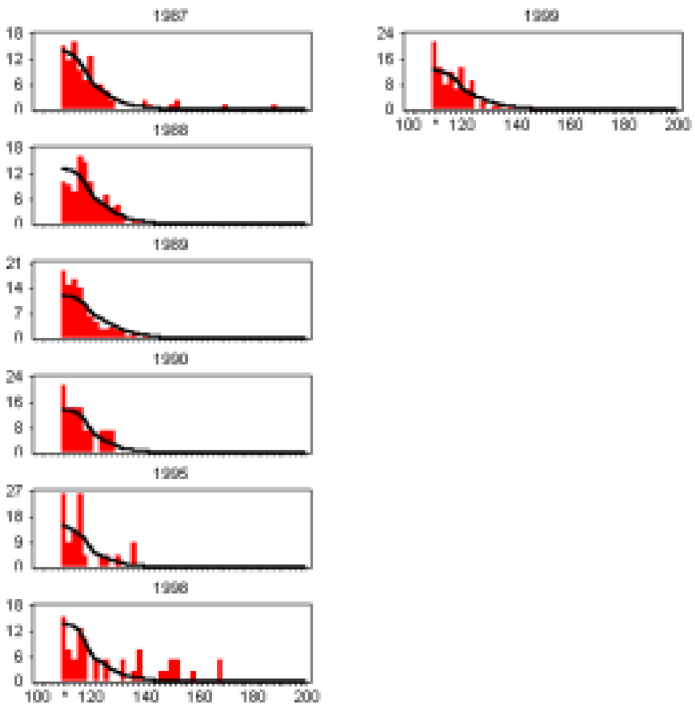


Figure 72. Area 3 – Males

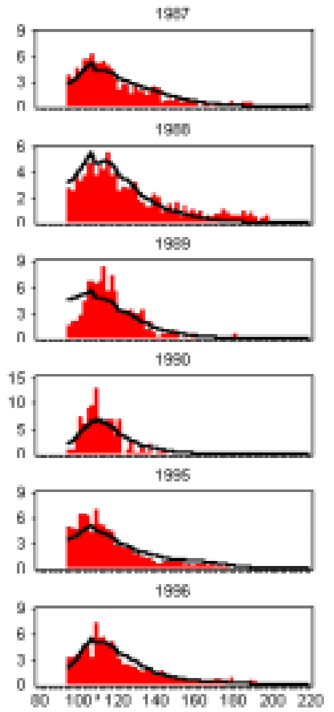


Figure 73. Area 4 – Males

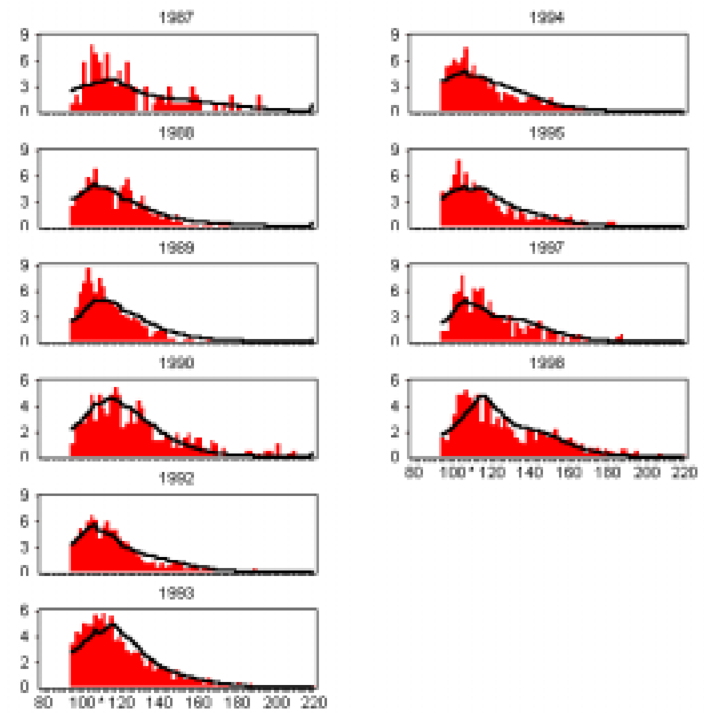


Figure 74. Area 5 – Males

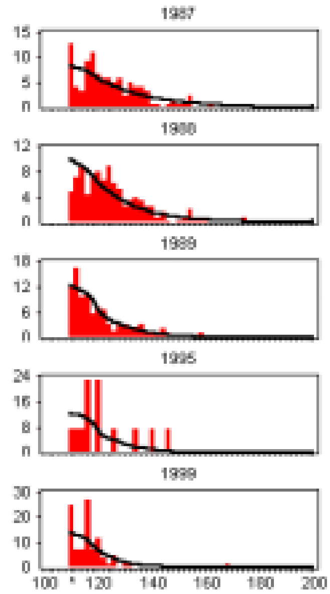


Figure 75. Area 6 – Males

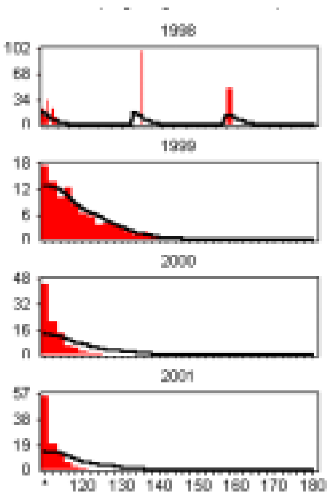


Figure 76. Area 7 – Males

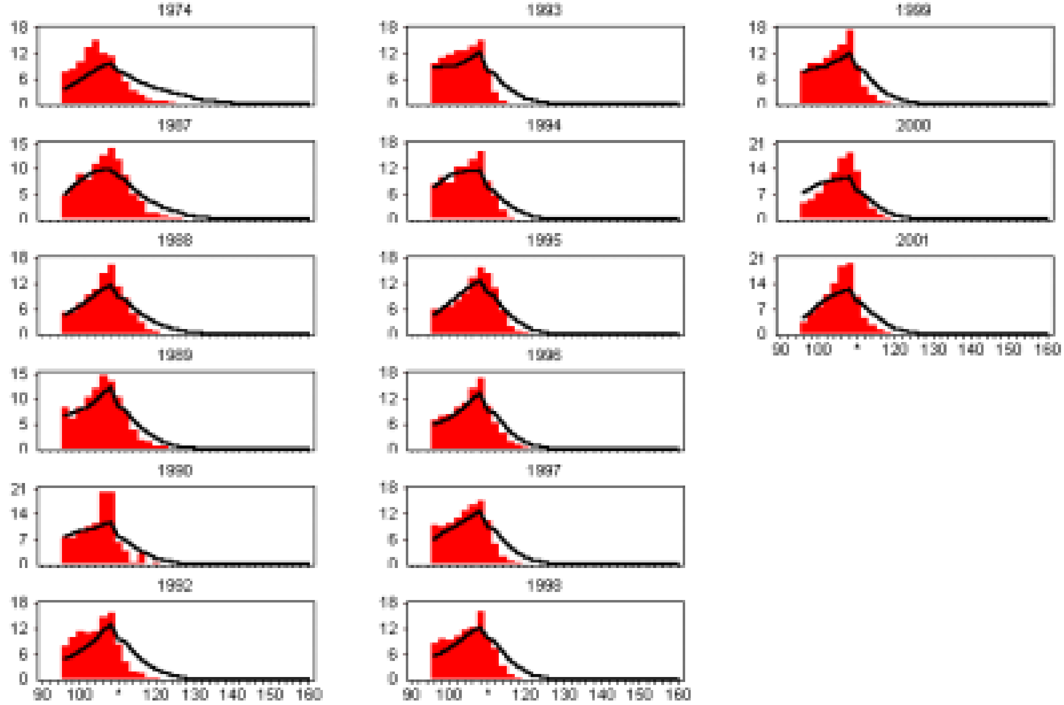


Figure 77. Area 8 – Males

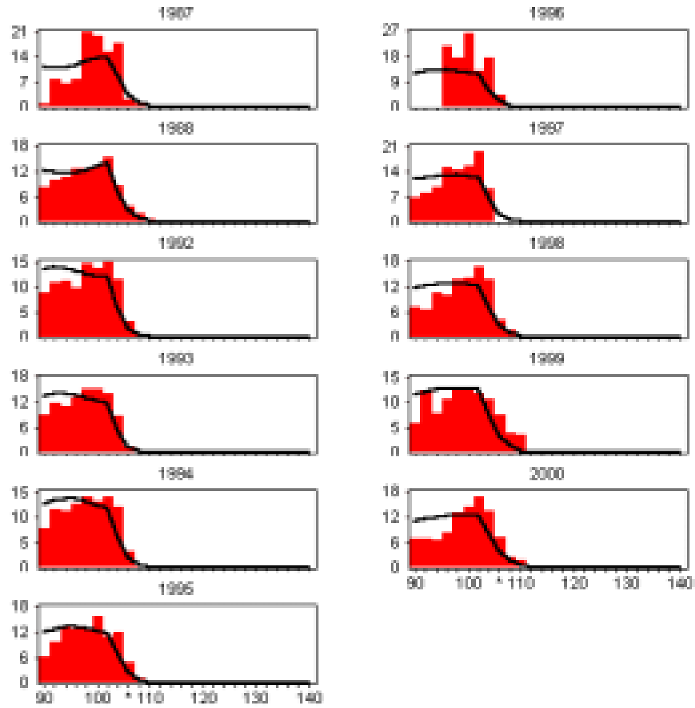


Figure 78. Area 1 - Females

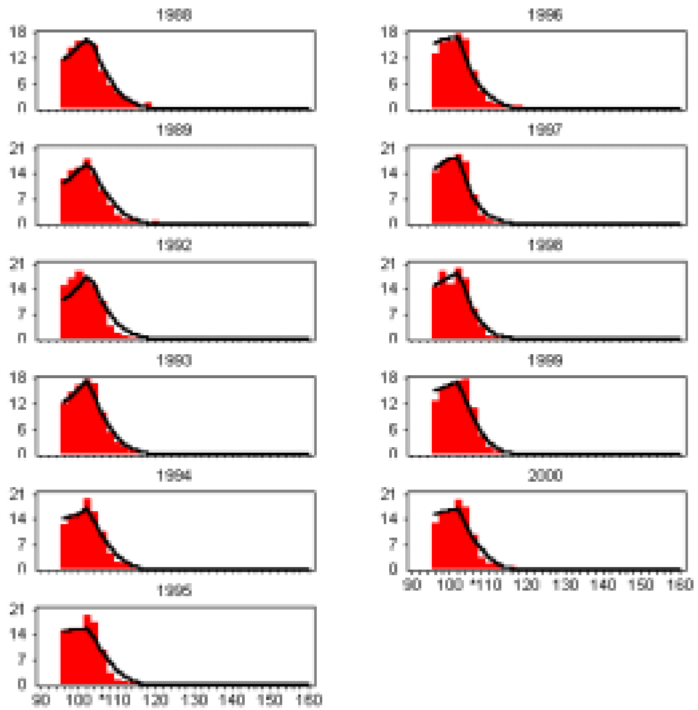


Figure 79. Area 2 – Females

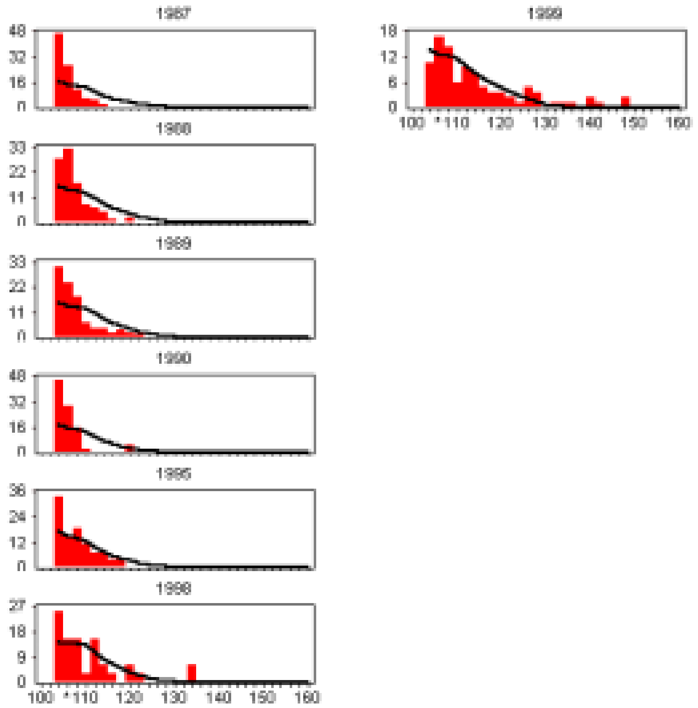


Figure 80. Area 3 – Females

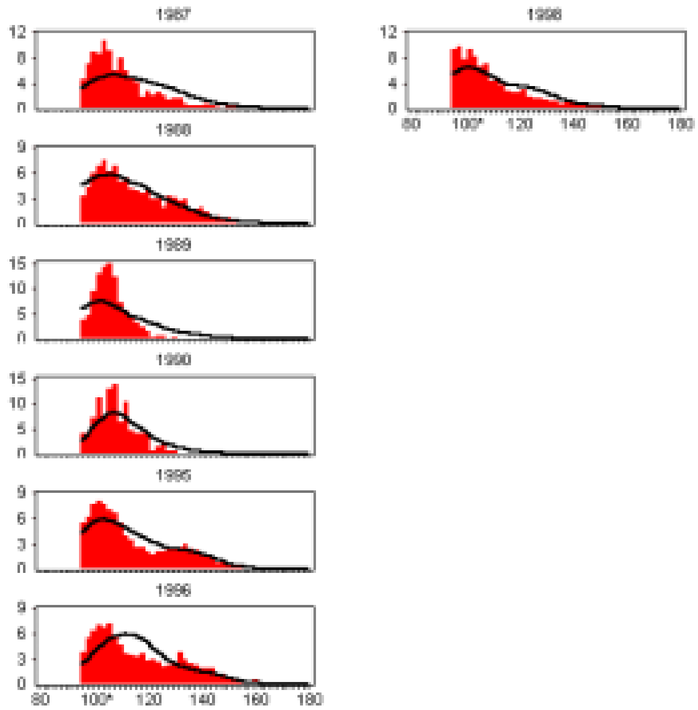


Figure 81. Area 4 – Females

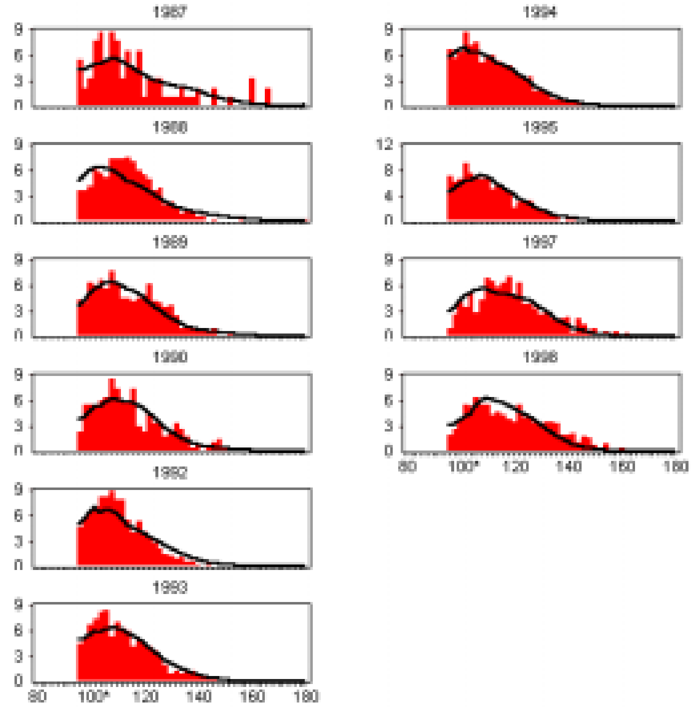


Figure 82. Area 5 – Females

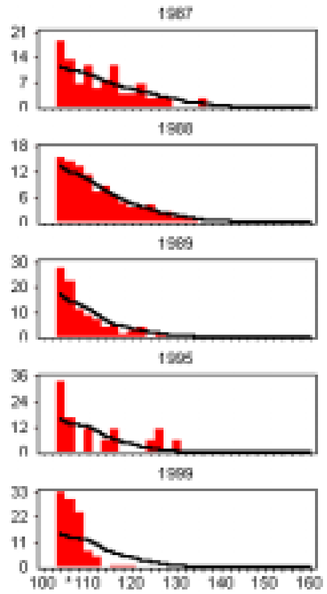


Figure 83. Area 6 – Females

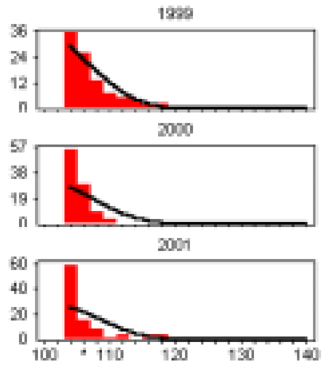


Figure 84. Area 7 – Females

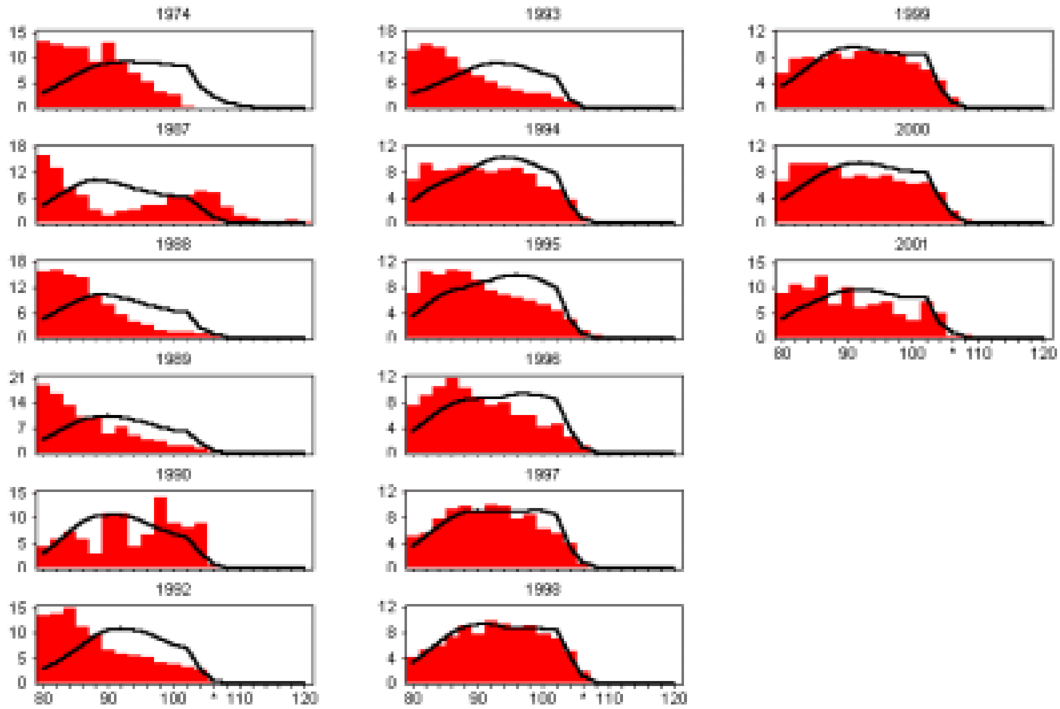


Figure 85. Area 8 – Females

16. Acknowledgments

This report used information provided by Wes Ford on changes in the fleet and licensing and Craig Johnson provided information on urchin research.

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