FISHERY ASSESSMENT REPORT

TASMANIAN ROCK LOBSTER FISHERY
2003/04

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This assessment of the Tasmanian rock lobster resource is produced by the Tasmanian Aquaculture and Fisheries Institute (TAFI) and uses input from the Rock Lobster Assessment Working Group (RLAWG). These reports provide summaries of our current understanding of the state of the stocks rather than management recommendations.

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Rock Lobster Fishery Assessment: 2003/04

Executive Summary

The economic value of the Tasmanian rock lobster fishery contributes significantly to the State's regional economy. The fishery has recreational and commercial components and this annual analysis of the state of the resource is important for management advice in both sectors and to identify potential for growth.

Opportunities for economic growth exist through both increasing catches (through improved management of spatial components of the fishery) and increasing the value of harvests. However, in the commercial fishery trading conditions are currently difficult due to continued pressure on margins through a combination of increased product globally, exchange rate, and most recently the closure of the Chinese border to Australian lobsters.

The state of the resource was formally evaluated against a series of performance indicators (Table 1). These were assessed for the most recent quota year: March 2003 to February 2004. The recreational catch was estimated through surveys and the latest estimate had almost reached the trigger point of 10% of the commercial catch, which indicated that a review was required. Other performance indicators were not close to trigger points.

The Australian Government Department of Environment and Heritage reviewed the monitoring and management of the Tasmanian rock lobster fishery as part of wildlife export accreditation. This process provided recommendations to focus research onto ecosystem based management issues (Table 2). While all recommendations were met at least in part there is scope for improvement, which provides direction for future research.

Several other measures of the resource were analysed aside from the formal indicators. Many of these showed some problems with the resource, especially in sheltered and shallow areas off the north and east.

- Catch rates were standardised to remove effects of depth, block, month and skipper. Assessment Areas 1 (SE), 8 (SW), and 7(W) all exhibited continued increases in standardised catch rates relative to 2002/2003, and this was despite the catches taken from Areas 1 (SE) and 8 (SW) increasing over those taken in 2002/2003.

- In assessment Areas 2 (E), 3 (E), 4 (NE), and 5 (NW) the standardised catch rates all exhibited a strong reduction during 2003/2004. This reversal of the previous trend of growth was assumed to be the result of fished down of a strong year class that arose in 1999/2000.

- There was a trend of increasing commercial catch in shallow waters (<20 m) from Areas 2 (E) and 3 (E). The recreational sector removed a large proportion of the total catch from shallow waters (<20m) in these Areas (around 1/3 of the total). Thus the recent trend of steadily increasing recreational catch compounds the concern in the fishery.

- Non-standardised commercial catch rates in Areas 3 (E) and 4 (NE) fell by around 20% over the last year.

- Non-standardised commercial catch rates in all east coast Areas remains below 0.9 kg/pot lift, which is lower than most southern rock lobster management areas in Australia. Recent declines in Area 3 have resulted in very low mean annual catch rates (0.64 kg/potlift).

- Absolute commercial catch taken from shallow waters (<20 m) has not tended to increase in most Areas, however, the proportion of catch from shallow waters increased due to reduced effort in deeper waters. This led to a trend of stock rebuilding in deeper waters.

- Model projections for biomass indicated stability in northern Areas 4 (NE) and 5 (NW), although this did not consider possible shifts between depths.

- Model projections for egg production indicated that is unlikely that the management target of 25% virgin egg production in Areas 4 (NE) and 5 (NW) will be achieved in the foreseeable future under the current management system.

- Puerulus catches indicate future recruitment to the fishery in Areas 2 (E), 3 (E), and 4 (NE) will be low. Puerulus catches for Areas 2 and 3 have been low for a prolonged period with the last 8 years being lower than 5 of the 6 years previous. Likewise, puerulus catches for the last 4 years in Area 4 (NE) have been lower than the 5 years previous. These trends are of concern because puerulus-monitoring data appears to correlate with model estimated recruitment (which is derived from commercial catch rates).

It is recommended that management be cognisant of apparent declines in eastern and northern regions when considering options for the fishery. The fishery increasingly appears to be one of spatial extremes with concerns for the north and east coasts while western deep-water stocks appear to be undergoing strong stock rebuilding. These spatial disparities are driven by accessibility and also regional differences in the biology of lobsters.

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

Performance indicator	Trigger point	Status in 2003/04	
Statewide commercial catch rates	<95% of reference year	✔	128%
Regional commercial catch rates	<75% of reference year	✔	>131%
Fishery independent catch rates	Significant decline from matching surveys in reference year	✔	313%
Statewide legal-size stock biomass	<95% of reference year	✔	155%
Regional legal-sized biomass	<75% of reference year	✔	>132%
Regional biomass estimates from fisheries independent surveys.	Significant decline between years		Not available
Statewide egg production	< lowest year	✔	128%
Regional egg production	<95% lowest year unless production >40% unfished state (no decline tolerated in Areas where production <10% unfished)	✔	>54% increase except where production >40% unfished state
Undersized lobster CPUE	<95% of reference year	✔	113%
Total catch	<95% TACC	✔	>99%
Size of the fleet	<220 active vessels	✔	241
Recreational catch	>10%TACC	~	Most recent estimate around 10%

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

Recommendation	Status, plus relevant section/s in 2003/04 fishery assessment
Recommendation 4. DPIWE to continue to monitor the situation with respect to the harvest of immature females in the northern part of the fishery to ensure any reductions in egg production or puerulus settlement are detected in a timely manner and develop a management response for implementation in the event that a major issue develops.	TAFI continues to monitor egg production in the north of the State. This is through model estimates of egg production based on commercial catch rates and research catch sampling. Regional importance of egg production sources is under investigation through a 3-year project on larval dispersal. Puerulus settlement continues to be monitored although this program will be reviewed in 2005.
Recommendation 6. Stock assessment processes should incorporate, if not already done, a risk assessment into the ecological impact of the potential skew in sex ratio caused by a longer fishing season on males.	TAFI monitors sex ratios at a number of locations around the State. There is no evidence that ecological impacts are likely to be sex-linked *per se*, however, fishery impacts in terms regional egg production continue to be monitored in several areas. Note that the

	longer fishing season for males has a smaller impact on sex ratios than differences in growth rate and thus protection through the minimum size limit. This implies investigation of skew in sex ratio should be regional as per growth.
Recommendation 8. An analysis of measures to encourage the accuracy of by-product reporting should be conducted with a view to improving data collection, assessment and management responses.	Apart from Octopus, by-product is considered to be a relatively insignificant component of the rock lobster fishery. Giant crabs (*Pseudocarcinus gigas*) are caught occasionally.
Recommendation 9. Mechanisms should be developed to ensure better recording of by-catch in the fishery. A more formal assessment of the risks posed to by-catch species should be carried out before the next assessment.	At present, the fishery does not record by-catch, although TAFI research indicates that by-catch is small by comparison with other fisheries. The most common by-catch species are other crustaceans (crabs and hermit crabs) and the draughtboard shark. Relatively little is know about the biology of non-commercial crab species, although none are listed as threatened or endangered. A project on biology of the draughtboard sharks is currently underway at TAFI.
Recommendation 10. A structured reporting and monitoring program into interactions with protected species should be developed as high priority.	Information on the frequency and type of interactions between protected species and the fishery are cited in this assessment report. This is the first year that this data has been collected.
Recommendation 11. DPIWE should establish a program monitoring fished and unfished areas in the fishery with a view to identifying changes in the wider marine environment that may be a result of the fishery.	Unfished areas have now been in existence for a decade and have been surveyed regularly throughout this period. Statistically significant differences in the abundance and size-structure of unfished populations of rock lobster have developed over time. The abundance of some other species has also altered. Monitoring of these sites continues although is not within a formal program.

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1. Introduction

1.1 Historical overview of the Tasmanian Rock Lobster Fishery

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

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

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

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

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

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

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

In response to further pressure from northern commercial fishers, a Parliamentary enquiry conducted by Joseph Lyons considered that pots were not destructive and recommended that pots be legalised. However, it wasn't until 1925 that pots were finally legalised as part of a new fisheries bill that placed responsibility for the management of sea fisheries with a newly appointed Sea Fisheries Board. The centrepiece of this new bill was the allocation of varying numbers of pots to commercial vessels depending on their size. For example, a limit of 30 pots was adopted for larger vessels with proportionately fewer pots allowed for smaller vessels. Inevitably, the use of pots led to dramatic increases in commercial catch due to greater efficiency, halted fleetingly by reduced market demand during the depression years (1930s) and the Second World War.

Markets have adapted to change in technology throughout the development of the fishery. The adoption of diesel engines during the Second World War meant that more product could be shipped to mainland Australia, which led to expanded markets. Soon after this, the development of refrigeration enabled a rapid expansion into the American frozen tail market. Most of the commercial catch is now transported live into Asia, the world's premium market for lobsters. The increased value of lobsters that has resulted from the development of these markets is considered to be a motivating factor for the steadily increasing recreational effort.

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

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

1.2 The modern fishery

The present commercial catch is taken from around the State and involves the annual harvest of around 1.6 million animals. There are 233 licensed commercial vessels participating in the commercial fishery, with additional catch taken by the approximately 15,000 licensed recreational fishers. Commercial harvests have been capped by a quota management system since 1998, which has resulted in substantial and steady rebuilding of stocks in most Areas. This rebuilding can be seen in the historical trends in the fishery (Figure 1).

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

Lobsters are harvested from all around the State with considerable variation in patterns of commercial fishing from region to region. Biological parameters also vary dramatically from region to region and this presents a major challenge for fishery management. An important step towards meeting this challenge is assessing different regions separately. For this purpose the State is divided into eight different assessment Areas, shown in **Figure 2**.

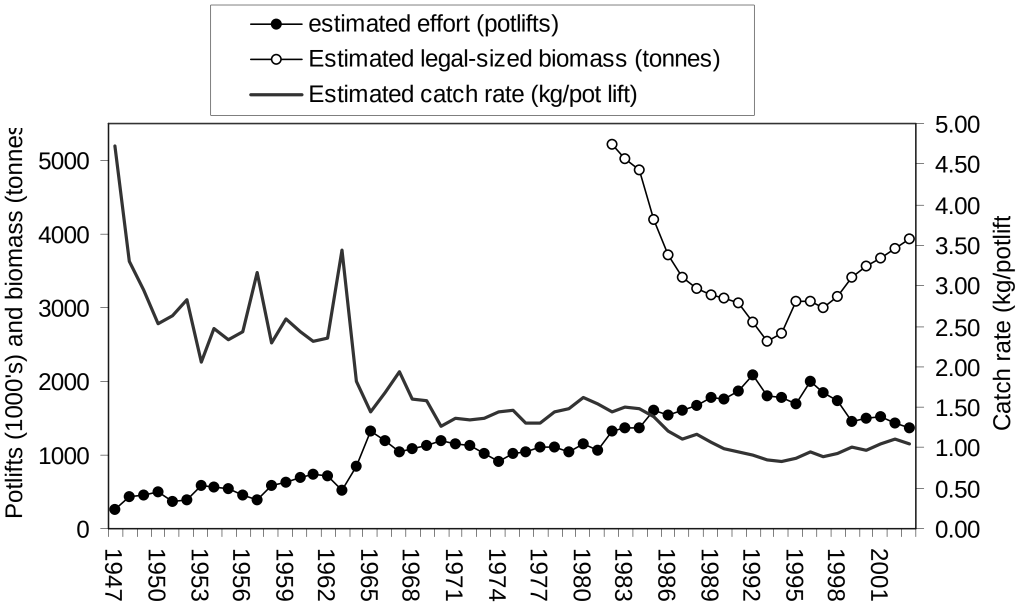

Figure 1. Historical trends in fishing effort (potlifts), catch-rate (kg/potlift) and estimated legal-sized biomass. Catch-rates after the 2nd world war and before the 1960s were much greater those seen today. As fishing effort has risen, catch-rates have fallen. Legal-sized biomass can only be estimated for later years commencing from a time when the resource was already fished down. The general trend in recent years is encouraging with biomass estimates showing a steady increase while catch rates are recovering.

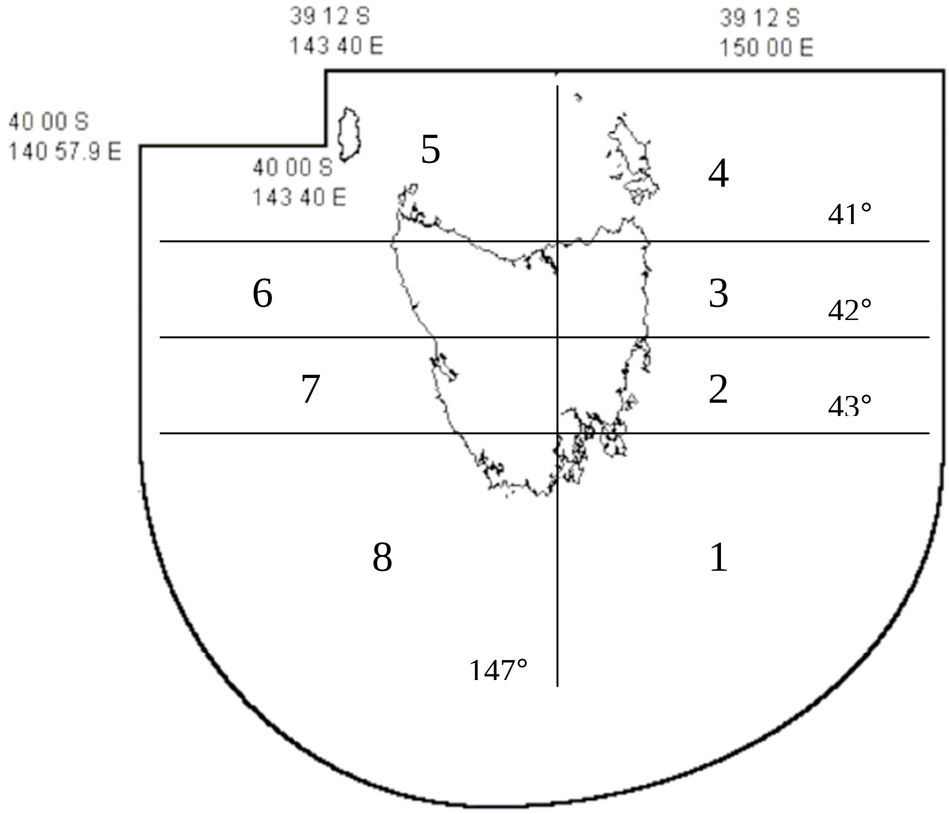

Figure 2. The boundaries of the eight Stock Assessment Areas and the area of State waters for the rock lobster fishery provided by the offshore constitutional settlement (OCS).
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1.3 Management

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

Since the inception of catch records in the 1880's, the reported annual catch steadily increased in the commercial rock lobster fishery to a high in 1984 of over 2,250 tonnes. During this period of growth in catches, concerns were expressed about overfishing in the commercial fishery, which resulted in changes in regulations. The most important changes were the legislation of design of pots in 1926, introduction of closed seasons to limit the harvest of soft-shelled lobsters in 1947, the restriction of the number of licenses in 1966, and a ceiling on the number of pots in the fishery set at 10,993 in 1972.

From the record high catch of 1984, the reported annual catch declined to a low of 1,440 tonnes in 1994 reflecting a decline in the available biomass. In recognition of the declining trend in biomass, an individual transferable quota (ITQ) management system was introduced for the commercial fishery in March 1998 following an industry ballot.

Management of the commercial fishery has remained relatively stable since the introduction of quota. Quota was initially set at 1503 tonnes for the 1998/1999 fishing season. After three years of successive improvements in biomass, the quota was increased to 1523 tonnes for the 2001/2002 fishing season. As catch is now constrained by quota, seasonal controls in the fishery have been relaxed. Lengths of seasonal closures have varied since their introduction in 1926 but complete closure of September and October was in place from 1963 to 1998. In 1998, the first 2 weeks of September were opened, to provide fishers with flexibility to take hard-shell lobsters that command a high price or fish for the lower priced soft new-shell lobsters that have a higher catchability after their moult. Timing of the September closure has changed regularly since 1998 with complete access in 2000. There remains some concern about fishing in September due to negative impacts on markets.

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

1.4 Economic and market status

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

The main objective of management of the recreational sector is social benefit rather than economic. Nonetheless, recreational lobster fishing also has an economic impact. The economic impact of all recreational fishing (lobsters, abalone, finfish etc), including secondary economic impacts, was estimated at $50 (Lyle *et al*., 2003).

Research on public perceptions of commercial fishing industries by Aslin and Byron (2003), included aspects on the economic value of fishing industries. That survey showed that there is a public perception that fishing industries are unlikely to contribute to economic growth, that is, they are seen as mature and stable industries. For the last decade, the commercial Tasmanian rock lobster fishing industry has performed contrary to this perception as it was a source of economic growth in the State (ABARE, 2004). This trend was reversed in 2003 due to the impact of Severe Acute Respiratory Syndrome (SARS), adverse exchange rates, increased world supply, and reduction of demand for small (<800 g) and large (>1500 g) lobsters. As a result, total value at point of first sale declined by around 20% over the last year.

2. Previous Assessments

This report is the ninth assessment report since regular reporting commenced in the 1995 calendar year (Table 3). This report uses data available up until 1st March 2004. It includes data for the first six years since ITQ implementation.

Table 3. Previous Tasmanian rock lobster fishery assessment reports.

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

3. Recent Developments

3.1 The Fishery

The implementation of the quota system in the commercial fishery has resulted in an increased focus on the value of the animals landed each season. Previous assessments have discussed the change in the dynamics of the fishing fleet since the change, the key observations being a shift in effort towards winter fishing when prices are highest plus a shift in effort towards shallower waters.

Changes in the market have impacted on the economic yield of the commercial fishery in recent years. In particular, the price received from processors exporting into China has declined.

Management of the recreational fishery has remained relatively stable although in 1999 the use of recreational rock lobster rings was licensed.

3.2 Developments in stock assessment analyses

3.2.1 Data collection

The analyses in the assessment are based on a range of data sources. Information about temporal changes are mainly driven by commercial logbook data, recreational surveys and research catch sampling surveys. These research surveys provide two main types of data for assessing temporal change in the resource; these are the size structure of lobster catches and measures of fishing mortality.

Our ability to measure fishing mortality from research surveys was reviewed recently. We had previously utilised techniques based on the number or ratio of legal-sized lobsters in research catches (change-in-ratio and index-removal methods). However, with the introduction of quota, the extended season opening was continually compromising these methods. Alternative methods to measure fishing mortality using tagging data were developed by Frusher and Hoenig (2001) and were seen as the best alternate option. The FRDC has funded a study to apply these models in Tasmania. This project started in August 2003 and will look at gaining estimates from broad regions of the fishery. The project has not been running long enough to provide estimates at this stage, but results are expected to contribute to the next assessment.

In the past, we have been criticised for a lack of sampling in certain regions of the fishery, for sampling in regions considered to be unrepresentative of the commercial fishery, and for using a research vessel that does not reflect a ‘true’ fishing operation. To obtain improved data from broader regions of the fishery, commercial vessels were used to collect data for the 2003/04 fishing season. This has allowed us to increase our coverage of the State to include Areas 1, 2, 4, 6 and 8. These Areas will be repeated in the 2004/05 season, plus additional sampling in Area 5. A summary of the catch sampling undertaken in 2003/04 is shown in Table 4.

Table 4. Areas and depth ranges selected after consultation with industry for shallow and deep categories for the revised catch-sampling program.

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

Although catch sampling coverage of the State has increased, our ability to sample undersize lobsters has decreased due to the use of stick pots, rather than standard meshed research pots. These stick pots commonly used by commercial fishers have larger gaps, which influences the retention of undersize lobsters. This issue is a function of trap selectivity and we are uncertain what effect it will have on model outputs. Trials are underway to standardise for this effect so that we can better account for selectivity in future assessments.

During the October 2003 pre-season survey, 2104 pot lifts were conducted, yielding 16,651 lobsters (Table 5). Of these 4903 were of legal size, all of which were tagged and released.

Table 5. Summary of fisheries independent catch sampling surveys conducted in October 2003 aboard commercial vessels with sampling by research staff.

Area	#Shots	# Pots	Total #		# Sized		# Recaptures		#Tagged	
			M	F	M	F	M	F	M	F
1	24	724	1522	2623	613	499	8	8	732	696
4	13	530	221	453	155	341	0	0	189	403
6	9	450	1705	1717	885	327	0	0	957	379
8	8	400	5792	2618	2051	32	43	0	2643	65

Another outcome of the review was that annual sampling of research sites established on both the east and south coasts in 1992 should continue (Figure 3). Preseason surveys in October will continue using *FRV Challenger*. Already this long-term data set has provided valuable insights into spatial and temporal changes in fisheries parameters such as size at maturity.

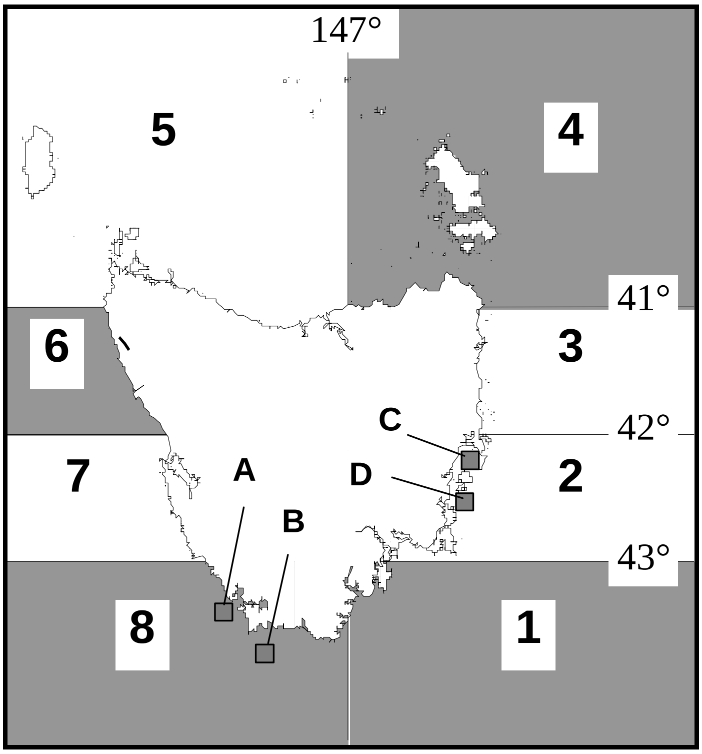


Figure 3. Fisheries-independent catch sampling coverage. Shaded areas represent Stock Assessment Areas covered by commercial vessels. Long-term survey sites sampled by research vessel (FRV Challenger) are indicated by shaded squares [A- Port Davey (2 sites), B – Maatsuyker Island (4 sites), C – Sandstone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

4. Fishery Assessment

4.1 Evaluation of Trigger Points

The management plan contains performance indicators relating to:

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

These indicators are intended to provide a guide to the status of the resource using as many sources of reliable data as possible. Acceptable limits or trigger points have been set for each of these indicators; if these limits are breached then a management review is initiated.

The trigger points are often based on the 5-year period prior to the introduction of quota. For instance, regional catch-rates for the current year are compared with those from the 5 years before quota; if the current catch-rate falls below the lowest value from those 5 years, then the trigger is activated. Many of these trigger points have been in place for several years and were established at a time when the biomass was much lower than it is today. With the increase in biomass that has occurred since the late 1990s, these trigger points are being re-evaluated as part of the review of the management plan. Although the criteria used for EPBC accreditation are assessed in this report, they are not formal performance indicators of the current management plan.

4.1.1 Commercial catch-rates

Throughout previous stock assessments, catch statistics have been expressed by calendar years out of a desire to contrast these figures against pre ITQ catch data. In this assessment we have standardised to the system of reporting on a quota year basis.

Statewide commercial catch rates for the 2003/04 quota year are higher than those recorded in the corresponding reference years and thus this trigger point has not been activated (Table 6). However, statewide catch rate has declined over the last year (Figure 4) and this decline was widespread (occurring in Areas 2, 3, 4, 5 and 7; Table 6 and Figure 5). Declines in Areas 3 and 4 resulted in catch rates similar to those at the commencement of quota management. The increase in catch rates in 2003/04 in Area 8 resulted in the first year where catch rates were higher than those in 19998/99, the first year of QMS.

Apparent declines in annual catch rates can be unrelated to declines in abundance when fishing effort shifts between seasons. For example, if more effort is expended in winter when catch rates are low, catch rate can appear to decline. This problem is overcome by examining monthly trends in catch rate. Figure 7 shows trends in catch rates across months for the 2003/04 quota year, the previous 2002/03 quota year and the corresponding reference year for each assessment Area. This figure shows that the decline catch rates in Areas 3 and 4 cannot be simply attributed to a shift in the timing of effort in these Areas. Declines in other Areas are less clear.

A decline in the rate of stock rebuilding in the NE was predicted in previous assessments as this region appeared to benefit previously from a recruitment pulse (Gardner et al., 2004). As this pulse has passed, catch rates have declined. Although the quota management system is intended to remove volatility from recruitment pulses, the NE remains driven by recruitment due to the relatively higher exploitation rate in this Area. High exploitation rates in this region are maintained at high levels due to several factors including recreational catch and the more sheltered coastline.

Table 6. 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 2002.

		Commercial catch rates (kg/pot lift)			**% change**		**Catch stats (March 2003-Feb. 2004)**	
Area	**Reference Year**	**Ref. Year**	**2002/03**	**2003/04**	**vs Ref. Year**	**vs 2002/03**	**Catch (t)**	**Effort (1000 potlifts)**
Statewide	1994	0.82	1.10	1.05	+28	-5	1434*	1360
1	1994	0.52	0.75	0.80	+53	+6	137	171
2	1994	0.54	0.97	0.89	+65	-8	129	145
3	1994	0.44	0.80	0.64	+45	-20	87	136
4	1994	0.63	1.15	0.90	+43	-22	184	205
5	1995	0.9	1.30	1.18	+31	-9	319	270
6	1995	1.21	1.65	1.68	+39	+1	171	102
7	1994	1.11	1.52	1.48	+33	-3	113	76
8	1993	0.77	0.93	1.16	+51	+25	296	255

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

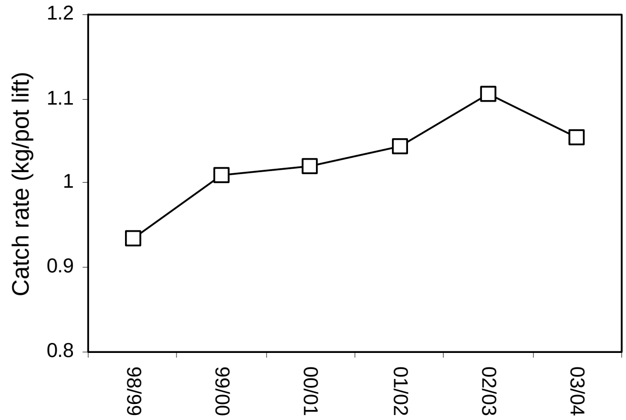


Figure 4. Change in non-standardised annual commercial catch rates since the introduction of the quota system in 1998.

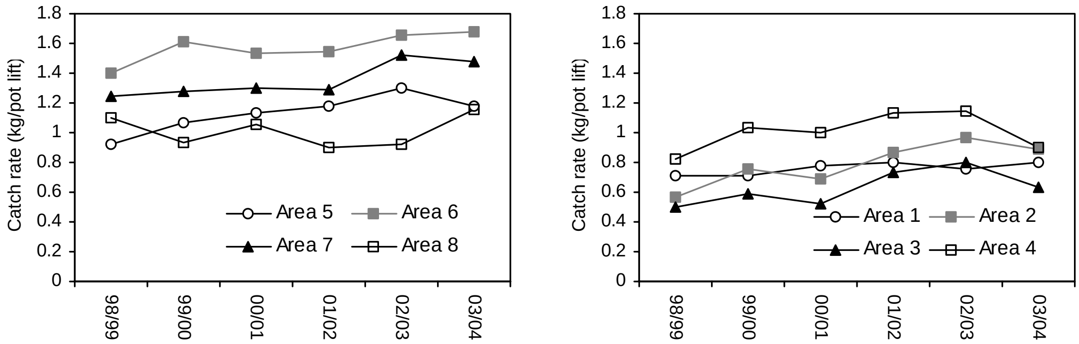


Figure 5. Change in non-standardised annual catch-rates for quota years between 1998/99 and 2003/04 for assessment Areas on the west (left) and east coast (right). Note that catch rates are higher on the west coast. Data shown in this figure is expanded over a longer time series in Figure 6.

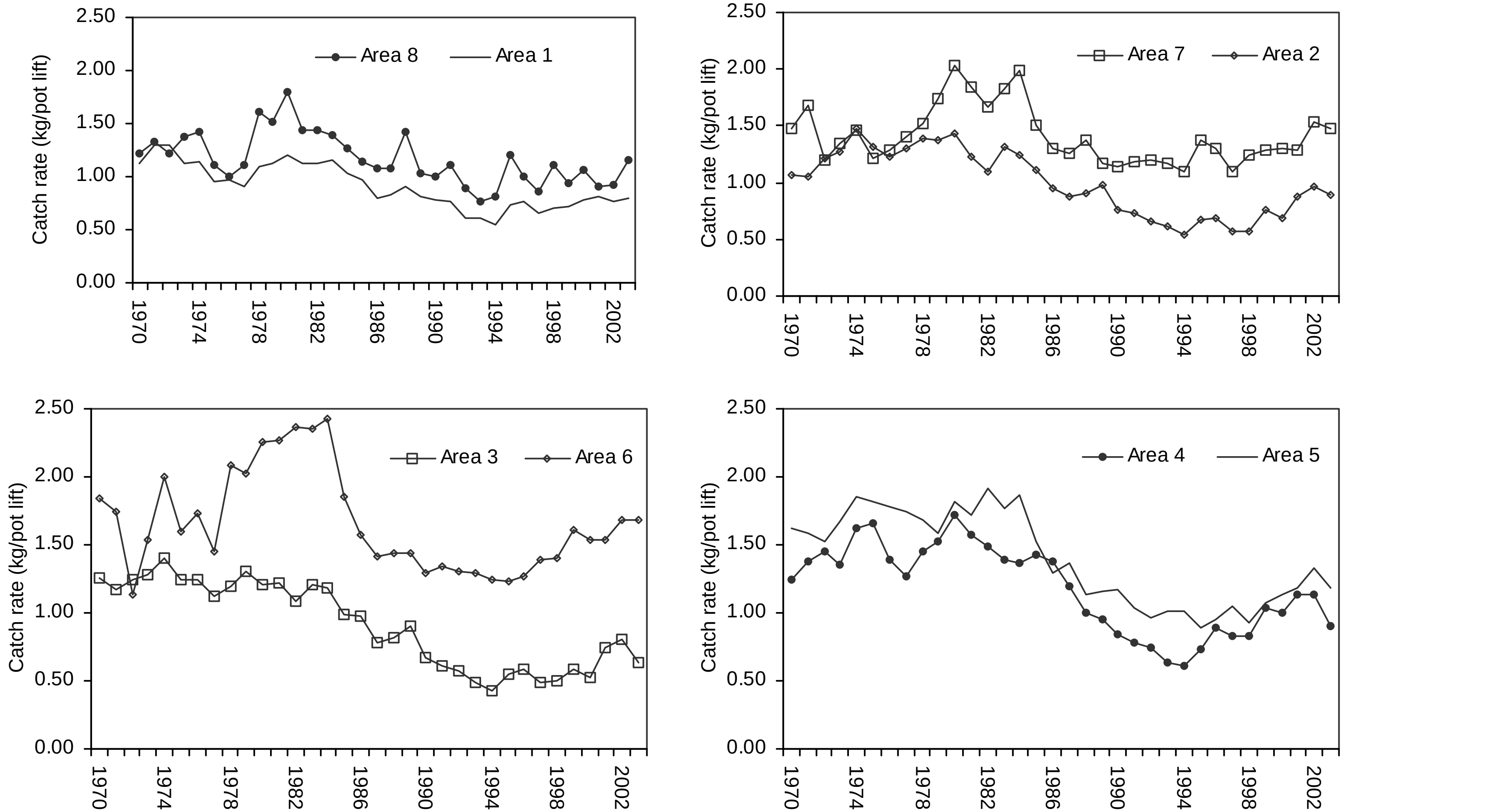


Figure 6. Regional non-standardised commercial catch rates since 1970. Data is presented on a quota year basis (i.e. March to February), so the last data point is for the period March 2003 to February 2004 inclusive.

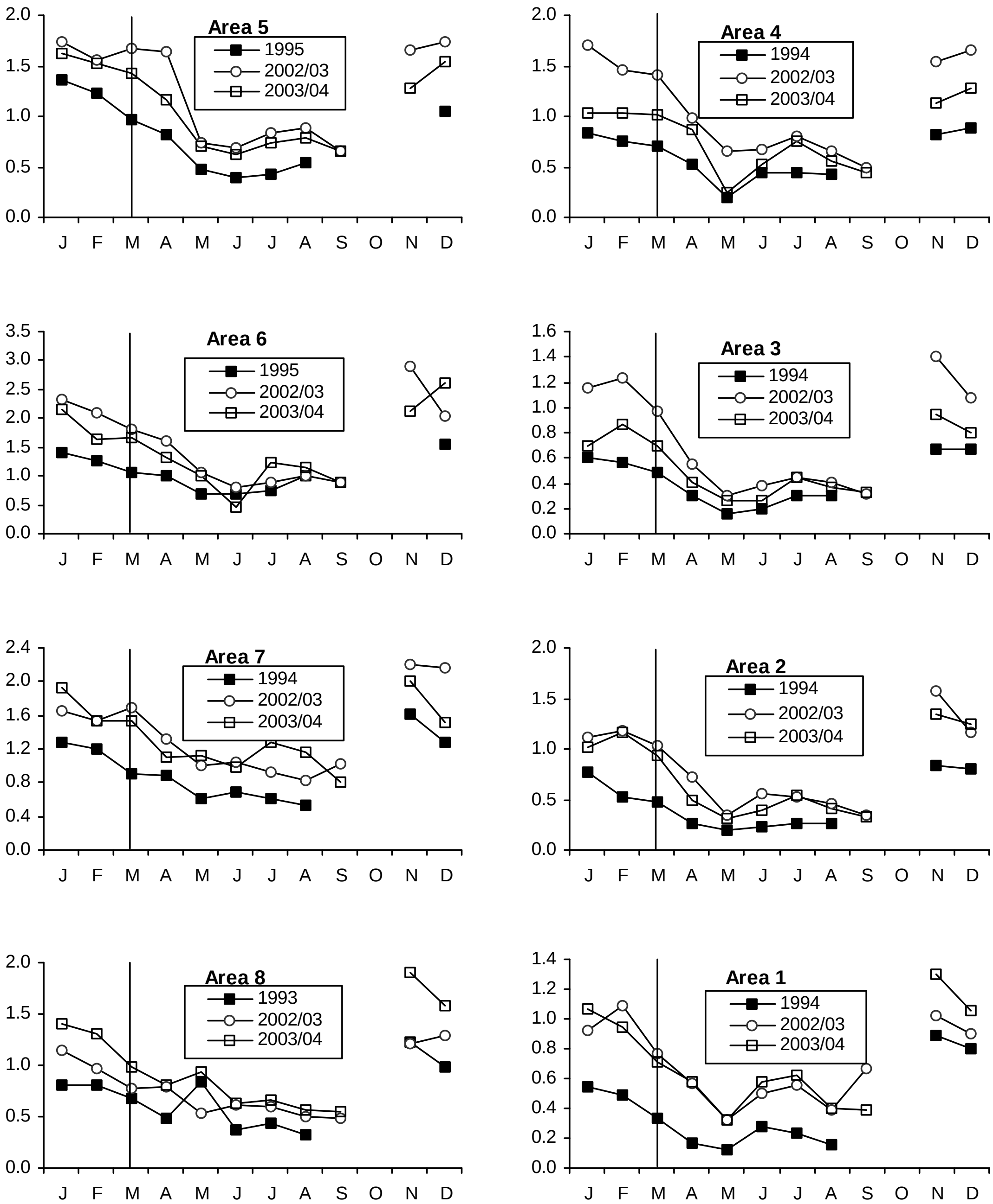


Figure 7. Change in non-standardised catch rate (CPUE, kg/pot lift) between months for the 2003/04 and the previous quota year and for the reference year. The vertical line in each plot indicates the start of the quota season. Note that the decline in catch rate in Areas 3 and 4 over the last year occurred throughout the season, thus the decline in annual CPUE was not a function of seasonal timing of effort in these Areas.

In previous stock assessments there has been a focus on fishing effort in Area 6 as an example of declining catch rates accompanied by a shift in fishing effort from deep to shallower waters (here defined as shallower than 50 m). Area 6 differs from the other Areas in that a higher proportion of the total catch for this Area comes from deeper waters (i.e. > 50 m); typically 40-50% of the total catch compared to less than 15% for the other Areas (Figure 8).

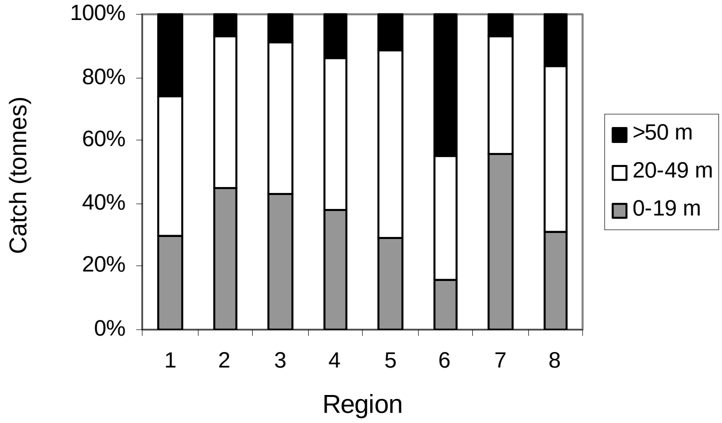


Figure 8. Percent commercial catch derived from depths <20 m, 20–49 m and >50 m for each Area during the 2003/04 quota year.

Encouragingly, the catch rate for Area 6 has remained static over the past quota year relative to the previous year (i.e. up by 1%)(Table 6). This is despite an increase in fishing effort in shallower waters in recent years, to the extent where 72% of all fishing effort is now expended in waters less than 50 m – up from 55% of total effort in 2000/01 (Figure 9).

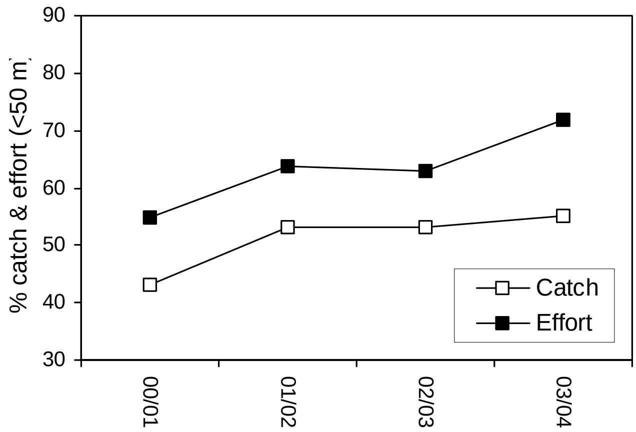


Figure 9. The percentage effort and catch from shallow waters (<50 m) from Area 6 since 2000/01.

As expected, catch-rates for the comparatively under-fished deeper stocks (>50 m depth) of Area 6 are higher than those obtained in shallower waters, although the two rates have essentially tracked one another over the preceding three quota years (2000/01-2002/03) (Figure 10). However, in 2003/04, catch rates in deeper and shallower waters appear to have diverged. Whereas catch rates among deeper waters have increased appreciably during the last year, catch rates in shallow waters have declined relative to previous years.

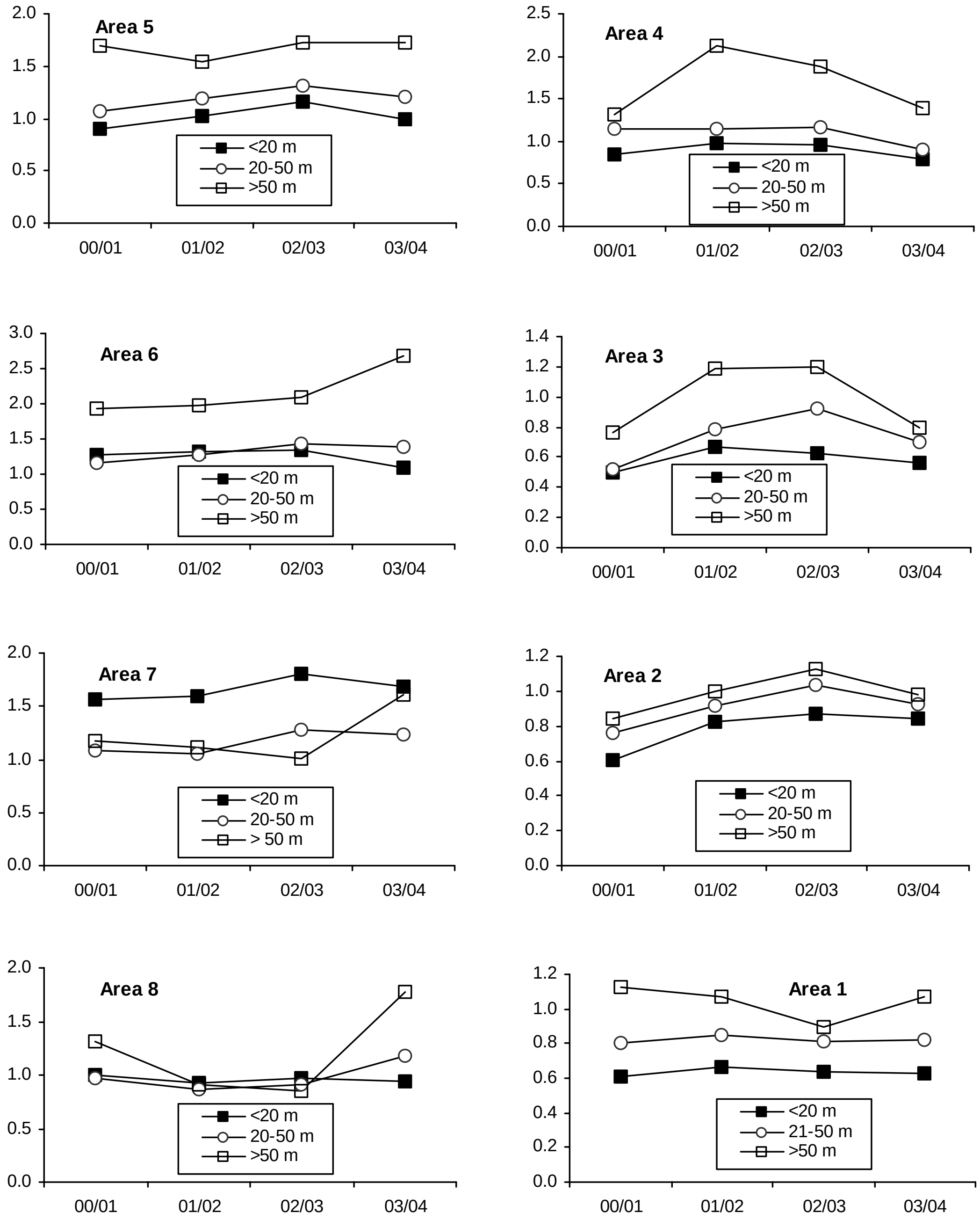


Figure 10. Regional change in catch-rates (CPUE, kg/pot lift) between quota years for depths <20 m, between 20-50 m and >50 since 2000/01**.**

A pattern of shift in the proportion of total effort expended in shallower waters is evident for data pooled for the entire State. Collectively (across all Areas) the proportion of total effort expended in waters less than 50 m has increased every year since 2000/01, to the extent that fishing in shallower waters less than 50 m now constitutes almost 89% of total fishing effort and 83% of total catch (Figure 11). Note that Figure 11 shows the proportion of catch in shallow water, not the absolute amount – thus the temporal pattern could be caused by either increased catch in shallow water, or less catch from deep water. The absence of a trend of increasing absolute catch in shallow water for most areas (Figure 12) implies that the main driver of change in the fishery is decreasing catch in deep water. Accordingly regional catch rates amongst are highest in waters greater than 50 m in depth, with the exception of Area 7, which shows the reverse trend (Figure 10). Areas 3, 4, 5 and 6 all show recent evidence of declining catch-rates in shallower waters (i.e. <50 m). This trend is again concerning and suggests that continued high fishing effort from both sectors in shallower depths maybe unsustainable in terms of maintaining catch rates at present levels.

Note that the change in commercial catch rates at different depths does not imply increased interaction with recreational fishers. The absolute commercial catch taken from depths less than 20m has trended upwards in Areas 2 and 3, however, no clear trend is evident in other areas (Figure 12).

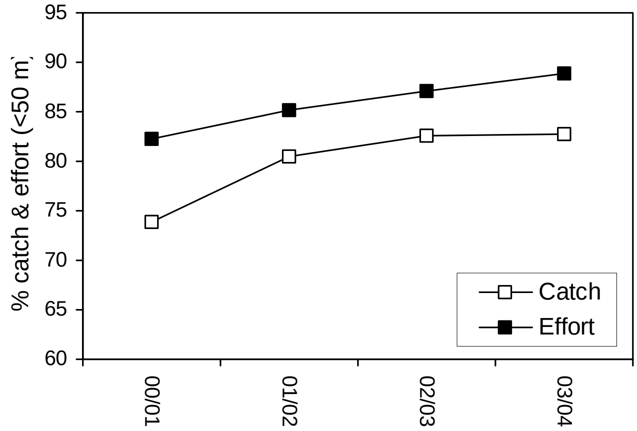


Figure 11. Percent effort and catch from shallower waters (<50 m) for all Areas combined since 2000/01.

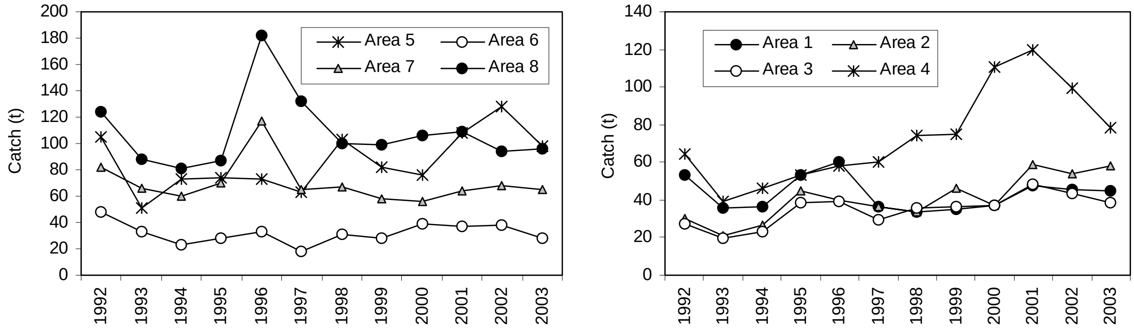


Figure 12. Change in annual catch taken by the commercial fishery from depths where there is most interaction between the recreational and commercial sectors (<20 m). Areas 2 and 3 have a pattern of increasing catch from these depths, while any trend is ambiguous in other Areas.

4.1.2 Standardised catch-rates

The Tasmanian rock lobster fishery has a long history stretching back into the 19th century (Winstanley, 1973) and the information recorded on the fishery has changed through this time. Thus, after 1992, fisheries data is available at a resolution of half-degree statistical blocks with daily records of catch and effort. From the early 1990s depth is available as an estimate of the average depth of activity. This increase in the type of data that was recorded enabled more in-depth exploration of factors that affected catch rates.

Since the introduction of quota, the behaviour and composition of the fishing fleet has altered significantly and this has had effects on catch rate data. For example, there is now more effort in water less than 50 m than in the past because shallower water animals are of a higher value. The potential for fisher behaviour to alter catch rates rather than changes to stock biomass has important implications. It might lead to the conclusion that the stock status is more or less positive than it is in reality i.e. it might bias the assessment.

Factors that are likely to have an impact on observed catch rates include location, who was doing the fishing, whether they were fishing at night or at day, and the depth of fishing. Standardizing commercial catch and effort data removes the influence of such factors. Following standardisation, any variation left in the catch-rate data will be more closely related to changes in the stock biomass.

The most commonly used method of standardization is to include the various factors thought to effect catch rates into a general linear model and to include year as a factor, in this way the parameters derived for each year become the indices of relative abundance (Klaer 1994; Vignaux 1992). Methods are described in more detail in Appendix 4.

The eight statistical models generated each Area are described in Table 7, the optimum models do not change the trends greatly from the geometric means (Figure 13).

Table 7. Definitions of the eight statistical models used in the standardization of the rock lobster catch rates for 1994/1995 to 2003/2004.
Cst was a constant, Qyear was quota year, BoatDM was vessel distinguishing mark, DayNight was whether a shot was overnight or during the day, DepCat was a series of 10 fathom depth categories, Block was statistical block.

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

Model 8 Ln(CE) = Cst + Qyear + Month + BoatDM + DayNight + DepCat + Block + Month*Block

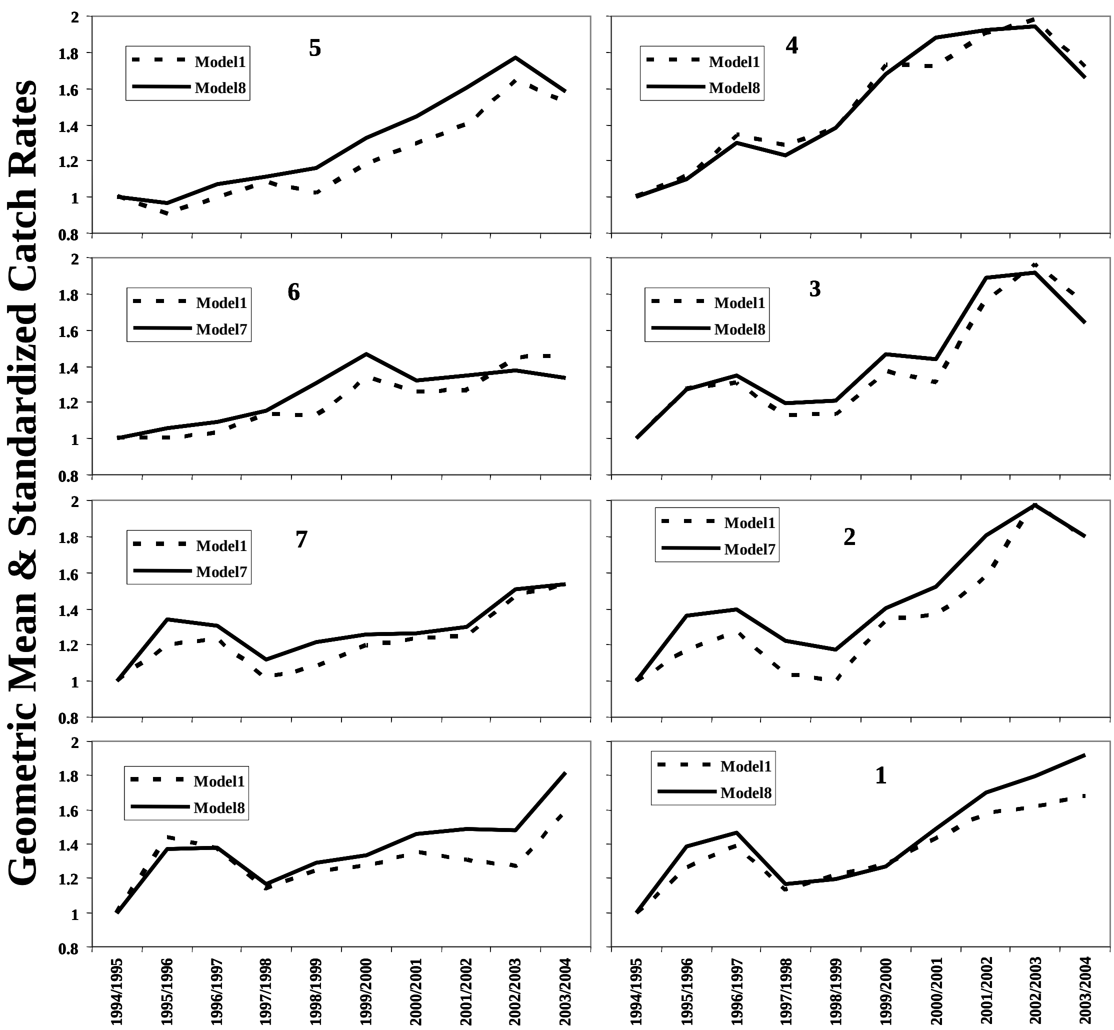


Figure 13. Geometric mean catch rates for each quota year compared with the optimal standardized catch rate series for each of the eight assessment Areas. Model 1 was the geometric mean in each case while the optimum statistical model was either Model 7 or Model 8.

The trends observed differ greatly between Areas. Increases in catch rates were seen in Areas 1, 8, and 7 over the last quota year. Area 6 had relatively stable catch rates, while Areas 2, 3, 4, and 5 had significant downturns in catch rates (Figure 13). This pattern was reflected in the relative catches from each Area (Figure 14), which were lower than the 2002/2003 quota year in Areas 2, 3, 4, and 5 but higher in 1 and 8.

The various factors affecting catch rate had different levels of influence in different Areas (Table 8). The seasonality of lobster catchability is so marked that the factor *Month* accounted for most of the variation in every Area except Area 6 where the *Vessel* doing the fishing was most important. In Areas 1, 2, and 3, *Month* accounted for about 70% of all variance described while *Vessel* accounted for about 15%. In Areas 4, 5, 6, and 7 *Month* accounted for about 43% while *Vessel* accounted for about 27% except in Area 6 where it was 45%. In general the *daynight* factor described more variation that the *depthcategory* factor, even in Area 6. In Area 7, *daynight* was almost as influential as *Vessel*. Depth was influential on catch rates than these other factors although it clearly has an effect as can be seen if catch rates are plotted against depth (Figure 15).

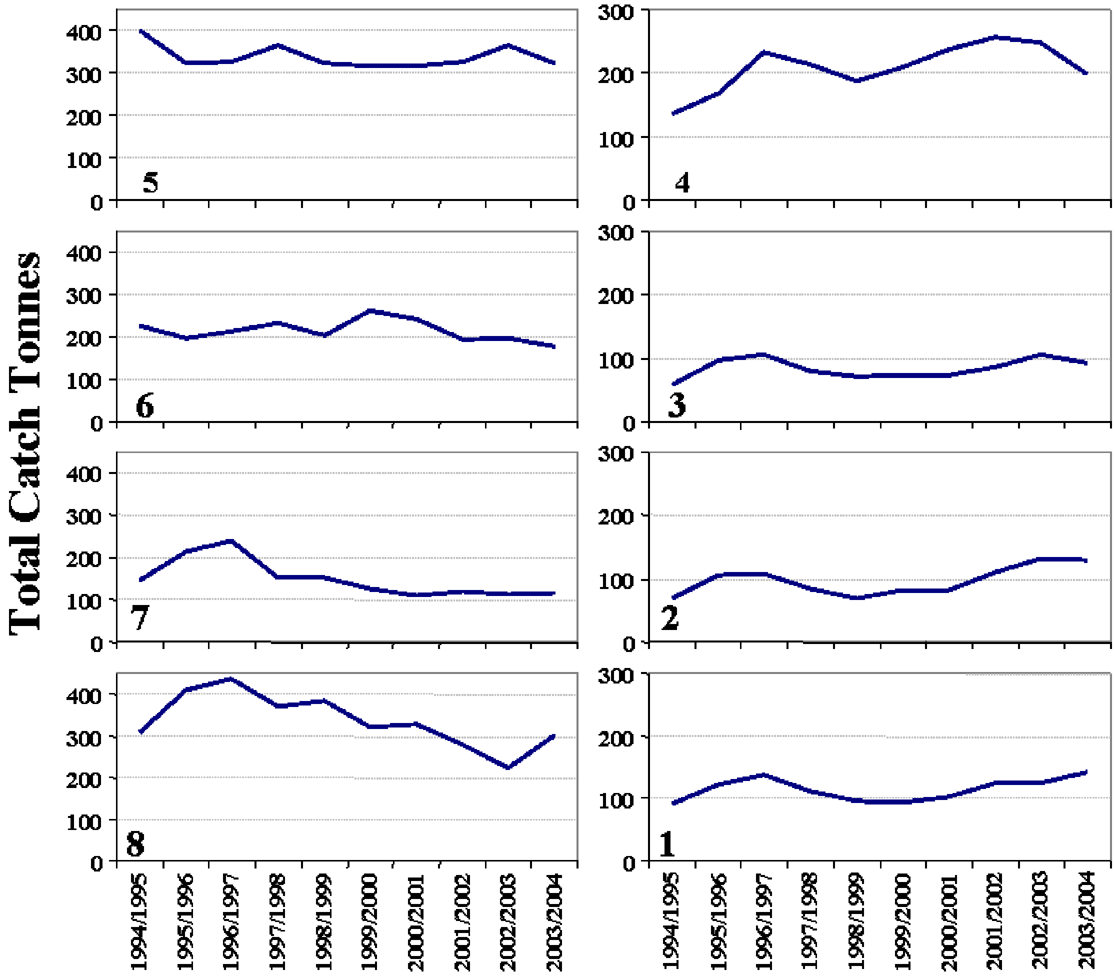


Figure 14. **Total catch by quota year for the eight rock lobster assessment Areas.**

Assessment Areas 1, 8, and 7 continued to improve since last year, especially Area 8. In Areas 1 and 8 the standardization had the effect of increasing the improvement above that observed in the basic geometric mean catch rates. In Area 7, the standardized catch rates were almost coincident with the geometric mean in the 2003/2004 quota year. The increases over the last year in Areas 1 and 8 occurred despite increases in the total catch removed from the Areas relative to the 2002/2003 catch.

The 2003/2004 catch from assessment Area 6 was slightly down on the 2002/2003 level but the standardized catch rate remained relatively stable or declined very slightly. Standardized catch rate from Area 6 was certainly lower than the basic geometric mean catch rate.

In 2003/2004, Areas 2, 3, 4, and 5 all exhibited a decline in both the geometric mean catch rates and the standardized catch rates. The overall effect of the standardization was minor. These declines occurred despite the total catch from each of these assessment Areas either declining or, in Area 2, remaining essentially the same. At first sight these declines appear to be alarming but they may be the results of unusually strong recruitment in the period 1999/2000. Standardized catch rates in these Areas have improved between 1999/2000 and 2003/2004 improvements, which implies some level of stock rebuilding has occurred.

While there is no immediate cause for concern, neither is there cause for complacency. If the observed decline in catch rates in northern Areas continues into the 2004/2005 quota year then this may be cause for concern.

Table 8. The contribution of factors to the total model fit (adjusted R^2) for each assessment Area. The models are described by adding each term down the left-hand size. QYear is quota year, DayNight is whether a shot was made during daylight hours or night, DepthCat were a set of 10 fathom depth categories, and block was the statistical block within each Area. Where the contribution of the Month*Block factor was negative (Areas 2, 6, and 7) Model 7 was optimal, elsewhere Model 8 was optimal. Month was the most important factor in all Areas except Area 6. The bottom half of the table are merely the R^2 values converted to percent of the total for ease of comparison between Areas.

	Area1	**Area2**	**Area3**	**Area4**	**Area5**	**Area6**	**Area7**	**Area8**
Qyear	2.99	6.80	5.34	6.85	4.17	2.86	2.09	1.90
Month	36.46	38.76	33.28	17.91	20.12	14.49	16.45	27.30
Vessel	7.54	8.13	8.32	12.27	11.94	16.90	9.05	10.54
DayNight	0.63	2.86	0.46	2.49	1.95	1.48	8.61	0.88
DepthCat	0.78	0.32	0.50	2.19	1.71	1.13	1.76	0.67
Block	0.59	0.21	0.02	0.88	0.37	0.31	0.09	2.85
Month*Depth	0.43	0.25	0.22	0.32	0.28	0.83	1.22	0.29
Month*Block	0.11	-0.15	0.10	0.28	0.48	-0.28	-0.65	0.18
Total R2	49.54	57.34	48.24	43.18	41.02	38.00	39.26	44.60
Qyear	6.03	11.86	11.07	15.86	10.18	7.53	5.33	4.27
Month	73.60	67.60	68.99	41.49	49.04	38.14	41.91	61.21
Vessel	15.22	14.18	17.24	28.42	29.11	44.47	23.05	23.62
DayNight	1.27	4.99	0.96	5.76	4.76	3.90	21.93	1.97
DepthCat	1.58	0.56	1.04	5.07	4.16	2.97	4.47	1.49
Block	1.20	0.37	0.04	2.04	0.91	0.81	0.22	6.40
Month*Depth	0.87	0.44	0.45	0.73	0.68	2.19	3.10	0.65
Month*Block	0.23		0.21	0.64	1.17			0.40

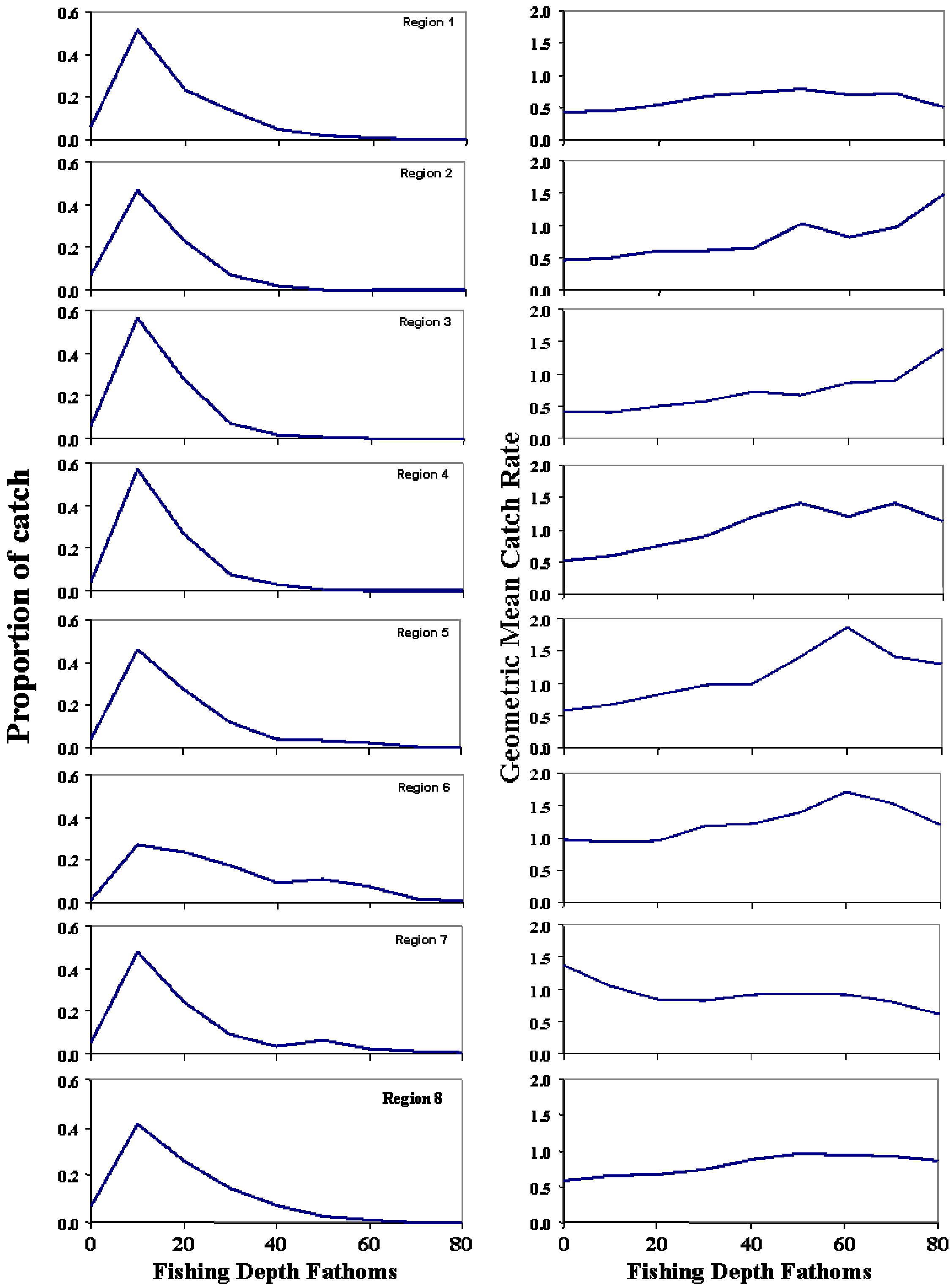


Figure 15. The proportion of the total catch and the geometric mean catch rate by depth category (10 fathom steps) for each of the eight rock lobster Stock Assessment Areas. In most Areas the catch rates in the deepest categories derive from very few data points.

4.1.3 Research catch-rates

Comparison of research-catch rates on an annual basis is currently only available for locations within Areas 2 and 8, although the scope of research catch sampling has recently been widened. Research catch-rates for 2003/04 are considerably higher than those recorded in reference years, and with the exception of medium depth sites in Area 2 (Table 9).

In the case of Area 8, the research catch rate in 2003/04 increased by almost 9-fold compared to same period in 2002/03, however, the extent to which this increase is the result of unusually low catch-rate in the previous year (the result of poor weather conditions) is unclear. When compared against the long-term average for this Area, a research catch rate of ca. 1.6 lobsters/pot lift, this result indicates that there has been a large and significant increase in the abundance of legal-sized lobsters. This pattern was also present in commercial catch-rates from this Area over the past year (see Table 6).

Research-catch rates in medium depth waters in Area 2 declined slightly relative to 2002/03 rates. Surprisingly, the catch rate for depths less than 35 m displayed significant increase. It should be noted, however, that this figure is based on very small sample size of 50 pots, and thus is likely to be inherently more variable than larger samples. Given this, a longer time series is required to establish any trend.

Table 9. Research catch rates from sampling conducted in November 2003 (no. lobsters/pot lift) on the East and South Coasts of Tasmania. Commercial catch rates were calculated using data from the first week of November within the specified range of depths.

Area	Depth	Commercial	Ref.	Catch-rates (#/ pot lift)			% change	
	(m)	Catch rate 2003	Year	Ref. Year	2002	2003	vs Ref. Year	vs 2002
Area 2	<35	2.11	Nov'94	1.06	1.40	2.74	+159%	+96%
Area 2	35-50	1.83	Nov'94	1.36	3.69	2.89	+113%	-22%
Area 8	45-100	4.06	Nov'93	0.97	0.51	4.53	+367%	+788%

4.1.4 Legal-sized biomass

Estimates of biomass from the rock lobster stock assessment model indicated stability rather than growth of legal-sized biomass over the last year (Table 10). The only notable decline in biomass was recorded for Area 3 (-19%), although the legal-sized biomass for this Area is still well above that recorded in the reference year. Only Areas 6 and 8 have had significant increases in legal-sized biomass over the past year (9% and 28% increase, respectively). Area 6 had received little research sampling in previous years and the length frequency data obtained through additional research sampling may have contributed to the estimated rise in biomass. In cases where biomass declined, the current estimates of legal-sized biomass are well above those recorded in the corresponding reference year.

All Areas have undergone rebuilding in stock biomass since 1994. In recent years this growth appears to have stalled in Areas 3, 4 and 5, while it has continued in others such as 6 and 8 (Figure 16).

Table 10. Change in legal-sized biomass in October.
Negative values indicate a decline in the percentage change. Shaded lines are Areas with greater uncertainty in biomass estimates. "State (adj)" is Statewide data adjusted to exclude Areas 1, 4, and 8 where biomass is estimated poorly for recent years (i.e. includes only Areas 2,3,5,6 and 7).

Area	Ref	Sized biomass estimate (tonnes)			% change in 2003	
	Year	Ref. Year	2002	2003	vs Ref. year	vs 2002
Statewide	1993	2349	3795	3932	+55	+4
State (adj)	1993	1362	2044	2024	+49	-1
1	1993	200	498	512	+109	+3
2	1993	122	250	241	+82	-4
3	1994	65	141	115	+54	-19
4	1994	385	734	730	+70	0
5	1993	636	945	932	+34	-1
6	1995	251	318	348	+33	+9
7	1994	291	390	389	+32	0
8	1993	391	519	666	+69	+28

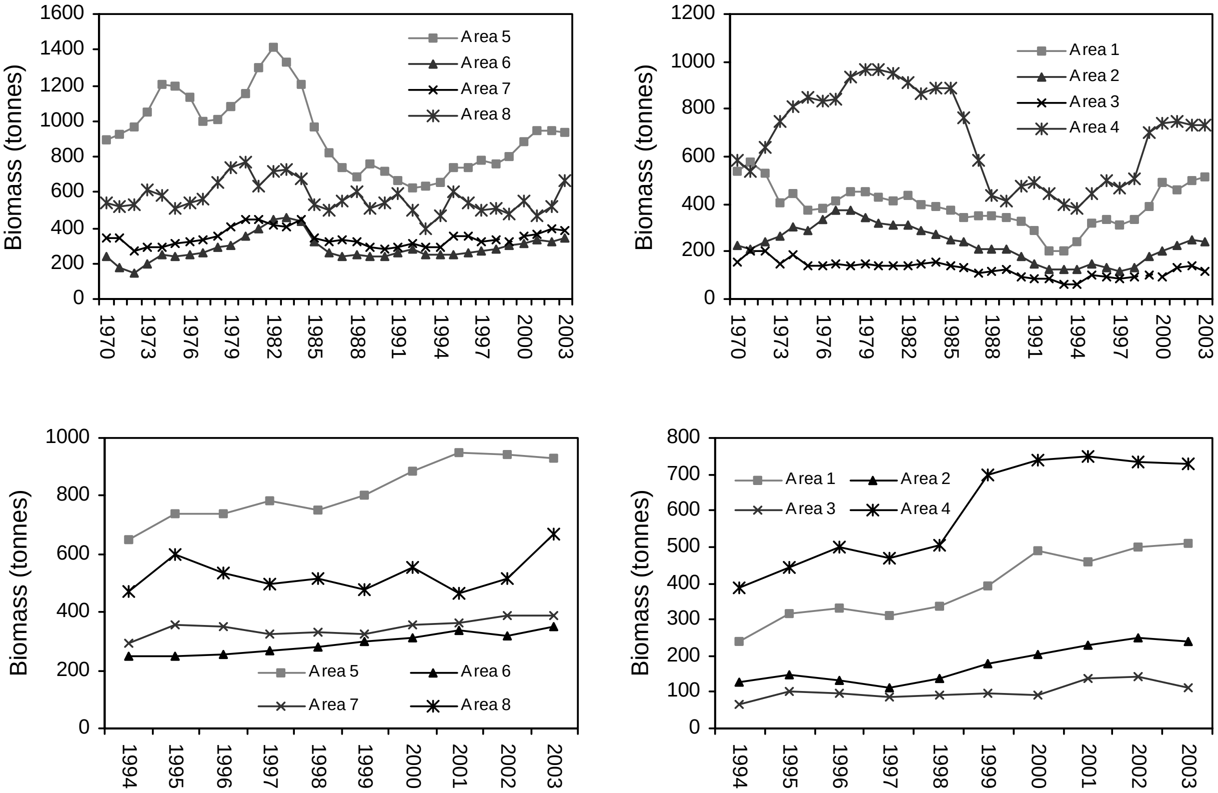


Figure 16. Legal-sized biomass estimates for the rock lobster fishery from (upper) 1970 to 2003 and (lower) from the historical lows of 1994 to the latest estimate in 2003. All estimates are for October, immediately after the main annual recruitment. Note that plots are on different scales. Total legal-sized biomass in Areas with large amounts of reef such as Areas 5 and 8 is mainly a function of size of habitat. Thus these figures are informative in terms of temporal trends, however comparison between Areas is of limited value.

4.1.5 Egg production

Egg production was generally stable over the assessment period, with only modest increases in egg production recorded across the State and for Areas 2 and 4. A large increase was estimated for Area 6 although estimates from this Area are often biased upwards (Gardner, 2000)(Table 11). Slight declines in egg production were estimated for Areas 1, 3, 7 and 8. Both Areas 1 and 7 have estimated egg production at levels lower than recorded in the corresponding reference years, although estimated egg production in these Areas still constitutes a very high proportion of the virgin egg production (i.e. 55 and 42%, respectively) and is thus of low concern.

Egg production as a proportion of virgin capacity remains lowest among the northern Areas (Areas 3, 4 and 5). All three Areas have shown improvements in egg production over the last decade (Figure 17) but egg production still remains well below the management target of 25% (Figure 18). This target is based on observations and management targets of other lobster fisheries. It is impossible to know how much egg production can fall before the stock collapses without actually collapsing the stock. However, 25% seems a safe target because lobster fisheries have only collapsed when egg production is lower than this level, hence there is concern regarding the continuing low levels in the northern regions.

The management objective of rebuilding egg production in depleted areas is justified by the observation that recruitment has declined relative to the 1960's (Frusher et al. 2003). That is, the maintenance of high egg production in the south of the State has not protected the resource from declines in recruitment.

Estimates of egg production relative to virgin in Area 8 exceed 100% due to the difficulty in estimating egg production in this Area because such a small proportion of females reach legal size. A value of greater than 100% is plausible if the harvesting of males has freed up resources to allow the population of females to increase above that in a virgin unfished state. While there is some uncertainty over the precise amount of egg production in Area 8, it is clear that production in this Area is massive and over double that of any other Area. Density of females is extremely high with research trapping surveys averaging almost 50 animals per pot lift.

Table 11. Change in statewide and regional egg production.
Virgin egg production is the estimated egg production prior to commercial exploitation, assuming average recruitment is the same as that from 1970 to the present. Relative egg production is a numerical (linear) index of egg production so that a relative egg production of 200 implies twice as many eggs are being produced compared to a relative egg production of 100. Shaded lines are Areas with greater uncertainty in egg production estimates. "State (adj)" is Statewide data adjusted to exclude Area 6, where egg production is estimated poorly for recent years.

Area	Ref.	Relative Egg Production			% change vs		% virgin prod.
	Year	Ref. Year	2002	2003	Ref. Year	2002	in 2003
Statewide	1993	894	1128	1148	+28	+2	30
State(adj)	1993	844	1047	1053	+25	+1	31
1	1995	158	143	142	-10	-1	55
2	1992	66	121	124	+87	+3	44
3	1993	27	42	42	+54	-1	12
4	1993	77	134	145	+88	+8	17
5	1992	81	137	137	+69	0	13
6	1986	50	81	95	+90	+18	25
7	1989	134	132	126	-7	-5	42
8	1994	300	338	336	+12	-1	118

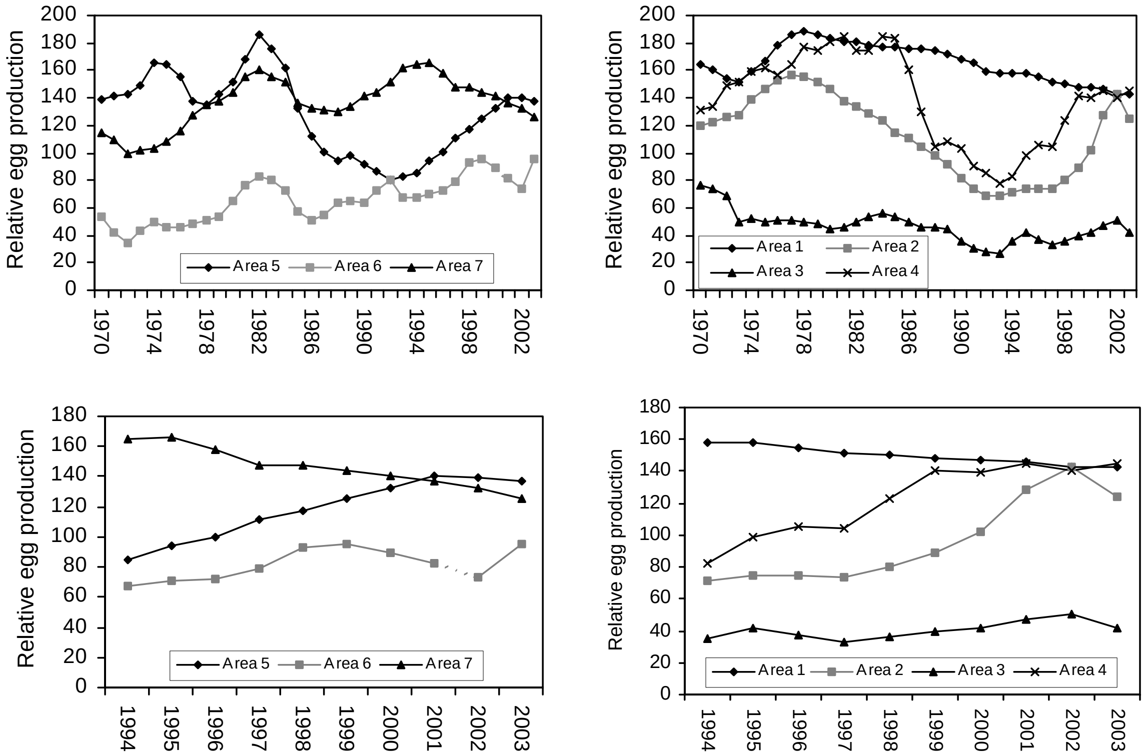


Figure 17. Relative egg production from 7 Areas around Tasmania, western Areas to the left, eastern Areas to the right. Area 8 is not included due to problems mentioned in the text.

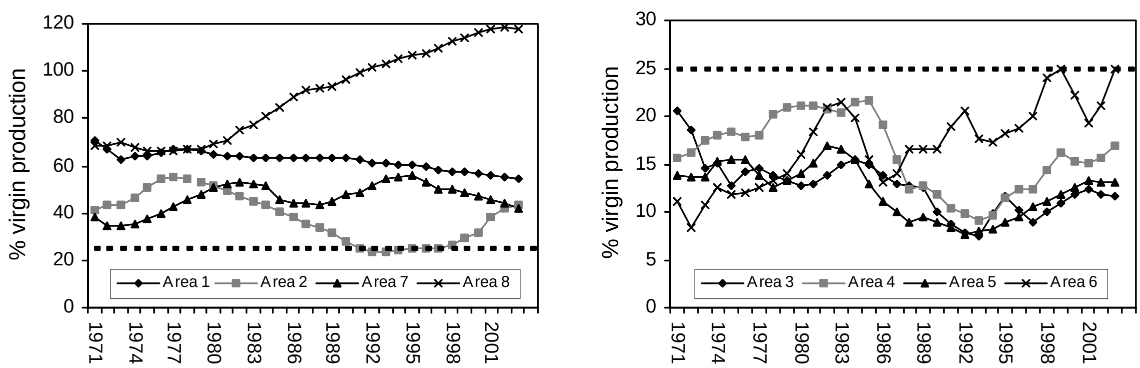


Figure 18. Percentage of virgin egg production from eight Areas around Tasmania, southern Areas to the left, northern Areas to the right. The horizontal bar in each plot represents the management target of 25%. The last year of the plot for Area 6 should be accepted cautiously.

4.1.6 Relative abundance of undersized lobster

For the abundance of pre-recruit lobsters (undersized lobster equivalent to one growth increment below legal size) to be useful as a performance indicator, a relationship between the catch rate of undersized and newly recruited legal-sized lobsters needs to be established. A link between the abundance of undersized lobsters and subsequent legal-sized lobsters has only so been defined for the south coast where catch-rates of undersized males between 102-110 mm CL provide an index of animals moulting to legal-sized in the following season.

Pre-recruit lobster abundance at Maatsuyker Island was above reference year levels (Table 12), despite falling considerably below the performance indicator in the proceeding assessment period (Oct. 2002). In the previous assessment this result was reported as an anomaly due poor weather conditions during research sampling and the time-series for these sites tends to support this conclusion (Figure 19). From 1996, research sites at Port Davey were included to increase the number of sites sampled in Area 8.

The catch-rates for pre-recruits from the Maatsuyker sites and the combined sites (Maatsuyker and Port Davey) are different (Table 12) and thus the combined data cannot be compared with the reference year, but are included to determine if the trends in the Maatsuyker data are reflected in the more extensive data. Figure 19 shows that although pre-recruit levels appear to be higher among the Port Davey sites, hence elevating the combined catch rate, the overall trend is similar. In general, catch-rate variability was greater in the more southerly Maatsuyker sites.

Table 12. Comparison of fishery independent preseason (Oct/Nov) catch-rates of undersized lobsters in the size bracket 102-110 mm sampled from waters adjacent to Maatsuyker Island and these sites combined with sites from Port Davey (Maat + PD) in similar depths. For Maatsuyker Island, 390 pot lifts were undertaken in the reference year compared to 150 in 2002 and 99 in 2003. Samples from Port Davey are based on 100 pot lifts in 2002 and 50 in 2003. No sampling was undertaken at Port Davey in the reference year.

Location	Ref. Year	Catch-rates (N/pot lift)			Change (N/pot lift) 2003 vs		% change	
		Ref. Year	2002	2003	Ref. Year	2002	Ref. Year	2002
Maatsuyker	Nov'95	1.43	0.47	1.61	+0.18	+1.14	+13%	+243%
Maat + PD			2.42	3.04		+0.62		+26%

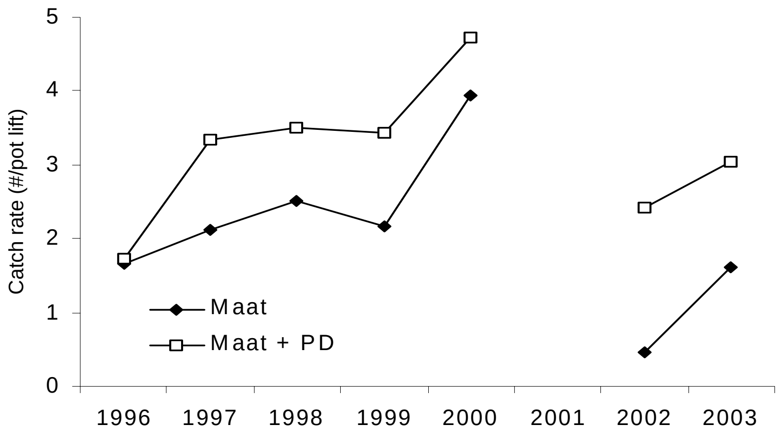


Figure 19. Pre-recruit (male lobsters 102-110 mm CL) catch-rates for Maatsuyker sites (Maat) and Maatuyker and Port Davey sites combined (Maat + PD) from November 1996 to November 2003. Note no catch sampling survey was conducted in November 2001.

4.1.6 The total annual commercial catch

The total annual commercial catch (TACC) is constrained by output controls on the fishery. A TACC of 1502 tonnes was introduced for the first time in March 1998, but was subsequently raised to 1523 tonnes in March 2002. The management trigger is set at 95% of the TACC (1447 tonnes). The total commercial catch for the period March 2003 to February 2004 reported through the quota management system was 1509.5 tonnes and is thus is well above the management trigger.

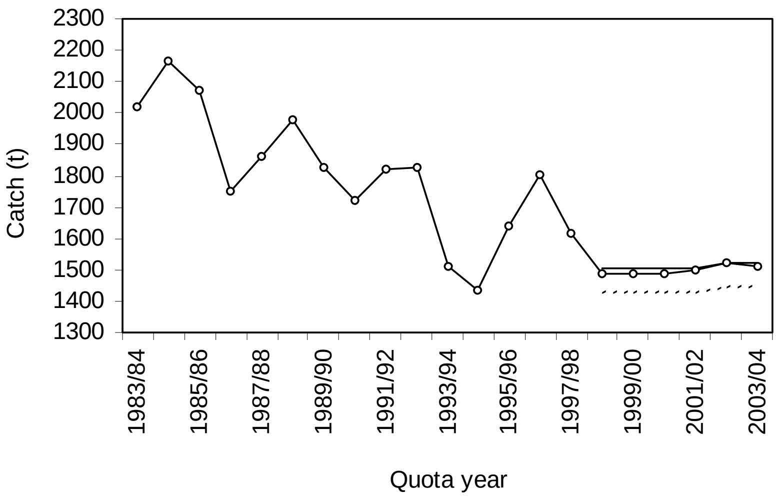


Figure 20. Change in annual commercial catch. The total allowable commercial catch (TACC) is shown as a separate solid line since its introduction in 1998 and the trigger point of 95% of the TACC is shown as a dashed line.

4.1.7 The size of the rock lobster fleet

The size of the active fishing fleet has declined steadily over the last decade. In 1993 there were 353 fishing vessels operating in Tasmanian waters, however, by 2003/2004 this number had fallen to 241 active vessels (Table 13, Figure 21). Note that the number of active vessels is influenced by several factors including the fishing of more than one license from a single vessel and the replacement of vessels so that more than one vessel is active under a single license. The trigger point for this performance indicator is 220 vessels and this was not breached.

Table 13. Changes in the number of licences and vessels in the Tasmanian rock lobster fishery. Active licenses and vessels are those that recorded catch.

Year	Number of licences	% change	Number of active licenses	% change	Number of active vessels	% change
1993/94	337	-	330	-	353	-
1994/95	334	-0.9	329	-0.3	342	-3
1995/96	331	-0.9	326	-0.9	348	2
1996/97	321	-3.0	315	-3.4	332	-5
1997/98	316	-1.5	309	-1.9	330	-1
1998/99	314	-0.6	304	-1.6	314	-5
1999/00	314	0	269	-11.5	270	-14
2000/01	314	0	259	-3.7	254	-6
2001/02	314	0	250	-2.4	246	-3
2002/03	314	0	242	-1.2	247	+0.5
2003/04	314	0	234	-3.3	241	-2

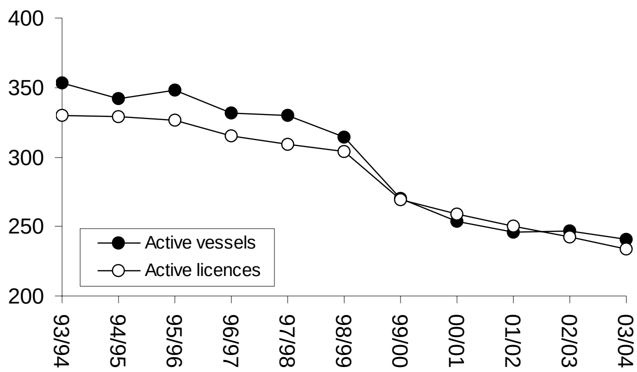


Figure 21. Trends in number of active licenses and vessels in the Tasmanian rock lobster fishery over the last decade.

4.1.8 The recreational catch

Frequent and precise estimates of the recreational fishery are more difficult to obtain than for the commercial fishery. Reliable estimates of the amount of lobsters captured by recreational fishers are typically based on surveys. In recent years there has been a growing commitment to regular surveys of recreational fishers. It is intended that these surveys will be conducted on a biannual basis.

In the previous assessment report, we indicated that the trigger point for the recreational catch had likely been reached. The management plan quantifies recreational catch as a percentage of commercial catch and the trigger point states that if the total recreational catch exceeds 10% of the TACC in a year, there will be a review. Shortly after previous assessment report, Lyle and Morton (2004) released a survey of the Tasmanian recreational rock lobster fishery that showed the recreational catch of rock lobster was around 10% of the total 2002/03 commercial catch (Figure 24). They noted that this value was an estimate (as with most performance indicators) and the true recreational catch could be slightly above or below the trigger point. The proximity to the trigger resulted in a review.

Fewer recreational licences were issued in 2003/04 than in 2002/03 (Figure 22). This decline in total licenses was at least in part a function of a decline in the total number of licence holders. The number of both dive and pot licences declined while rings remained steady (Figure 23). Pot licences remain the most commonly issued recreational licence and constituted 56% of all licences issued in 2003/04.

Considerable regional variability exists in the recreational catch. For example, the recreational catch is estimated to represent 35% of the commercial catch in Area 1, but only 3% of the commercial catch in Area 8 (Figure 24). However, the recreational fishery is largely limited to shallower waters (i.e. <20 m). When recreational and commercial catches are compared for shallow waters, recreational catches were found to equate to about one quarter (26%) of the shallow water commercial catch for the State. In Area 1, where the recreational catch constitutes the highest proportion of the commercial catch, Lyle and Morton (2004) estimated that the recreational catch was equivalent to 95% of the total commercial catch in waters less than 20 m. In Areas 2 and 3 (on the east coast) recreational catches were estimated to be equivalent to around half (54 and 49% respectively) of the shallow water commercial catch. Elsewhere, recreational catches are equivalent to a much lower proportion of the shallow water commercial catch (i.e. less than 30%).

These findings imply that management of the ecological effects of lobster fishing needs to target both recreational and commercial fisheries. This is because regions of greatest concern are the sheltered regions on the east coast where catch rates remain low and effort from both sectors remains high.

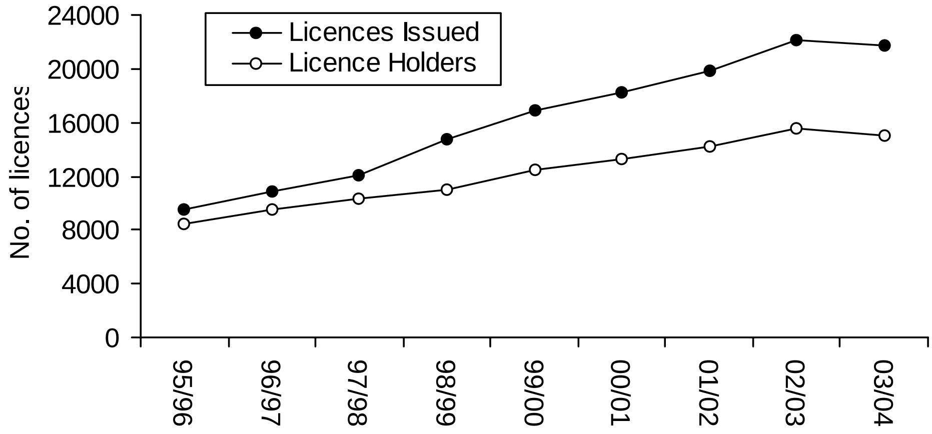


Figure 22. Comparison between the total number of recreational rock lobster licences issued (pots, dive and rings; solid circles) and the number of licence holders (open circles) from 1995/1996 to 2003/2004 recreational fishing season.

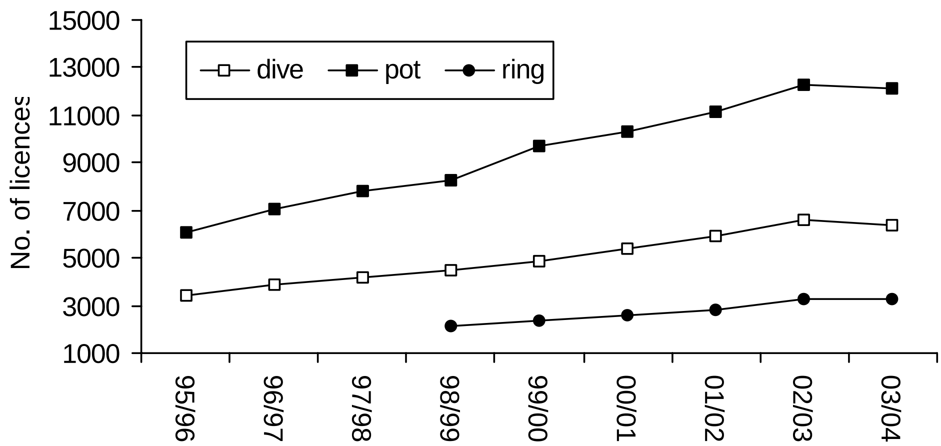


Figure 23. Number of recreational pot, dive and ring licences issued from 1995/96 to 2003/04.

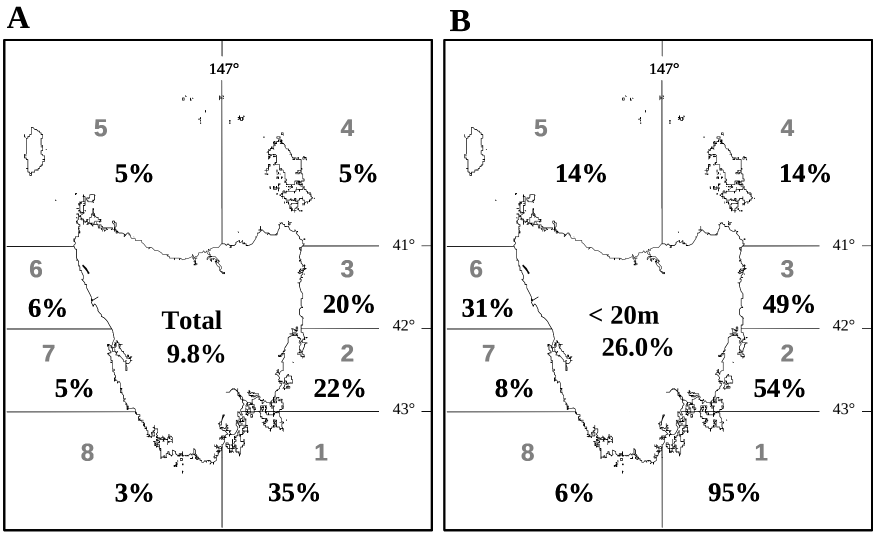


Figure 24. 2002/2003 recreational rock lobster harvest (weight) expressed as a percentage of the commercial rock lobster catch: (A) based on total catches; and (B) based on catches from shallow waters (<20 m) (taken from Lyle and Morton 2004).

4.2 Trends in fisheries-independent abundance indices

These abundance indices are collected through research sampling that is repeated in the same sites. The consistent sampling method eliminates biases present in the commercial catch rate data such as differences in the fishing behaviour of individual fishers. The limitation of fisheries-independent abundance indices is that sample sizes are typically low so that their main value is in examining longer trends, rather than annual fluctuations.

Formerly research catch sampling has been confined to localities on the eastern and southern coasts of Tasmania (Areas 2 and 8), however, in an effort to extend the spatial coverage of these indices, research catch sampling is now conducted from commercial fishing vessels in a range of other Areas (i.e. Areas 1, 4, 6 and broader sampling in Area 8).

4.2.1 East Coast – shallow depth

In general, research catch sampling in shallower waters off the east coast of Tasmania has had lower catch rates than in commercial samples (Figure 25). However, in the last year, research catch rates have undergone a dramatic increase not reflected in the commercial catch rate derived from the remainder of the fishing block. A possible explanation for this sudden increase in research catch rates can be provided by viewing the pre-recruit numbers at the research sampling site over the last two years (Figure 26). It would appear that the pulse in legal-sized lobsters is direct response to a significant peak in the abundance of pre-recruit lobster in the previous year. Encouragingly the number of pre-recruits continues to remain high (in comparison to the long-term trend) in the current assessment period indicating potential strong growth into the near future. Further sampling will be required to elucidate if commercial and research catch rates are actually comparable in magnitude because of the limited scope and size of the research catch sampling conducted in shallow waters.

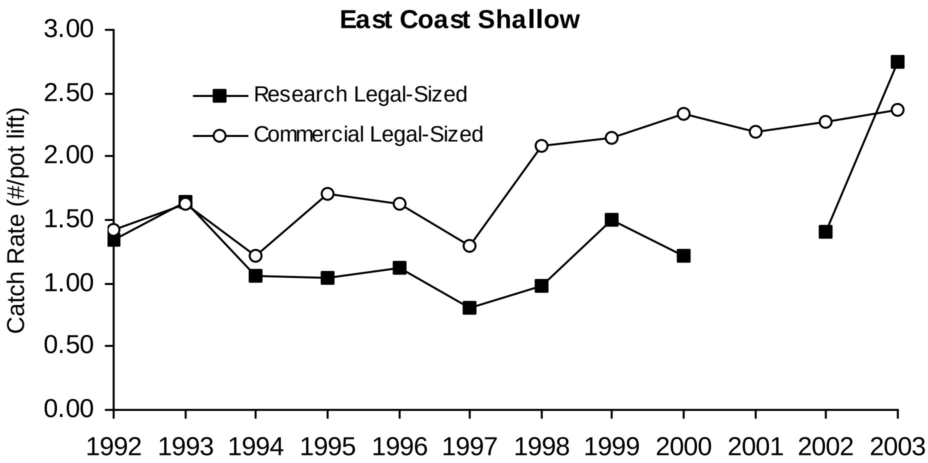


Figure 25. Shallow catch rates (<35 m) of legal-sized lobsters from research surveys and commercial fishing conducted on the east coast in late October/early November.

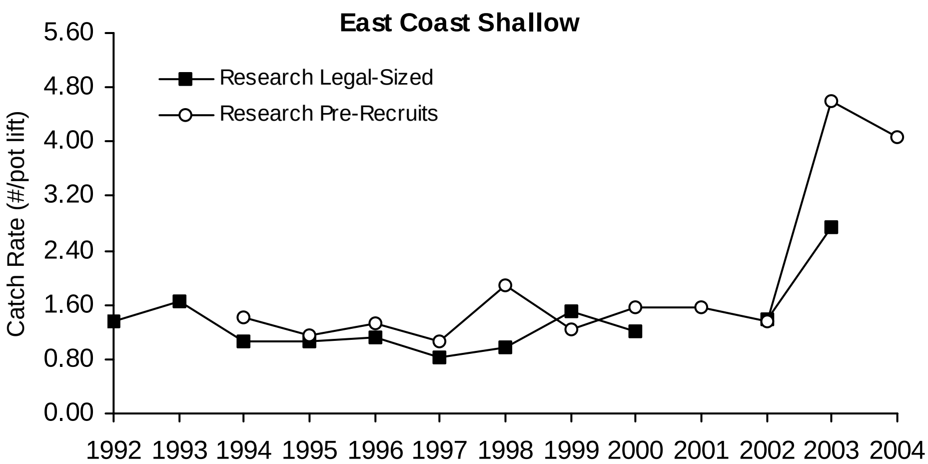


Figure 26. Shallow water catch rates (< 35 m) for legal-sized and pre-recruit lobsters on the east coast of Tasmania. The pre-recruits lobsters (males between 102 and 110 mm CL and females between 98 and 105 mm CL) have been advanced by 1 year to simulate growth of undersized lobsters to legal size.

4.2.2 East Coast – medium depth

Although research catch rates are variable from year to year, they had similar long-term trends to the commercial data (Figure 27). This implies that the trends in commercial rates reflect a change in lobster abundance.

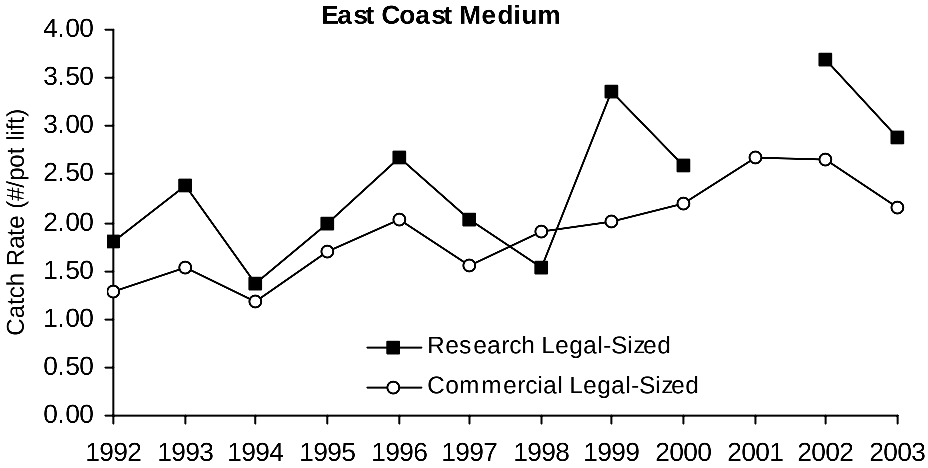


Figure 27. Medium depth (35-50 m) catch rates for legal-sized lobsters from research surveys and commercial fishing conducted in late October/early November on the east coast.

In contrast to the shallow water data there was little discernable relationship between legal-sized and pre-recruit lobster abundance from year to year for catch sampling in 35-50 m depths (Figure 28).

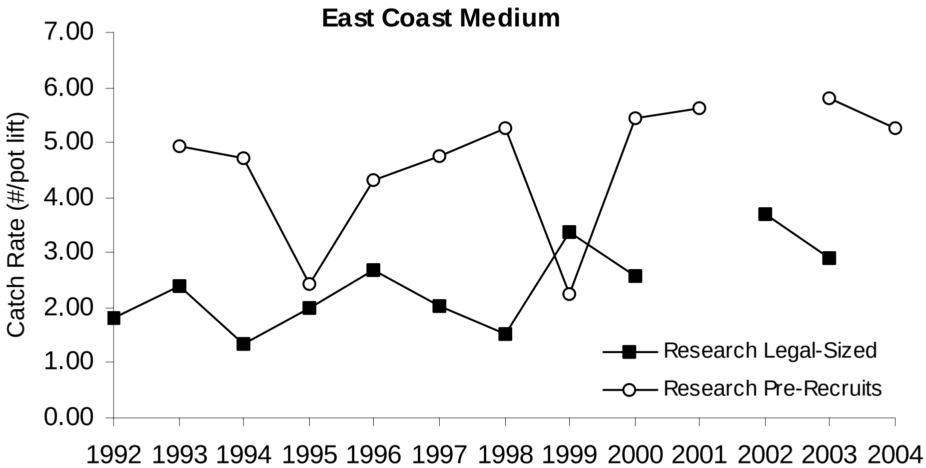


Figure 28. Medium depth (35-50 m) catch rates for legal-sized and pre-recruit (males between 102 and 110 mm CL; females between 98 and 105 mm CL) lobsters from the east coast. The pre-recruit catch rate has been advanced by 1 year to simulate growth of undersized lobsters to legal size.

4.2.3 South Coast – medium to deep depths

Research catch rates had a similar long-term trend to the commercial catch rates (Figure 29), including a dramatic increase among both research and commercial catch-rates in the last assessment period. This implies that the trend in catch rate in commercial areas reflects changes in lobster abundance or behaviour, rather than fisher behaviour.

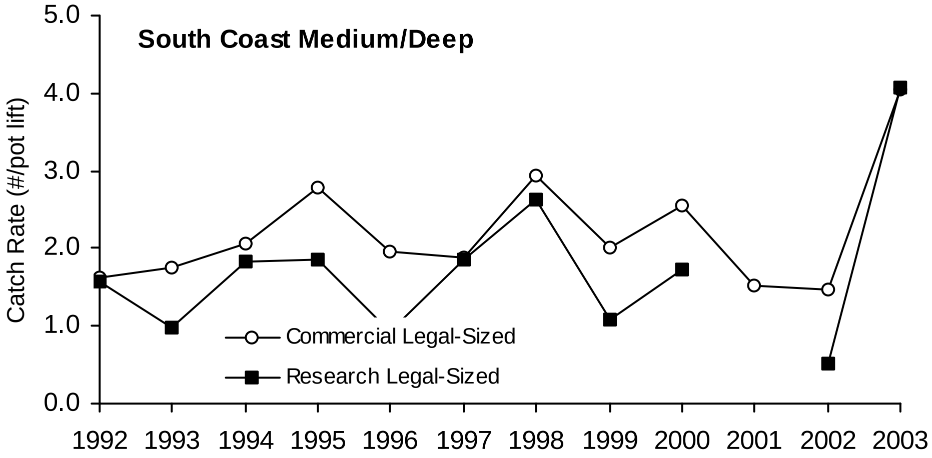


Figure 29. Medium to deep water (45-100 m) catch rates for the south coast of legal –sized lobsters from research surveys conducted in October/November and commercial fishing for the start of the fishing season (i.e. 1st week of November).

The pre-recruit data suggests that the increase in catch of legal-sized lobsters in 2003 may be in response to high levels of pre-recruit lobsters observed at these sites between 1997 and 2000 (Figure 30). Unfortunately this is difficult to infer directly because there was a two-year break in the data series (no catch sampling was undertaken in 2001 and the previous year sample was deemed to be anomalous due to poor weather conditions) for this site. Encouragingly, pre-recruit levels for 2003 (shown as 2004 on Figure 30) continue to remain high.

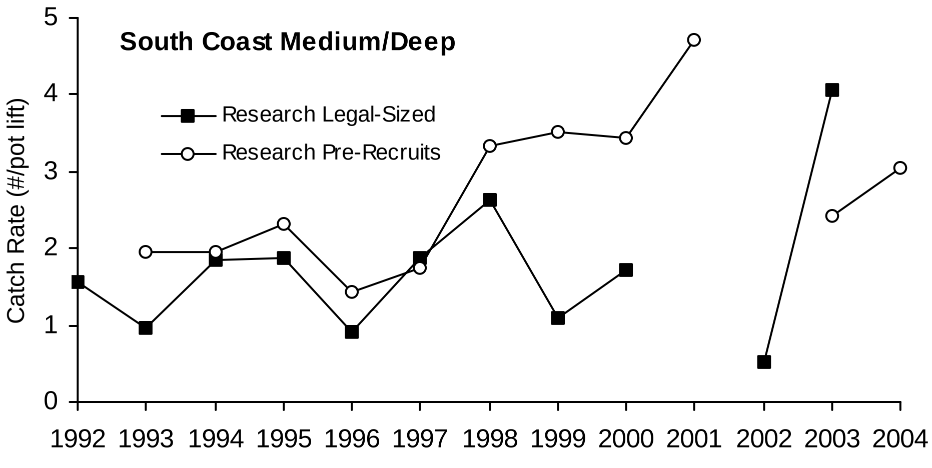


Figure 30. Medium to deep water (45-100 m) catch rates for the south coast of legal –sized and pre-recruit (males between 102 and 110 mm CL; females between 98 and 105 mm CL) lobsters from research surveys conducted in October/November. Pre-recruitment lobster numbers have been advanced by 1 year to simulate growth of lobsters to legal-size. Note no research survey was conducted in 2001.

4.2.4 Statewide fisheries-independent abundance indices

Fisheries-independent catch data has previously been restricted to sites in two of the eight assessment Areas (i.e. Areas 2 and 8, see above) providing limited statewide coverage. In an effort to enhance the coverage of fisheries-independent data across Tasmania, TAFI has commenced collecting catch-sampling data using commercial fishing vessels in the closed-season. This sampling has extended the range of sites sampled within Area 8, in addition to facilitating, for the first time, the comparison of research and commercial catch rates for Areas 1, 4 and 6 (Table 14). The commercial and research catch rates for each of the Areas considered are comparable, although there is little consistency in respect to whether research catch rates lie above or below commercially derived catch rates (and hence whether there is consistent bias in regards to commercial catches). In the instances where research and fisheries derived catch rates depart substantially (e.g. Areas 2, 6 and 8) the research catch rates suggest greater rock lobster abundance than is reflected by the commercial rates (i.e. the research catch rates are appreciably higher).

Table 14. Comparison of fishery independent catch-rates sampled in October 2003 with commercial catch-rates from the first week of November (season opening) for Areas 1, 2, 4, 6 and 8. Shown also is the vessel utilised and the fishing block in which the vessel operated. Note FRV Challenger is TAFI's research vessel, all others are commercial vessels. *Commercial catch-rates were based in all cases on more than 2000 pot lifts.

Research surveys (Oct. 2003)	**Area 1**		**Area 2**		**Area 4**	**Area 6**	**Area 8**	
Fishing Block	7G1	7G2	6H1	6H3	4H3	5D2	7F3	7F3
Total catch (# lobsters)	549	542	433	137	497	1221	634	2077
Total effort (# pot lifts)	274	450	150	50	580	437	149	447
Vessel	Barralee		Challenger		JacquelineII	Pera	Challenger	Minamurra II
Catch rate (# lobsters/pot lift)	**2.00**	**1.20**	**2.89**	**2.74**	**0.86**	**2.79**	**4.06**	**4.65**
Commercial catch rate* (Nov. 1-7th 2003)	**2.15**	**1.60**	**1.83**	**2.11**	**1.03**	**1.85**	**3.21**	**3.21**

4.3 Alternative harvest strategy evaluation

Projections of probable trends in legal biomass and egg production were generated using the rock lobster stock assessment model (Punt and Kennedy 1997). Scenarios of changes to commercial TAC and recreational catch were evaluated.

The catch of the recreational and commercial sectors was apportioned in the model as follows:

- The amount and spatial distribution of catch by each sector was defined in hindcast fits on the basis of logbook and survey data.

- Catch for both sectors varied through time in hindcast fits on the basis of logbook and survey data. As recreational catch data was not available for each year, missing years were estimated by linear extrapolation from the surveys before and after. Recreational catch prior to the commencement of surveys was set to be the proportion of commercial catch seen in the first survey (1995).

- Possible future harvests by the commercial sector were evaluated by allocating a global TACC and modelling the spatial response of effort on the basis of that observed over the last 10 years (through a fleet dynamics model).

- Possible future harvests of the recreational sector were evaluated by two methods. The first assumed that recreational catch would increase in proportion to the TACC. This was done by attributing a proportion of the catch from each Area to the recreational sector. The spatial attribution was done on the basis of the survey results from the most recent recreational survey. Thus, if the TACC is increased by 2%, the recreational catch is modelled to increase by the same proportion.

- Modelling changes in recreational catch independently of the TACC is more problematic because there is no equivalent of the fleet dynamics model for recreational catch. Instead, the recreational catch from each Area was altered for future years. The absence of a fleet dynamics component here means that the behaviour of recreational fishers in the model will be unresponsive to catch rates. This approach has support from recent surveys by Lyle and Morton (2004), which showed that the distribution of recreational effort tended to be mainly influenced by proximity to population centres and accessible coast, rather than regions of highest catch. Their survey showed that the highest proportion (ca. 60% of total catch) of the recreational catch was taken along the east and southeast coasts (Areas 1 to 3). Thus an increase in recreational catch would likely have most impact on these Areas. We have therefore assumed that future changes in recreational catch will occur in a similar spatial pattern to current recreational catch.

Note that the model simulations of change in commercial quota and recreational catch do not account for localisation of effort or concentration into shallow depths.

Projections of future biomass and virgin egg production were conducted using 100 simulations with averages of these simulations shown here. The error around these averages was estimated by the variation in these different simulations. This error is intended to account for the natural variation in recruitment that has been observed over the last 30 years.

Various projection scenarios were tested to explore the effects of altering the catch. Scenarios were based on round number change to the per-pot quota holding (with a total of 10507 pots in Tasmania) or proposed upper and lower extremes of the recreational catch.

In this assessment we include scenarios for reducing the TACC in an attempt to increase the rate of stock rebuilding. Commercial fishers who were motivated by the economic benefit of being able to capture lobsters when the price was greater requested this scenario. They considered that the economic benefit of capturing lobsters when the price was greater (say $40/kg in winter vs $20/kg in summer) outweighed the economic benefit of a small percentage loss in total catch. This concept is motivated by the increasingly seasonal patterns in catchability of lobsters as legal sized biomass was depleted; when the legal-sized biomass was higher, fishers were able to maintain higher catch rates throughout the year. Figure 31 shows seasonal patterns in catch rate for 2003 and earlier decades. Although data shown in this figure is influenced by changes in depths and location of fishing, it does provide some evidence that rebuilding of stocks should facilitate taking lobsters during winter when prices are highest.

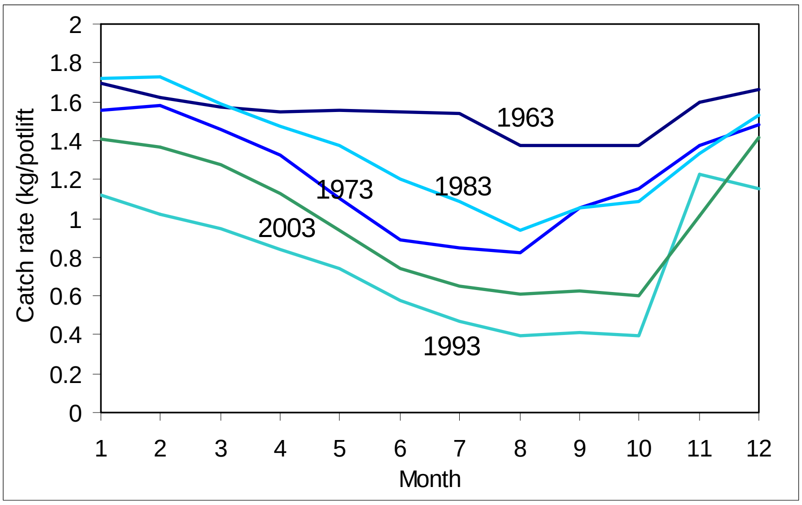


Figure 31. Change in monthly catch rate for the State for 2003 and preceding years in decadal time steps. Time series for each year is a 3 month moving average. Note that as stocks became depleted from the 1960’s to the 1990’s, the efficiency of fishers catching lobsters during winter decreased.

The scenarios tested were:

Scenario #	Strategy	TACC (tonnes)	Recreational catch (tonnes)	Per pot quota allocation (kg)
1	Maintain status quo	1523	149	145
2	Increase TAC 1.8%	1550	151	147.5
3	Reduce TAC 3.5%	1470	144	140
4	Reduce recreational catch	1523	130	145
5	Increase recreational catch	1523	170	145

The effects of each scenario on both egg production and legal-sized biomass are presented. Note that egg production and legal-sized biomass can vary independently of each other as undersize females contribute a large proportion of egg production in southern regions. Furthermore, in some regions females never reach legal size and thus never contribute to legal-sized biomass.

4.3.1 Biomass

Legal-sized biomass projections for the next three years show an increase in the TACC for all scenarios when all Areas are pooled (Figure 32 and Figure 33). Ninety five percent confidence limits around these estimates are shown in Figure 33 and are based on the range of inter-annual fluctuations in recruitment that have been observed since 1970. An important point with these confidence limits is that it is possible that catches over the next 3 years may be driven by recruitment outside the bounds experienced over the last 3 decades.

Previous assessment have discussed the tendency for positive biases in projections of biomass in southern Areas (Areas 1 and 8) with actual changes in biomass typically falling short of that predicted. Excluding these Areas (Figure 34 and Figure 35), the trend of increasing biomass remains, although the increase is not as great.

The model tends to perform best in projection of biomass in northern Areas 4 and 5 so these are shown separately (Figure 36 and Figure 37). These projections indicate low probability of biomass increase under all scenarios tested.

The stepwise exclusion of areas indicates that the positive trends of growth in the pooled statewide projections should be accepted cautiously. The more reliable estimates restricted to specific Areas indicate a more modest rate of rebuilding or simply stability. The range of possible outcomes indicated by confidence limits is informative. These imply that the magnitude of natural recruitment variation tends to be greater than the changes in harvest levels likely to be considered by industry and resource managers.

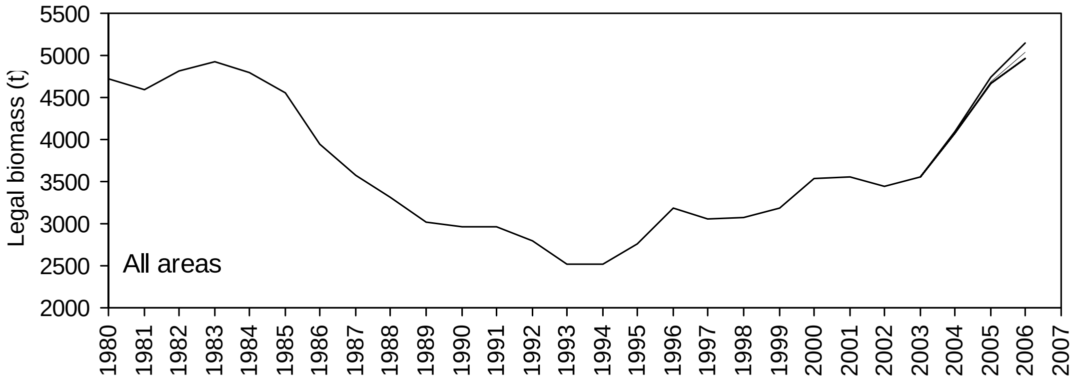


Figure 32. Statewide legal-sized biomass estimates from November 1980 to November 2003 with averaged trajectories to 2006 of biomass for TACCs of 1470 (upper line), 1523 (middle line) and 1550 (lower line).

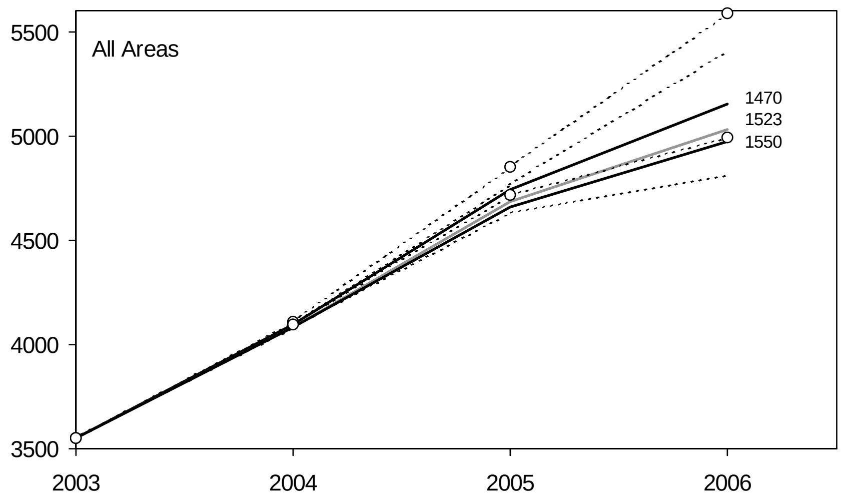


Figure 33. Statewide legal-sized biomass projections showing the same data presented in the previous graph (Figure 32) but focused on projections for the next 3 years. Maximum and minimum ranges of the 100 simulations are shown for the 1470 and 1550 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

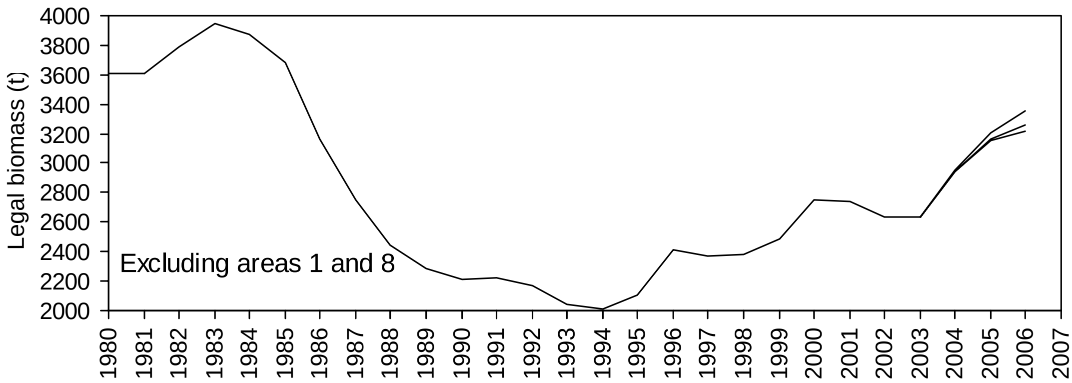


Figure 34. Legal-sized biomass estimates from November 1980 to November 2003 with averaged trajectories to 2006 of biomass for TACCs of 1470 (upper line), 1523 (middle line) and 1550 (lower line) for Areas 2 to 7 (that is, with Areas 1 and 8 excluded). Biomass projections from Areas 1 and 8 are typically most positively biased.

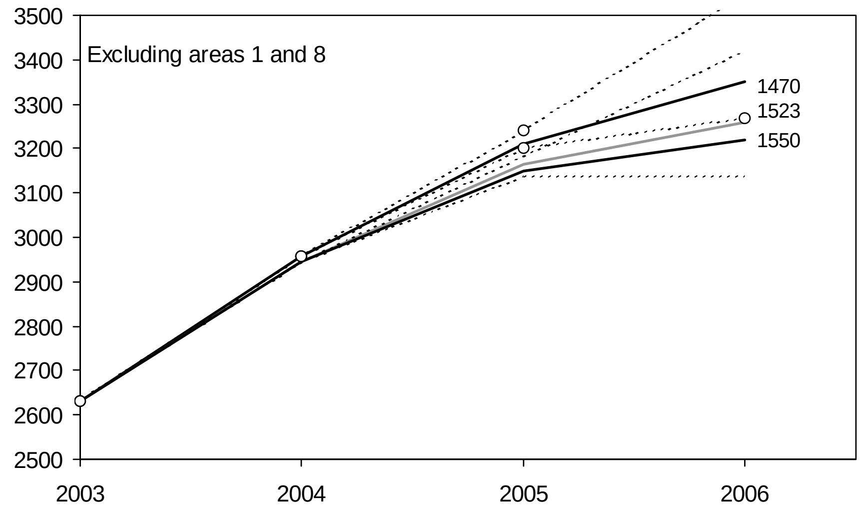


Figure 35. Legal-sized biomass projections with Areas 1 and 8 excluded showing the same data presented in the previous graph (Figure 34) but focused on projections for the next 3 years. Maximum and minimum ranges of the 100 simulations are shown for the 1470 and 1550 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

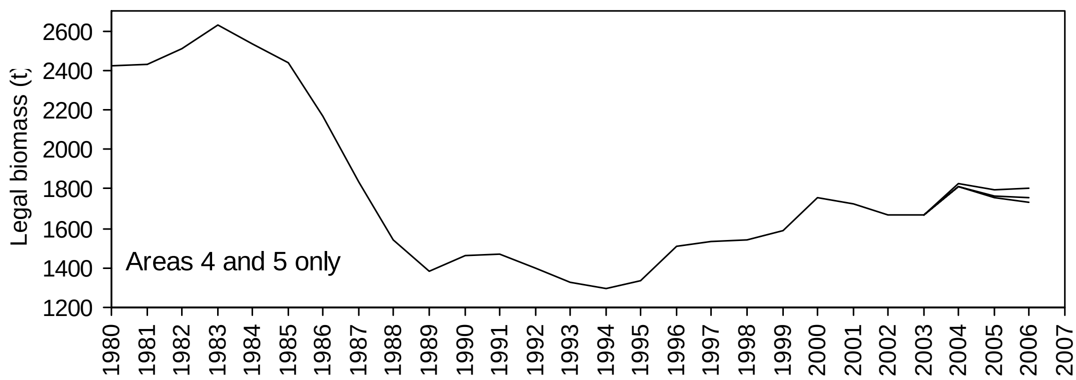


Figure 36. Legal-sized biomass estimates from November 1980 to November 2003 with averaged trajectories to 2006 of biomass for TACCs of 1470 (upper line), 1523 (middle line) and 1550 (lower line) for Areas 4 and 5 only (Northern Areas). Biomass projections from Areas 4 and 5 are typically least biased.

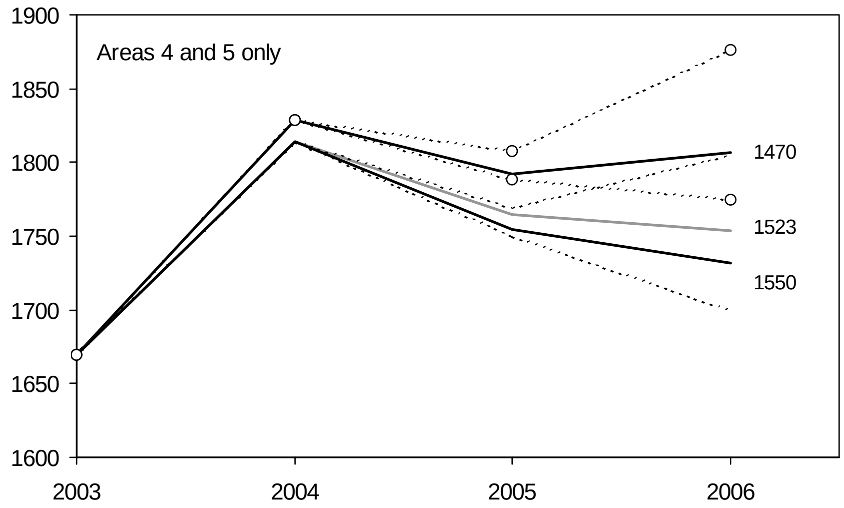


Figure 37. Legal-sized biomass projections for Areas 4 and 5 only showing the same data presented in the previous graph (Figure 36) but focused on projections for the next 3 years. Maximum and minimum ranges of the 100 simulations are shown for the 1470 and 1550 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

Recreational catch was estimated to be 149 tonnes in 2003 and this scenario along with changes in the recreational catch to 130 and 170 tonnes were modelled. Model projections indicated that statewide legal-sized biomass would be little influenced by these changes (Figure 38). Biomass is likely to be more affected in some Areas than others by changes in the recreational catch (Figure 39) with projections for Areas 4 and 5 indicating a more severe decline with elevated recreational catch. This is despite these Areas being of relatively low importance to the recreational fishery and is caused by displacement of commercial effort as catch rates decline.

The model is less suited to projecting recreational catch than commercial catch because of the spatial scale of effort. Recreational effort tends to be more focused with high effort in smaller regions relative to the commercial fishery. This is due to differences in gear, access, and the different economic drivers (commercial fleet dynamics are more mobile statewide in response to catch rate). This spatially focused nature of the recreational fishery implies that the broad spatial regions of the model would be less useful in capturing trends.

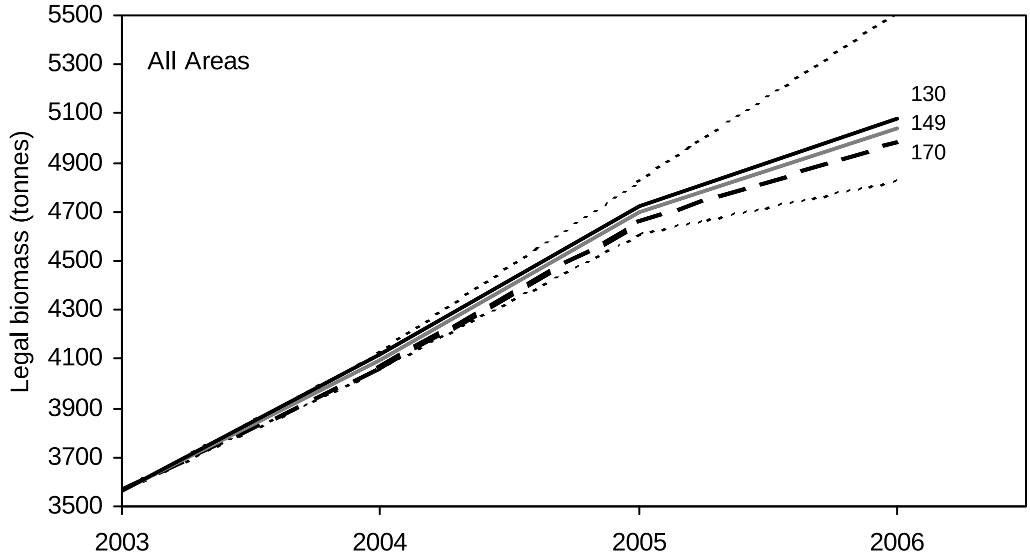


Figure 38. Legal-sized biomass projections for all Areas combined with alternative recreational catches (130, 149 and 170 tonnes). Maximum and minimum ranges of the 100 simulations are shown for the 130 tonne (upper dashed line with circles) and 170 tonne (lower plain dashed line) scenarios respectively. TACC was set at the current level of 1523 tonnes.

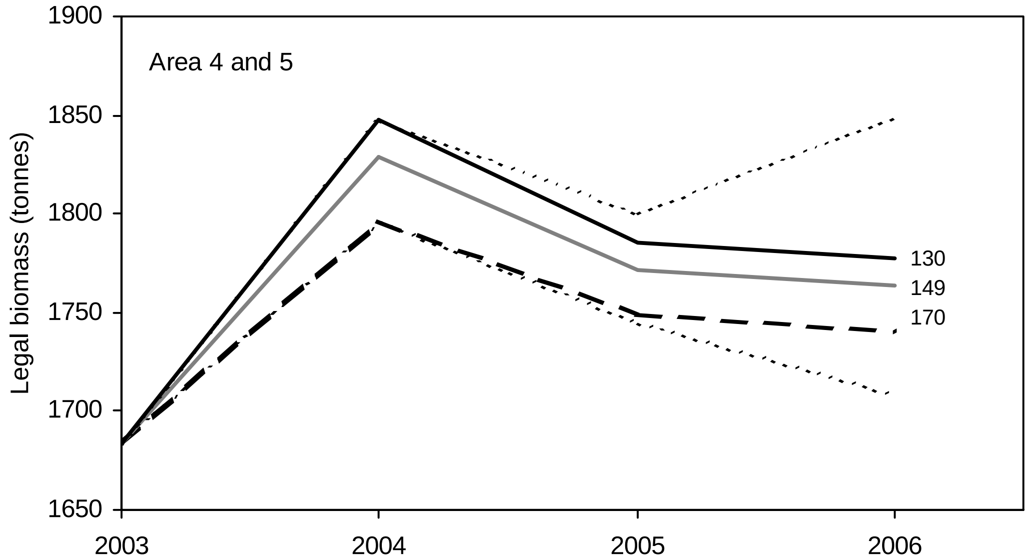


Figure 39. Legal-sized biomass projections for Areas 4 and 5 with alternative recreational catches (130, 149 and 170 tonnes. Maximum and minimum ranges of the 100 simulations are shown for the 130 tonne (upper dashed line with circles) and 170 tonne (lower plain dashed line) scenarios respectively. TACC was set at the current level of 1523 tonnes.

4.3.2 Egg production

Model projections of statewide egg production for the next three years indicate a steady increase following a period of stability/reduction for the next 12 months (Figure 40 and Figure 41). The northern region of the fishery (Areas 4 and 5), where there is greater certainty with the model outputs, has a different trend (Figure 42 and Figure 43). Projections of northern Areas suggest egg production will decline over the next few years. These Areas are of greatest concern for egg production as their current production is less than 25% of virgin.

Changes in the recreational catch has a similar impact to that of biomass – little change to statewide production but a change to regional production (Figure 44 and Figure 45). Even though recreational effort in Areas 4 and 5 is low, an increase in recreational catch is expected to lead to further depression of egg production in northern Areas.

As with biomass, the spatial scale of the model is too coarse to adequately model the effect of change in recreational catch. For example, although recreational effort is greatest in Area 1, the model predicts little impact on egg production from change in recreational catch in that Area. This is because a large proportion of the commercial catch in this region comes from deep water and is skewed towards harvest of males. The model assumes a similar pattern in recreational catch, although more recreational effort occurs in shallow waters where females contribute more to the catch. Thus the model underestimates the impact of increasing recreational effort on egg production. Reducing the spatial scale of the cells in the model will be evaluated over the next year. Our ability to do this will be largely a function of the resolution of tagging data.

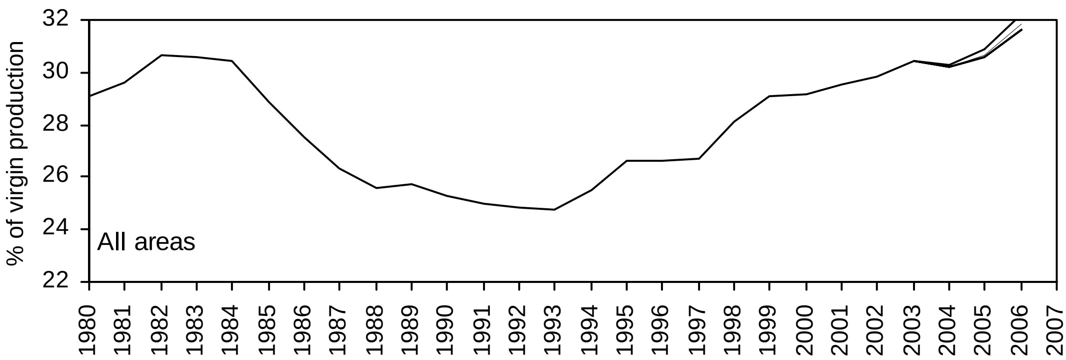


Figure 40. Averaged statewide egg production as percent of virgin under 3 TACC scenarios: 1470 (upper line), 1523 (middle line) and 1550 (lower line). All trajectories are the average of 100 simulations.

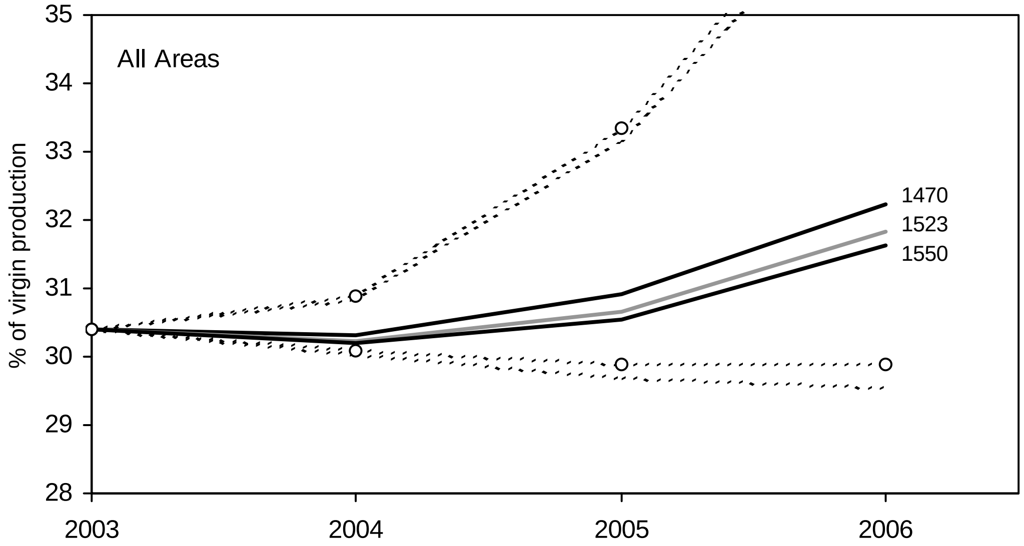


Figure 41. Statewide egg production projections (as % of virgin) showing the same data presented in the previous graph (Figure 40) but focused on projections for the next 3 years. Maximum and minimum ranges of the 100 simulations are shown for the 1470 and 1550 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

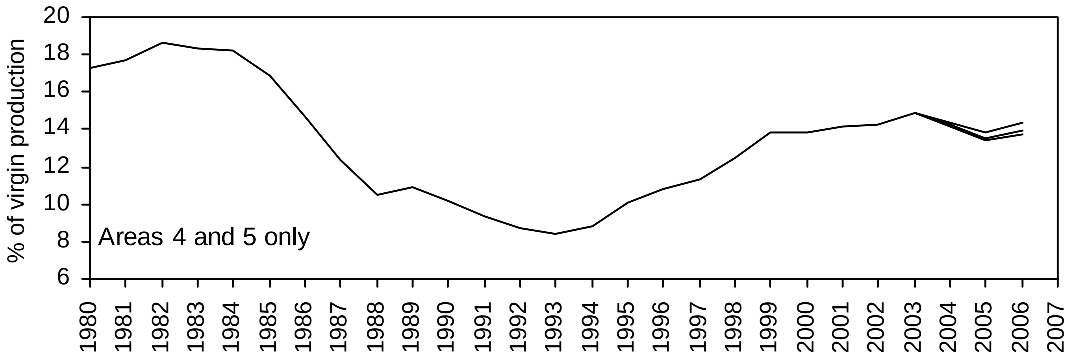


Figure 42. Mean egg production as percent of virgin in the north of the State (Areas 4 and 5) under 3 TACC scenarios: 1470 (upper line), 1523 (middle line) and 1550 (lower line). Means are drawn from 100 simulations.

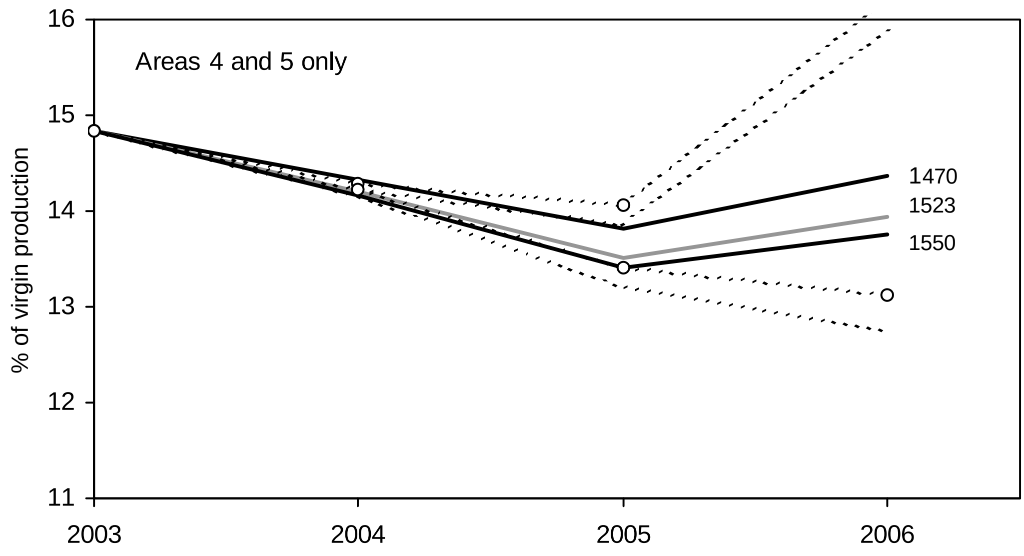


Figure 43. Egg production projections (as % of virgin) from Areas 4 and 5 combined showing the same data presented in the previous graph (Figure 42) but focused on projections for the next 3 years. Maximum and minimum ranges of the 100 simulations are shown for the 1470 and 1550 tonne TACC scenarios (shown respectively by the dashed lines with circles and plain dashed lines).

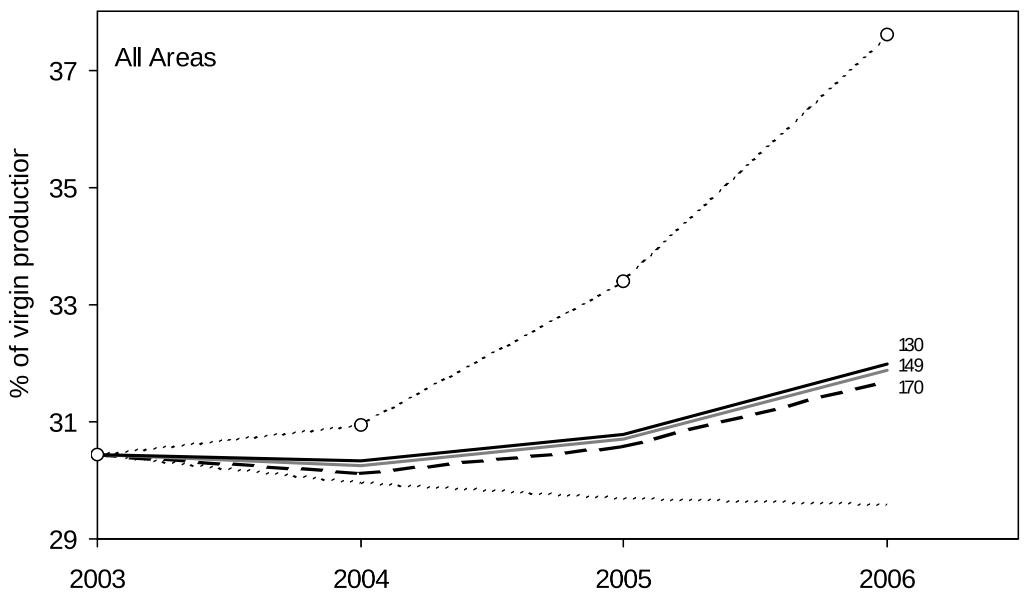


Figure 44. Statewide egg production projections (as % of virgin) for the next 3 years with alternative recreational catches (130, 149 and 170 tonnes). Maximum and minimum ranges of the 100 simulations are shown for the 130 tonne (upper dashed line with circles) and 170 tonne (lower plain dashed line) scenarios respectively. TACC was set at the current level of 1523 tonnes.

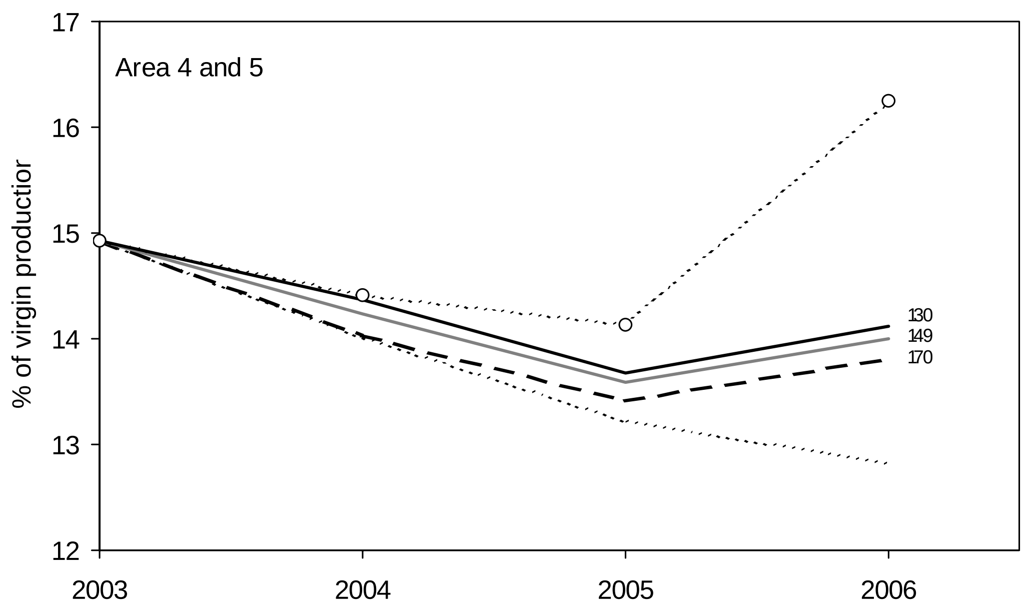


Figure 45. Egg production projections (as % of virgin) for Areas 4 and 5 for the next 3 years with alternative recreational catches (130, 149 and 170 tonnes). Maximum and minimum ranges of the 100 simulations are shown for the 130 tonne (upper dashed line with circles) and 170 tonne (lower plain dashed line) scenarios respectively. TACC was set at the current level of 1523 tonnes.

4.4 Lobsters removed by the commercial fleet, but not included in the quota

Under the current quota system, up to 5 lobsters per trip may be retained by fishermen for personal use under recreational rules and are therefore not considered as commercial catch and are not included in the quota. These recreationally caught lobsters are not included in estimates given in Section 4.1.8. In addition, lobsters caught, but killed accidentally during transport to port (e.g. if freshwater contaminates the well) may also be reported and excluded from the quota. Information for both these categories has been unavailable in previous years, but was recorded from May 2003. A total of 2392 lobsters were kept for personal use from May 2003 to March 2004 (not a complete quota year) (Table 15.9). A further 1786 lobsters were reported accidentally killed during this period.

Table 15. Total number of rock lobsters retained for personal use by fishermen and killed accidentally for the period May 2003 to February 2004.

	Total # rock lobsters	
	Personal Use	Accidental deaths
May 2003 - Feb 2004	2329	1786

Predictably, the retention of rock lobsters for personal use displays a seasonal pattern (Figure 46). Most lobsters were retained during the warmer months, peaking around the Christmas–New Year period (i.e. December). Fewer rock lobsters were kept during the winter months when presumably lobster prices are higher and catches lower. Accidental deaths were also higher in the warmer months, following the closed season, loosely correlating with an increase in overall catch following the resumption of the fishing season. Most accidental deaths were recorded in November (1015 lobsters); this was largely due to a single event.

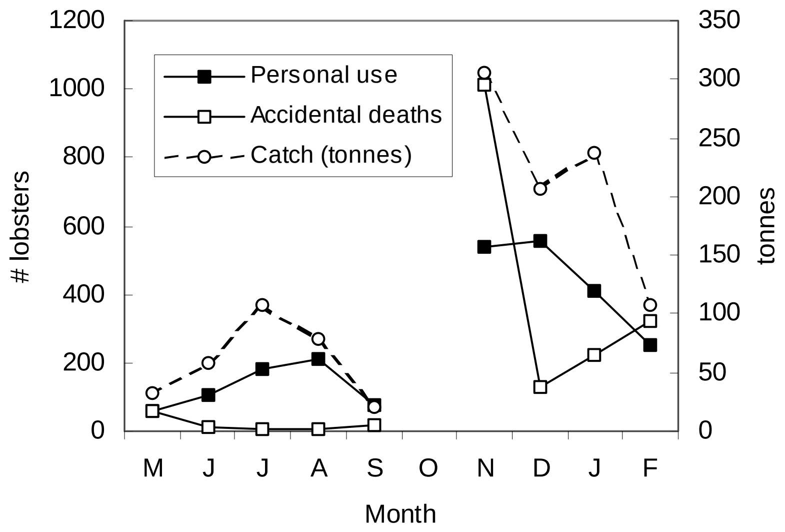


Figure 46. The number of lobsters retained for personal use and accidentally killed (left-hand axis) and the total commercial catch (right-hand axis) between May 2003 and March 2004.

4.5 Lobsters removed for research activities

One percent of the lobster TACC is allocated to research use. In 2003/04, this was used to fund catch-sampling exercises and a total of 4115 kg was harvested.

5. Developments in estimation of biomass

A review of TAFI's rock lobster catch sampling program was conducted in 2003 with input from both industry and management. This review confirmed that fisheries independent catch sampling was an essential component of the annual lobster assessment. Recent assessments of the fishery had shown continued rebuilding of the rock lobster biomass (stock). However, estimates were not as based on a much data as could be achieved by reconfiguring the program.

The catch sampling program meets several needs. It provides length-frequency data, which is used for model fitting and ultimately estimation of biomass and egg production. It also provides data for estimating the stock biomass independently of the length-based model. This second output is important because the length based model is heavily reliant on commercial catch rate data, which can alter independently of stock abundance (e.g. through fishers high-grading).

Independent estimates of biomass were previously obtained through the catch sampling program using population-based estimators of fishing mortality (eg change-in-ratio and index removal methods). More recently these became compromised by changes occurring in the fishery and they were abandoned. Those methods were subsequently replaced by tagging models developed by Dr Stewart Frusher (TAFI) and Prof John Hoenig (Virginian Institute of Marine Science – USA). Promising results have been obtained with preliminary work conducted with data collected from the King Island region.

Tagging models require a large number of legal-sized lobsters to be tagged, released and recaptured. This has been made possible with the help of commercial vessels and skippers chartered to sample selected Areas of the fishery. Two research surveys have been completed to date. The precision of estimates from tagging models is improved with higher levels tag reporting by industry. An attempt to increase reporting rates has been made by promotion of the projects benefits to the fishery and also through simplification of the reporting process. The tags have also been made more visible by changing the insertion point to between the carapace and tail on the upper surface (Figure 47).

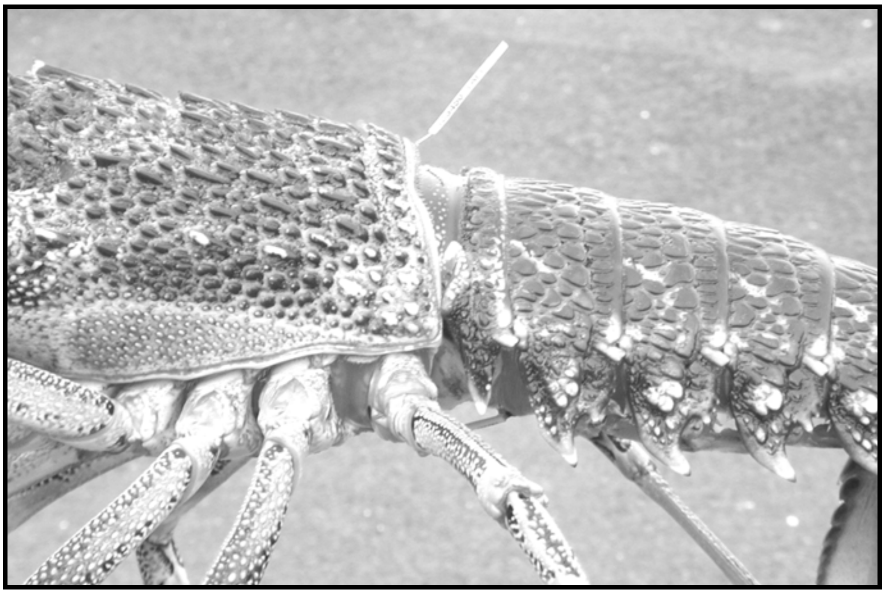


Figure 47. Rock lobster with tag located dorsally between the carapace and the tail.

6. Recruitment

6.1 Recruitment monitoring and catch prediction

Settlement of puerulus is monitored at several sites around the Tasmanian coast as part of TAFI's pre-recruit monitoring program. Puerulus collectors are designed to mimic natural rocky reef with crevices that provide shelter for puerulus swimming in to shore from oceanic waters. These collectors have been deployed at Recherche Bay (Area 1), South Arm (Area 2), Bicheno (Area 3), Flinders Island (Area 4) and King Island (Area 5). Several attempts have been made to establish sites in the remaining Areas on the west coast; however, all of these attempts have failed due to low catch rates.

The objectives of the puerulus monitoring project are to provide a measure of recruitment of juveniles into the population. This information has a number of potential benefits including early warning of large increases or declines in settlement, improved basis for future projections of the assessment model, and contributing to an improved understanding larval sources. Analyses are presented below that compare estimated larval recruitment from the stock assessment model with observed larval recruitment from the puerulus-monitoring project. The estimates of larval recruitment from the stock assessment model are derived from commercial catch and effort data and research catch-sampling data. Estimates of recruitment are hindcast based on growth models within the stock assessment model. This means that catch and effort data from 2003 are used to estimate larval recruitment from previous years, say 1998 (i.e. in this case five years previous). We have contrasted these model estimates with actual observed puerulus catches; where the pattern between the two indices is close it implies that puerulus catches will be of value as a model input for future projections of the fishery.

Further analysis of this data is planned for 2005 and the results shown here are thus preliminary. Aspects that require further investigation include the time of year that should be compared for catches (comparisons here are simply for calendar year) and accounting for variation in growth rate of individuals.

6.1.1 South East Coast

Puerulus catch rates and estimated recruitment have little contrast throughout the period for which there is corresponding data (1991-1998). The last two years have had the lowest catch rates on record, although this low was preceded by the highest catch rate yet recorded in 2002. This contrast in interannular puerulus catches will provide a useful test of the relationship between puerulus settlement and fishery catch rates.

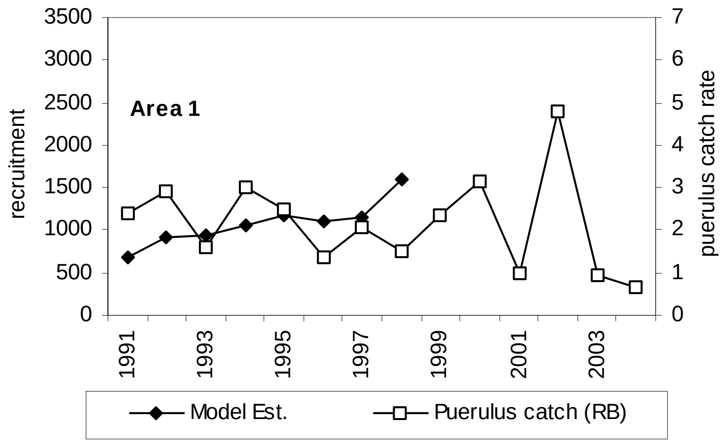
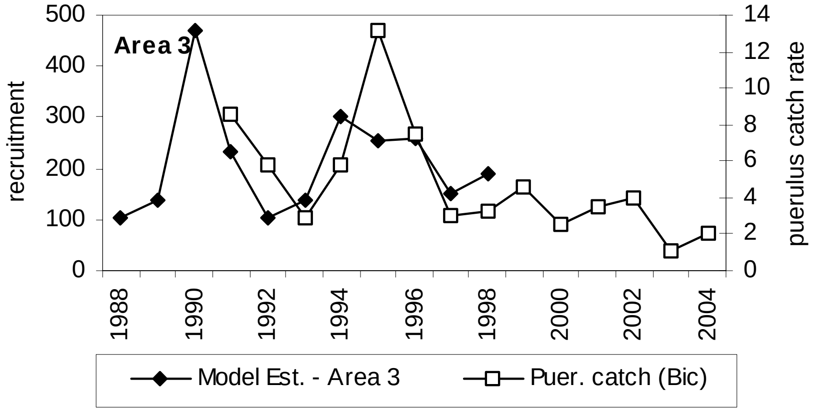


Figure 48. Puerulus catches (N/collector/month) from Recherche Bay (RB) contrasted with estimated recruitment from the stock assessment model. Estimated recruitment and puerulus catches show some congruence through the period 1991-1998.

6.1.2 East Coast

The Bicheno puerulus-monitoring site lies close to the boundary between Areas 2 and 3 and therefore puerulus catch rates are contrasted against model estimates of recruitment from both these Areas. Model estimated recruitment appears to mirror puerulus catch rates more so in Area 3 than Area 2. This could imply that puerulus catch rates derived from the Bicheno collectors are a better predictor of future recruitment in Area 3. However, the large spikes in both puerulus catch and recruitment from Area 2 suggest that peaks in settlement are being detected by both methods, but are out of phase. This lack of alignment of peaks would be caused by incorrect growth information in the stock assessment model. This appears a reasonable conclusion as growth of juveniles is poorly estimated by the model and has only been extrapolated downwards from growth of adults. Research is underway on this topic (see Section 6.3).

In comparison to the early and mid 1990s, recent puerulus catch rates from this location appear low, suggesting that larval recruitment for this region has reduced in recent years.



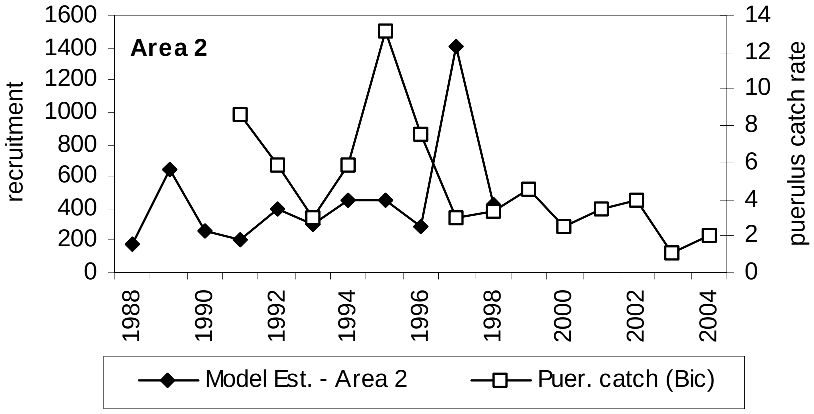


Figure 49. Puerulus catches (N/collector/month) from Bicheno contrasted with estimated recruitment from the stock assessment model for Area 3 (upper) and Area 2 (lower). Greater congruence between puerulus catch rates and estimated recruitment is demonstrated for Area 3 compared to Area 2.

6.1.3 North East Coast

Puerulus catch data from this site has only been collected since 1996 so there is less data with which to make comparisons between estimated recruitment and puerulus catch rates. Nonetheless, with the exception of 1996, puerulus catch rates and recruitment demonstrate similar trends. In light of this, the concern for this region is that puerulus catch rates have shown low and declining catch rates over the last four years indicating potentially low future recruitment to this region.

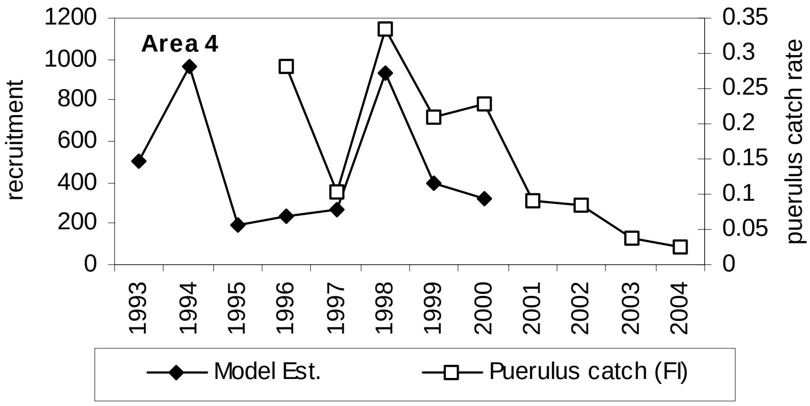


Figure 50. Puerulus catches from Flinders Island (FI) contrasted with estimated recruitment from the stock assessment model for Area 4.

6.1.4 North-west Coast (King Island)

No data was available for 2004 at the time this report was produced.

6.2 Larval transport

Research on larval dispersal processes is underway in collaborative project headed by David Griffin and Barry Bruce from CSIRO and involving researchers from TAFI, MAFRI (Vic.), SARDI (SA) and NIWA (NZ). The project is due for completion in 2005 and is funded through FRDC.

Objectives of the project are:

1. To examine the relationship between spawning region and settlement success across the range of the SRL fishery – *where do successfully settling puerulus come from?*

2. To model the effects on settlement, throughout the range of the fishery, of changing spawning output in various areas of the fishery – *provide information on whether increasing spawning stock biomass in some areas will help increase recruitment, and hence yield.*

3. To identify major physical processes contributing to differences in settlement between years and between regions – *help understand whether variations in puerulus settlement result from management changes or environmental effects.*

4. To identify mechanisms for incorporating findings into on-going assessments of recruitment indices and stock status – *how best to develop the model outputs into a form that managers, researchers and industry can use on an ongoing basis.*

6.3 Pre-recruit growth, mortality and effects of density.

Due to the difficulty in sampling small lobsters, very little is known about the basic biology of juveniles, such as growth rates and mortality schedules. Research on these issues is underway in collaborative project involving researchers from TAFI, MAFRI (Vic.) and SARDI (SA). The project is due for completion in 2005 and is funded through FRDC.

Objectives of the project are:

1. To identify preferred habitat for early benthic phases.

2. To estimate growth rates of pre-recruit lobsters.

3. To estimate mortality rates of pre-recruit lobsters.

4. To evaluate the effects of density on growth and mortality.

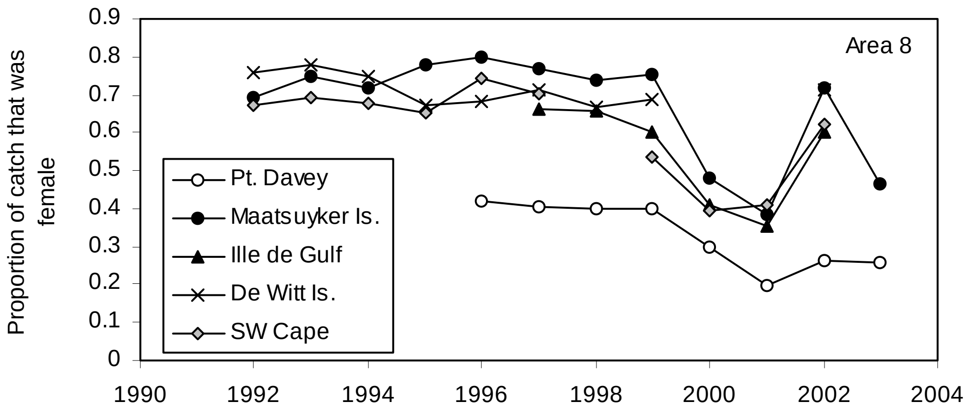
An important application of objective 4 is to assess the potential for stock rebuilding to dampen recruitment.

6.4 Trends in population fertility

Estimates of regional egg production given in Section 4.1.5 assume that all females that reach mature size will produce eggs each year. However, recent tank-based research has indicated that there is potential for sperm limitation and subsequent infertility in lobster populations (MacDiarmid and Butler, 1999). If sperm limitation, caused by lack of males, was impacting on Tasmanian lobster populations then we would expect to see increasing incidence of infertility in lobsters collected during catch-sampling.

Patterns in change in sex ratio through time are unclear due to a sharp decline in the number of females in the catch in 2000 and 2001 (Figure 51). This pattern appears to be caused by a change in catchability of females rather than a change in the population structure because the decline occurred across all sites in Area 8 and then recovered in 2002. Nonetheless, the general trends in both Areas appears to be that sex ratios are shifting towards the more natural distribution of 1:1, which would be expected with the current trend of stock rebuilding.

When females fail to mate with a male the ovaries are resorbed which produces marked change in pigmentation of the haemolymph so that the underside of the tail appears bright red (MacDiarmid and Butler, 1999). The presence of females with this condition has been monitored in research sampling since 1992 but is observed only rarely. Of those sites where infertility has been recorded, the incidence remains very low (Figure 52).



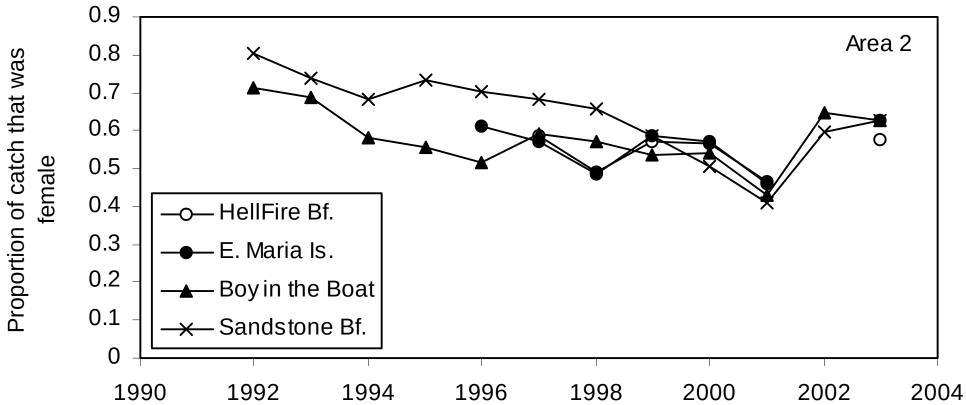


Figure 51. The proportion of lobsters in research catches that were female. A proportion of 0.5 equates to a ratio of 1:1 while a proportion of 0.7 equates to a ratio of 7 females : 3 males.

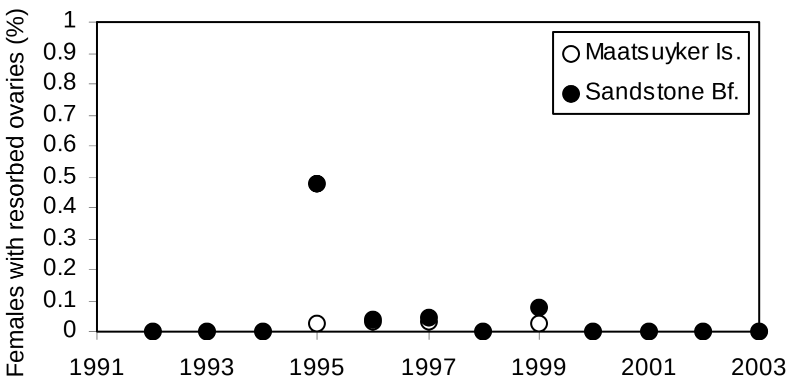


Figure 52. Proportion of females in research catch sampling with evidence of resorption of ovaries. Sites where no observations of females with resorbed ovaries have been recorded are not shown.

In summary, the risk of infertility in the population caused by lack of males appears low. However, MacDiarmid and Butler (1999) noted that reduced fertility can also be manifested in reduced brood size, rather than complete failure of females to produce eggs. This could be assessed in Tasmanian populations by conducting a survey to determine current fecundity:size relationships and comparison with data collected in 1989.

7. Translocation of rock lobsters

7.1 Project background

The Tasmanian lobster resource is characterized by large spatial differences in growth and reproduction parameters. Although the biology is variable spatially, the same management rules are applied across the fishery. Fleet dynamics are also uneven and effort increasingly targets depleted inshore areas where high value, hard-shelled, red lobsters are located. Problems with the current approach include (a) massive loss of yield through growth overfishing/underfishing depending on growth rate; (b) egg production concentrated in one region, rather than naturally distributed; (c) reduced economic yield through discounting of deep water lobsters; (d) stock rebuilding objective of quota management impaired; (e) elevated potential for ecological impacts of fishing.

One management option to address these issues is the translocation or shifting of lobsters between regions.

A pilot scale translocation experiment was initiated in April 2004 to investigate change in carapace colour and growth rate. This was a cooperative project between the Tasmanian Rock Lobster Fishermen's Association and the Tasmanian Aquaculture and Fisheries Institute.

7.2 Preliminary results

Undersized lobsters of both males and females from deep waters (80-90m) were tagged, measured and photographed before being released into shallow (10-20m) waters at Stanley in April 2004. In the 10 months after release, 56 males and 1 female were recaptured and reported by the fishing community and TAFI research staff. The experiment was intended to measure only growth and colour change, so there was no attempt to recapture very large numbers of animals to establish survival rates.

Preliminary results from recaptures indicate some variation in the timing of colour change and growth rate.

By the third resurvey in January 2005, all recaptured lobsters had changed from brindle, white to a uniform rich maroon colour. This remarkable change in the increase of red pigmentation is indicative of the shift in diet in shallow water and represents a significant increase in the marketability of the product.

Collectively, the range in growth increments varied from 2-26mm after a single moult, with a possibility of some animals moulting twice. One male increased from 88mm to 114mm in 301 days. The improvement in growth related to the duration between release and the next moult. Almost half the recaptures had reached legal size within the first 300 days after release. This indicated that lobsters adapt to the growth rate of their new home very rapidly.

These changes in growth are of some significance because the same animals would have taken over 3 years to reach legal size in their original location. Thus the translocation exercise appears likely to produce two benefits for yield from the stock.

First, lobsters grow much faster so productivity increases - over the 3-year period that the released lobsters would have normally taken to reach legal size, this would equate to a benefit of over 50% (ie. 50% more legal-sized biomass).

Secondly, because lobsters spend less time as undersize animals, they experience less predation and other sources of natural mortality. The increases in growth observed in this study suggest that the number of lobsters reaching legal size could be increased by around 25%.

Based on these results, TAFI hopes to undertake a much larger scale translocation experiment in 2005 to explore other key aspects such as the economic viability of the operation, short-term survival, movement, and ecosystem impacts.

8. Reseeding

This project developed methods to optimise the survival of juvenile rock lobsters released for enhancement purposes. An immediate application is for the release of juveniles in Tasmania as part of puerulus harvest operations. These operations collect settling puerulus for aquaculture and are obliged to return a portion of the juveniles after 12 months (35 g) to compensate for those that would have naturally survived.

Although juvenile rock lobsters in culture tend to forage in open areas during daylight hours, feeding at dusk can induce more normal foraging patterns. Initial concerns that juveniles reared in tanks would fail to recognise predators were unfounded. We found that the juveniles avoided predators in the same manner as wild controls immediately after release onto coastal reef. Unlike overseas enhancement operations with clawed lobsters, predation around the time of release was not significant and release in to cages did not appear to be necessary to exclude predators. Survival was highest when releases were conducted at night and in winter.

Suitable release habitats can be adequately selected by divers on the basis of qualitative factors such as presence of other juveniles, abundance of shelter, and good algal cover. There did not appear to be justification for expensive surveys of potential predation rates when selecting sites for release.

An initial period of movement following release, particularly in the first 24 hours, was detected in all pilot-scale releases. This movement was occasionally over 1 km and had the potential to reduce survival as juveniles were not constrained by reef boundaries and walked into exposed sandy Areas, sometimes failing to find shelter by morning. Release into cages for 48 hours in Areas of complex reef structure, or release onto large Areas of reef overcame this problem.

Survival of cultured juveniles was compared to that of wild controls in pilot scale releases at 4 sites with over 2200 juveniles. Estimates of the survival of cultured juveniles were equivalent to wild controls after 48 hours. At one site, survival of cultured juveniles appeared to be lower than that of controls in the first 48 h post release, although this appeared to be due to movement. That is, released juveniles appear to have disappeared from surveys by walking rather than from predation. Tethering results provided an upper estimate of predation during the first 48 hours of 5%.

Survival of southern rock lobsters in enhancement operations appears to be high and can be optimised by simple protocols during release. These results have application in addition to the release of juveniles and have recently been applied in pilot-scale translocation of larger mature lobsters in Tasmania.

9. Ecosystem based management

9.1 Protected species interactions

Improved reporting of interactions with protected species commenced at the beginning of 2003/04 assessment year. Each fisher is now equipped with a logbook containing a protected species interaction section to improve reporting. One hundred and sixty interactions with protected species were reported in the last assessment period. The overwhelming majority of these involved reports of fur seals removing bait, and/or smashing or taking bait savers and skewers from pots. The interaction was negative for the protected species on one occasion where a fur seal was reported to be wrapped in a surface fishing line, but was released alive. No interactions with birds were reported.

9.2 By-Product

By-product is by definition by-catch that is retained for sale rather than discarded at sea. Most by-catch species in the Tasmanian rock lobster fishery are released unharmed or with unknown discard mortality whereas by-product involves defined fishing mortality. By product of species captured in lobster traps has been reported through the general fish logbook system since 1995 so that catch of these species in lobster pots is included in separate assessments. Total reported by-catch of most fish types was small and only two fish types had reported annual catches greater than 1 tonne – cod and octopus (Figure 53). Catches of cod have declined since 1996/97 while little pattern is evident for octopus.

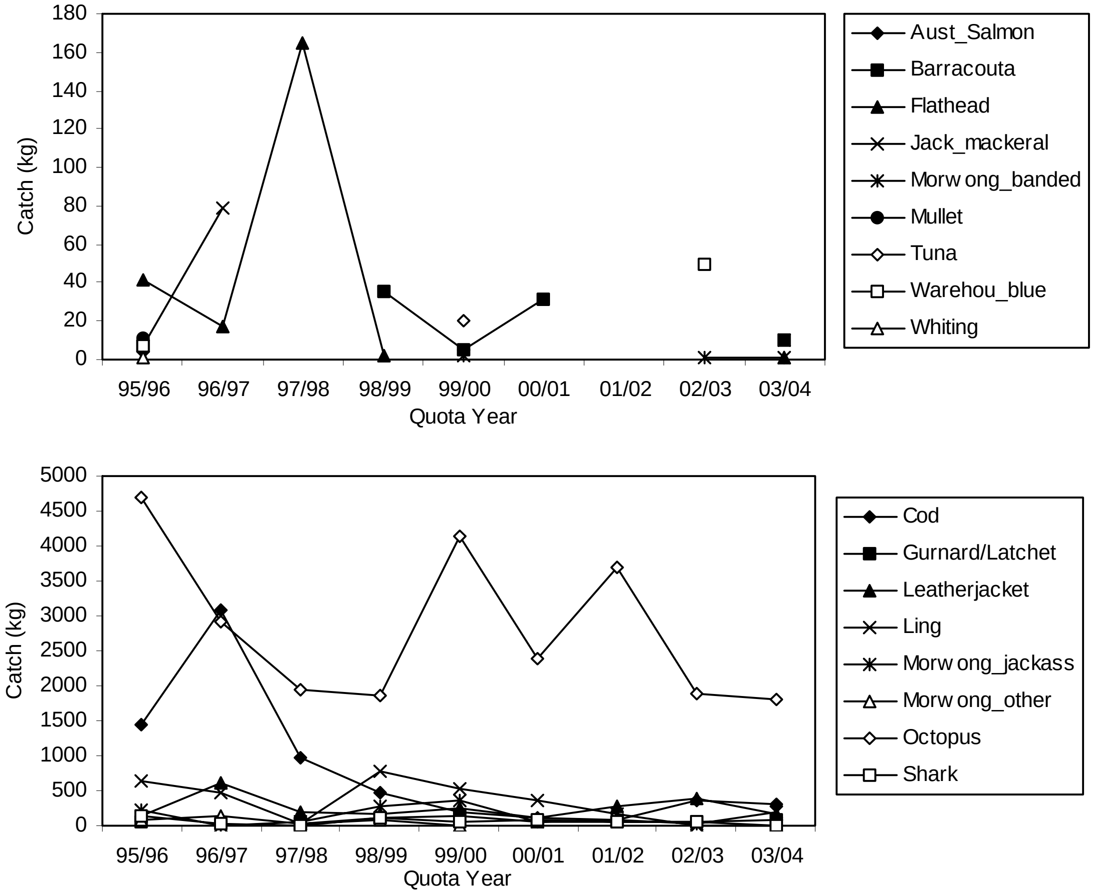


Figure 53. Reported by-product from rock lobster pots, January 1995 to August 2002. Data is grouped into quota years (March to February) so annual catches are incomplete for the 1995/96 and the 2002/03 quota years. Catches of minor species are shown in upper plot, those with greater catch are shown in the lower. Values for catches of octopus are shown on the right-hand axis of the lower plot.

9.3 By-Catch

During October 2003, TAFI commenced a new catch sampling project aimed at sampling broad regions of the fishery using commercial vessels. In conjunction, a project was undertaken to assess the impact on by-catch from commercial potting by using pots with and without escape gaps. This project follows on from the earlier work of Frusher and Gibson (1999) and also compliments an 11 year ongoing fishery independent project that has, as a component of the project, recorded by-catch from research pots without escape gaps.

Eighty percent of all by-catch recorded in the surveys were hermit crabs. The incidence of other by-catch species by comparison was scarce. This program will continue during 2004/05 to assist in documenting the impact of escape gaps on the fishery.

Differences between pots with and without escape gaps, between night and day fishing and between different regions were detected. Hermit crabs, draughtboard sharks and both the brown striped and Degen’s leatherjackets were found in higher numbers in pots with escape gaps closed. Hermit crabs and Degen’s leatherjackets were also in higher abundance at night whereas the rough rock crab, bearded rock cod and brown striped leatherjacket were caught in greater numbers during the day. By-catch in the northeast was considerably higher and dominated by hermit crabs. In the southeast Area the amount of by-catch was not as large and although dominated by hermit crabs, the cleft fronted shore crab also accounted for a relatively large part of the by-catch. In the southwest the by-catch was very low and consisted largely of three species: hermit crabs, rough rock crabs and draughtboard sharks. The by-catch composition in the northwest was similar to the southeast, but more species accounted for larger parts of the by-catch.

Table 16. Species list of by-catch caught in October 2003 from 2,120 pot lifts.

Common name	**Scientific name**	Total number
Hermit Crab	*Strigopagurus strigimanus*	2984
Draughtboard Shark	*Cephaloscyllium laticeps*	118
Rough Rock Crab	*Nectocarcinus tuberculosis*	112
Cleft Fronted Shore Crab	*Plagusia chabrus*	82
Bearded Rock Cod	*Pseudophycis barbata*	66
Red Gurnard Perch	*Helicolenus papillosus*	66
Brown-striped Leatherjacket	*Meuschenia australis*	62
Degen's Leatherjacket	*Thamnaconus degeni*	55
Southern Conger Eel	*Conger verreauxi*	34
Blue-Throat Wrasse	*Pseudolabrus tetrians*	28
Octopus	*Fam. Octopodidae*	25
Giant Tasmanian Crab	*Pseudocarcinus gigas*	24
Morwong	*Nemadactylus macropterus*	9
Decorator Crab	*Stimdromia lateralis*	6
Rosy Wrasse	*Pseudolabrus psittaculus*	5
Toothbrush Leatherjacket	*Penicipelta vittiger*	4
Pink Ling	*Genypterus blacodes*	3
Purple Wrasse	*Pseudolabrus fucicola*	3
Southern Rock Cod		2
Barber Perch	*Caesioperca rasor*	2
Starfish-unidentified		2
Red Rock Cod	*Pseudophycis bachus*	1
Rock Ling	*Genypterus tigerinus*	1
Stripey Trumpeter	*Latris lineata*	1

Figure 54. Steel research trap (left) and standard "beehive" trap (right) used in the commercial and recreational fisheries. Note that some fishers also use steel traps although designs differ from the research trap shown here.

9.4 Observations from Marine Protected Areas

Although marine protected areas or MPAs in Tasmania appear to have limited value as fisheries or ecological management tools, they provide valuable sites for research on the impact of fishing (Buxton et al., 2004). Previous assessments have included summaries of research conducted on the impacts of MPAs through the FRDC project "The use of marine protected areas as a fisheries management tool" (FRDC 1999/162; C. Buxton, M. Haddon, N. Barrett, G. Edgar and C. Gardner). That project included analysis of change in the community structure within MPAs to evaluate possible ecological effects of the harvest of exploited species, including rock lobsters. A more extensive summary of this research was provided in the previous assessment report and a brief update on recent findings is given here.

Tasmania's first 'no-take' MPAs were established a decade ago. At this time a monitoring program was initiated to document changes occurring in the MPAs and to compare these with changes at external (fished) reference locations. By surveying reef fishes, invertebrates and plants on an annual basis, a comprehensive database has been established allowing some understanding of natural variability at this temporal scale and the extent that fishing, introduced species and range-extensions of habitat modifying species can influence this.

The most obvious change within the MPAs was in species targeted by fishers. As would be expected, these increased in abundance and size after fishing effort was removed. The magnitude of change detected depended on the exploitation rates prior to closure, movement of species (and thus protection by spatial management), and MPA design. Changes within the Maria Island MPA (the largest) relative to reference sites have included increases in the abundance of lobsters and net-susceptible fish (eg bastard trumpeter *Latridopsis forsteri*) and increases in the mean size of rock lobsters.

Of more interest are the secondary community effects such as a change in the abundance of prey species such as urchins and abalone. Abalone abundance has appeared to decline following protection in the MPA, perhaps through increased natural mortality (especially predation). More recent sampling by Neville Barrett and Graham Edgar has extended the temporal data series for urchins beyond that described previously.

The abundance of common urchins (*Heliocidaris erythrogramma)* within the Maria Island reserve has been monitored over the last 13 years and has remained stable through this period with overlap in standard errors of transect counts throughout the temporal data series (Figure 55). At nearby sites outside the reserve there is a non-significant trend of increasing abundance, which was not observed inside the MPA. The trend of urchin abundance within the MPA appears to be heading downwards, although at this stage results are inconclusive. This may be the first Tasmanian insight into ecosystem effects related to fishing. These results show MPAs at the Maria Island scale (7km) can be effective reference areas for determining and understanding the effects of fishing in the absence of historical baseline data.

Increased fishing effort and reduction of lobster biomass should be avoided given the indications of a relationship between lobsters and urchins (*Heliocidaris erythrogramma).* These findings support the current management policy of stock rebuilding that was initiated in the early 1990's through changes to closed seasons and quota management. Although MPAs provide a valuable resource for reference sites on the effects of fishing, they appear counter-productive as a management tool to reduce the impact of lobster fishing on ecosystems, at least in terms of commercial fishing. This is due to the displacement of fishing effort and subsequent nett decline in total lobster biomass.

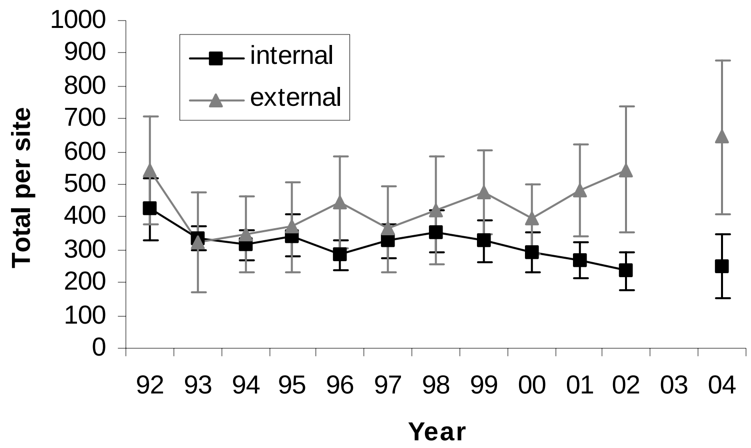


Figure 55. Mean Heliocidaris erythrogamma abundance within Maria Island reserve and at external reference sites during surveys between 1992 and 2004. Abundances are numbers per site (+/- se).

9.5 Assessment of potential threats to rock lobster fishery of range extension of the long-spined sea urchin (*Centrostephanus rodgersii*) in eastern Tasmania

This research has been conducted through the FRCD project "Range extension of the long-spined sea urchin (*Centrostephanus rodgersii*) in eastern Tasmania: Assessment of potential threats to fisheries" (FRDC 2001/044; C. Johnson, S. Ling, S. Shepherd and K. Miller). The results of the project are summarised here by the investigators of the FRDC project, with detailed results provided in the final report, due in late 2004.

9.5.1 Project Summary

The pattern of distribution of the long-spined sea urchin *Centrostephanus rodgersii* over ca. 40 y in the Kent group, Bass St., suggests initial establishment in the mid 1960s with subsequent expansion of populations to its current status as the dominant invertebrate on shallow subtidal rocky reef. On the east coast of Tasmania, *C. rodgersii* is most abundant in the vicinity of its location of initial discovery in 1978, but it occurs throughout the east coast between Eddystone Pt in the north and Recherche Bay in the south. Barrens habitat, supporting high densities of sea urchins but largely devoid of macroalgae, occurs extensively in the Kent group and at several sites on the northern half of the Tasmanian east coast, but declines with increasing latitude and does not occur south of the Tasman Peninsula (Figure 56). At the southern extent of barrens habitat on the open coast, barrens are incipient and occur as small patches in macroalgal beds. It is suggested that the barrens habitat in the Kent group and on the open rocky coast of Tasmania is formed by grazing of *C. rodgersii* and not by *Heliociaris erythrogramma*, another sea urchin that occurs on these barrens. This is largely because there is a significant positive relationship between *C. rodgersii* density and extent of barrens but not between *H. erythrogramma* density and extent of barrens, and because *H. erythrogramma* is not known to form barrens on exposed coast.

These collective patterns suggest that the incursion of *C. rodgersii* into Tasmanian waters was from the north, and that spread on the east coast of Tasmania propagated from an 'epicentre' in the vicinity of St Helens in the northeast. We suggest that the initial incursion was via larvae transported from NSW in the East Australian Current, which has increasingly influenced the east coast of Tasmania over at least the past 4-5 decades. The lack of any genetic differentiation among *C. rodgersii* populations in NSW, the Kent group and the east coast of Tasmania is consistent with this view.

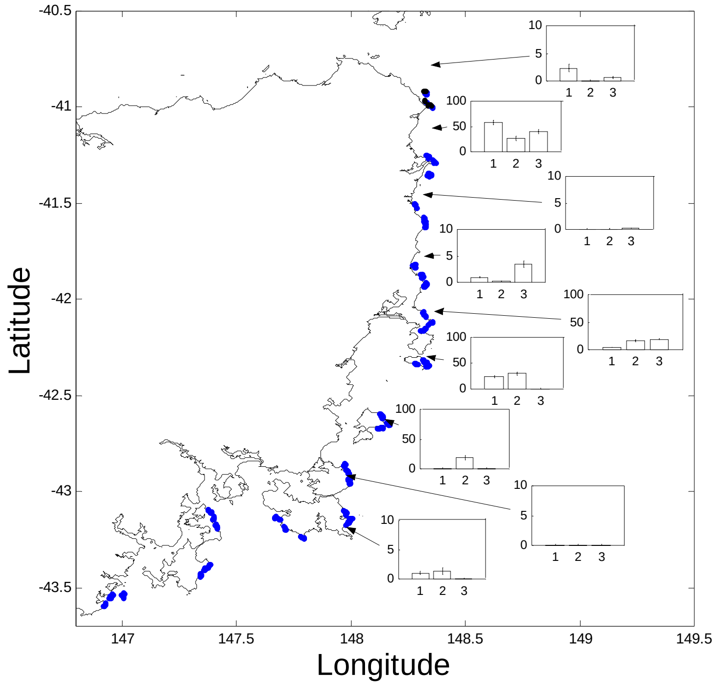


Figure 56. Mean cover of *C. rodgersii* barrens on rocky reef at sites (±SE based on transects within subsites as replicates) on the east coast of Tasmania determined from video transects.

On the east coast of Tasmania, there is a clear negative relationship between the abundance of *C. rodgersii* (Figure 57) and the density of rock lobster (*Jasus edwardsii*). The density of abalone is significantly lower on barrens habitat than in adjacent macroalgal beds at the same depth and on the same substratum type. It is concluded that abalone and rock lobster are unlikely to occur in commercial quantity on *C. rodgersii* barrens.

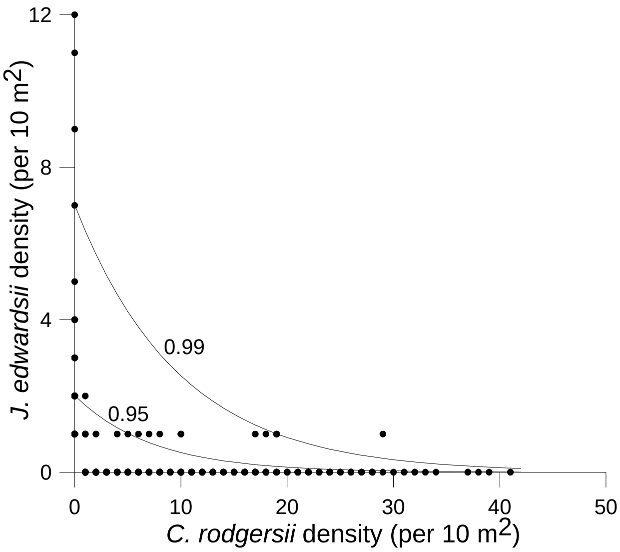


Figure 57. Relationship between abundances of *C. rodgersii* and *J. edwardsii* at a scale of 10 m^2 across sites 1-9. Quantile regressions (95^{th} and 99^{th} quantiles) revealed significant negative relationships.

In Tasmanian waters, large continuous tracts of *C. rodgersii* barrens do not develop in shallow water (2-10 m) as occurs in NSW, but largely occur within a depth range of ca. 10-20 m in the Kent group, and ca. 15-35 m on the east coast of Tasmania (Figure 58). Barrens habitat is more prevalent on boulder substratum than other types of consolidated reef, extending to cover >75% of the seafloor on this substratum at some sites, and averaging ca. 33% cover on boulder substratum across all sites in Tasmania where incipient barrens occur (Figure 58). Given these collective observations, and estimates that boulders comprise ca. 55% of consolidated reef in depths ≤18 m and 34% of consolidated reef to ca. 40 m depth, barrens habitat could potentially expand to account for ca. 50% of rocky reef on the east coast of Tasmania, as currently occurs in the Kent group and NSW. This scenario would have serious implications for abalone and rock lobster fisheries on this coast. However, the capacity to predict future patterns of barrens habitat requires better understanding of the mechanisms that initiate barrens formation and that determine the position and dynamics of boundaries between barrens and macroalgal-dominated habitat. Given these considerations, and evidence worldwide of the connection between fishing of sea urchin predators and formation of sea urchin barrens, the project investigators suggest that management intervention to limit the spread of *C. rodgersii* barrens in Tasmania is warranted.

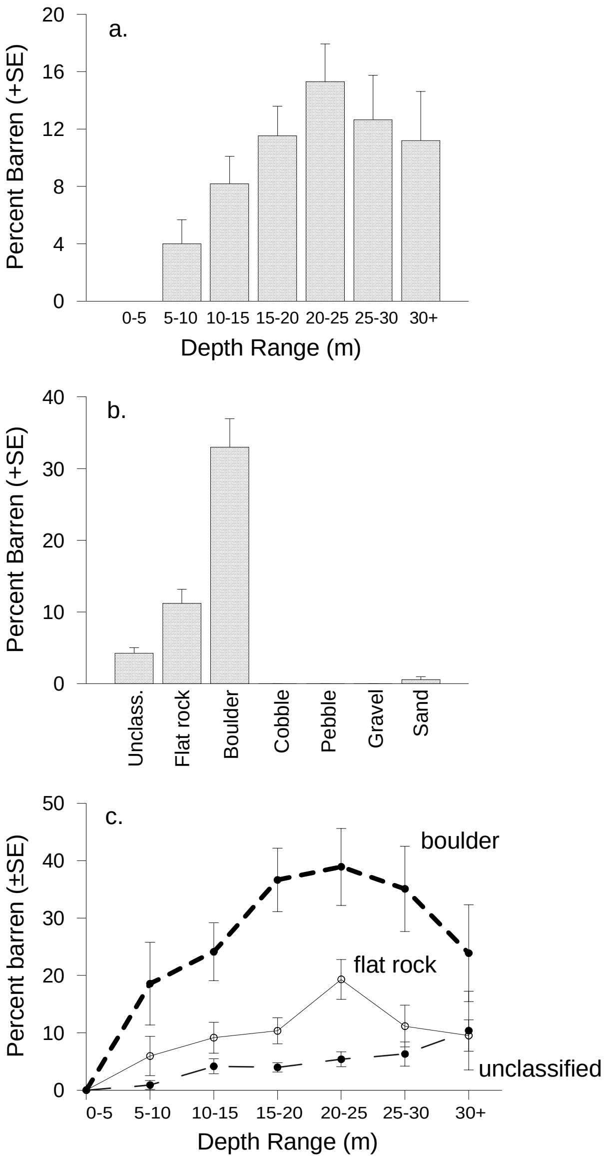


Figure 58. Distribution of *C. rodgersii* barrens determined by video transects across sites by (a) depth, (b) substratum type and (c) by depth for the main substratum types on which *C. rodgersii* were encountered.

9.5.2 Implication of barrens formation for rock lobster fishery

It is clear that extensive *C. rodgersii* barrens habitat in Tasmania is unable to support abalone (*Haliotis rubra*) and rock lobster (*Jasus edwardsii*) at levels suitable for recreational or commercial harvesting. Reduced secondary production on sea urchin barrens reflects levels of primary production ca. 100-fold lower than exists in macroalgal beds (Chapman ,1981) and, in the case of abalone, the result of direct competition with sea urchins for food and space. The ultimate impact of the incursion of *C. rodgersii* into Tasmania on the abalone and rock lobster fisheries will depend on the extent to which associated barrens habitat develop, and on the spatial overlap of barrens habitat with preferred areas of fishing. At this stage it is not possible to predict the expansion of barrens habitat, although the extent of incipient barrens that was observed, particularly on boulder substratum, suggests that further expansion of extensive barrens is likely. The most extensive barrens occur between 15-30 m depth, and the majority are in depths ≥15 m. Rock lobster is fished intensively throughout the depth range of barrens formation, but also in deeper water. The impact of barrens formation for the rock lobster fishery is therefore two-fold in that the advent of barrens habitat not only represents area lost to the fishing, but since catch in both the recreational and commercial fishery is trending upwards or capped (respectively), increases in barrens habitat inevitably leads to greater fishing pressure in remaining habitat suitable for fishing.

Any management response to the incursion of *C. rodgersii* into Tasmanian waters would sensibly focus on preventing further spread of barrens habitat and, possibly, rehabilitation of existing barrens. The transition from productive macroalgal beds to poorly productive sea urchins barrens habitat has occurred in temperate waters worldwide. The common denominator underpinning this transition is fishing pressure on predators of sea urchins, although at specific sites there may also be other influencing factors. Fishing of both rock lobsters and scale fish have been implicated or demonstrated to limit sea urchin populations. In Tasmania, extensive experiments have indicated that legal-sized rock lobsters are more important predators of *H. erythrogramma* than are reef-associated fishes, and that fishing of legal-sized rock lobsters is sufficient to account for increases in populations of this species to levels where *H. erythrogramma* barrens can form. While wrasse are an important predator of invertebrates in the kelp-bed systems of southern Australia, in studies with *H. erythrogramma*, only large fish preyed on the sea urchins and they were a poorly preferred prey.

This collective evidence, combined with the depletion of legal-sized lobsters on the east coast of Tasmania in recent decades, raises the question of whether fishing of sea urchin predators, and rock lobsters in particular, has been a key factor in facilitating formation of *C. rodgersii* barrens. If this is demonstrated, then there is a compelling case for management intervention. Our initial experiments show that legal-sized rock lobsters are an important predator of *C. rodgersii*. While management decisions have already been implemented to increase the biomass of legal-sized lobsters, it is unclear to what level this biomass is likely to build and whether it will have any effect on the population dynamics of sea urchins. Also note that rebuilding of lobster stocks through QMS has been least effective in regions where barren formation is of concern.

Management intervention to limit further expansion of *C. rodgersii* barrens in Tasmania is likely to be more tractable than any attempt to rehabilitate existing barrens. There are two reasons for this. First, large-scale removal of sea urchins, particularly in deeper water, is difficult. Second, the density of *C. rodgersii* necessary to create barrens habitat is significantly greater than that needed to maintain barrens. Thus, the transition to *C. rodgersii* barrens represents a shift to an alternative ecological community state that has high resilience to change.

10. Appendix 1: List of Management Objectives and Strategies

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

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

The proposed policy objectives listed in the draft plan are:

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

- Maintain a fishery that is conducted in an orderly manner recognising different participants need to access shared fishing grounds.
- Provide reasonable recreational access to the fishery.
- Provide access to the fishery for Aboriginal people to undertake cultural activities.
- To promote and maintain handling and processing practices that attempt to ensure the highest quality rock lobster product.

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 commercial rock lobster fishing fleet

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

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 (i.e. 1993, 1994, or 1995). For the first year of the Management Plan only, catch-rate will be permitted to fall to 90% of that in the reference year with the lowest catch-rate. The analysis to assess this trigger point must standardise CPUE to take account of possible biases caused by changing fishing patterns on at least a monthly and regional basis.

- Annual CPUE from commercial catch returns for any 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 (Statewide) legal-sized biomass from the stock assessment model falls below 95% of that estimated for the reference year with the lowest biomass.

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

- Any regional estimates of egg production falls to less than 95% of the related egg_{low} unless the affected 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.[1]

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 commercial rock lobster fleet

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

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.

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

12. Appendix 3: Summary of Rules

Table 17. 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 2001: closed season 24-28 February (both sexes); 1st October – 2nd 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 1523 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 48 hours 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
Possession limit	10 for holders of recreational licenses, 5 for those without a rec. license (a receipt of purchase is required if more are held). No possession on State waters without a recreational license.
Limited seasons	In 2001: closed season 1st May-2nd November (females); 1st September-2nd 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.

13. Appendix 4: Methods for standardisation of catch rates

The General Linear Models were all conducted using SAS version 9.1.1. The analysis was conducted to provide standardized catch rates for what would have been each quota year of the fishery, that is, each quota year was treated as a separate parameter estimate. The factors available for analysis included month, vessel distinguishing mark, 10 fathom depth-categories, half-degree statistical block, and the day/night flag. By including QYear as a dummy variable into the statistical model the parameter estimates for each QYear constitute the indices of relative abundance. When these are examined they should provide a cleaner representation of the status of the rock lobster stock through time.

It should be noted that the output from a GLM does not guarantee that a relation exists between stock size and standardized catch per unit effort. It is possible that factors not included in the GLM (through no other information being available) may be obscuring any effects of changes in stock biomass. This is model uncertainty at its most fundamental and implies that while the standardization should be an improvement over using the raw catch rates, they may still be biased or significantly influenced by factors for which we have no information.

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

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

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

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

where where SSE is the sum of the squared residuals, *n* is the total number of observations, and *p* is the number of parameters. A second definition is:

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

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

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

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

14. Acknowledgments

This report received comment from members of the Rock Lobster Assessment Working Group :

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Mr Rodney Treloggen	Executive Officer, Rock Lobster Fisherman's Association
Mr Charles Wessing	Industry Representative
Mr Michael Holmes	TARFish Representative
Albie Setcliff	TARFish Representative

This report includes contributions from a range of sources:

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