FISHERY ASSESSMENT REPORT

TASMANIAN GIANT CRAB FISHERY 2001/2002

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This is the second in a series of giant crab fishery assessments to be produced by the Tasmanian Aquaculture and Fisheries Institute (TAFI).

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Giant Crab Fisheries Assessment: 2001/02

Executive Summary

The giant crab fishery expanded rapidly between 1992 and 1995 and was managed at the time as a Commonwealth fishery. Management was later transferred to the State of Tasmania, which imposed a closure in 1998 to allow the formulation of a new management plan. The fishery subsequently reopened in November 1999 under an Individual Transferable Quota Management System (ITQMS). Total catch was set at 103.5 tonnes, which was a reduction of around 20% on the total catch landed in the last full year of fishing (1998). Several other management restrictions were retained such as trap number and size limits.

The giant crab management plan introduced in 1999 included a series of performance indicators on the state of the stock. These indicators are accompanied by trigger points that define the limits of change that can be tolerated before the management is reviewed (although they do not prescribe management change). This giant crab fishery stock assessment outlines developments in the fishery against these trigger points and is the second such report since the introduction of ITQMS.

Trigger point	Breached in 2001/02 ?
Decline in statewide CPUE for 2 consecutive years	No
Total decline in CPUE of 20% in 2 years in any assessment area	Yes, all areas except Area 7 (18% decline)
Total catch is less than 90% of the TACC	No
Total bycatch of giant crabs taken by lobster fishers without giant crab licenses is greater than 5 tonnes	No
The proportion of the catch above 5kg varies by more than 30% compared to the 1996/97 distribution	No
The proportion of the catch below 3 kg varies by more than 30% compared to the 1996/97 distribution	No

In the last assessment report it was noted that the information in the catch and effort database contained numerous errors. Correcting these errors has been a focus of research effort over the last year. As a result, our interpretation of catch rate in the fishery is quite different in this report to that presented last year.   The value of this is shown in our ability to interpret seasonal trends in catch rate – last year, no seasonal pattern could be detected. With the corrections to the database completed, seasonal patterns in catch rate are apparent and these match the interview reports of fishers.

Catch per unit effort (CPUE) has trended downwards since data collection commenced in 1995. In a developing fishery such as this, it is normal for catch rates to decline as the virgin biomass is depleted. However, at some stage, catch rates need to stabilise if the fishery is to be managed sustainably. The catch rate trigger point – statewide catch rate has declined for 2 consecutive years – was reached last year but failed to go off this year. This suggests that catch rate may have stabilised.

The trigger point relating to regional catch rate is a total decline in CPUE of 20% in 2 years in any assessment area. This was breached in each assessment area except area 7 (SW) where catch declined by only 18%. However, the fishing season in 1999/00 was restricted to summer months when catch rates are higher, so this 2-year comparison is of limited value in 2001/02. The change in catch rate relative to 5 years ago indicates large declines in all areas except Area 2 (SE), where insufficient data is available to make a valid comparison. Regional changes in catch rate between 2000/01 and 2001/02 are mixed, with declines seen in 3 of the 6 assessment areas (4 (NE), 5 (NW) and 7 (SW)).

Fishers caught almost the entire quota available to them in 2001/02 with a total of 98.1 tonnes of a quota of 103.5 tonnes taken. This did not, therefore, activate the trigger of 90% of the TACC. Total bycatch of giant crabs taken by lobster fishers without giant crab licenses was 650 kg and thus considerably less than the trigger of 5 tonnes. Although no trigger relates to crab taken as bycatch using methods other than lobster pots, data have been analysed for these also. Retained catches of giant crab by gear types other than trawl were negligible (<100 kg). Retained catches of crabs by trawlers are not recorded by species type, but it appears that between 1000 kg and 2500 kg of giant crabs were retained by trawlers in 2001/02.

Two trigger points relate to the size splits of crabs handled by processors: the proportion of the catch above 5kg varies by more than 30% compared to the 1996/97 distribution; and the proportion of the catch below 3 kg varies by more than 30% compared to the 1996/97 distribution. Both these triggers were activated for the previous 3 years but not in 2001/02, although there was a reduction in the proportion of the total catch included in this analysis.

Fishers record the number of males and females in their catch, which allows us to follow changes in sex ratio. The sex ratio of the catch was stable between 2000/01 and 2001/02 and is skewed towards females, at around 3 females for 2 males. This skewed sex ratio appears to be due to the higher catchability of females. The implication of this skewness is that it would be expected to reduce reproductive output, relative to a ratio closer to 1:1. The proportion of undersize in catches appears to have remained stable over the last 3 quota years.

Observers on board commercial vessels have recorded bycatch of other animals in giant crab traps. Most bycatch consists of one species of brachyuran crab and a species of hermit crab. These animals are returned alive apparently undamaged. Finfish are occasionally captured and are generally moribund due to the effect of pressure change on their swim bladder. No interactions with protected species were reported over the last year, although this is probably a function of reporting. A revised logbook has been drafted to address this issue.

"Byproduct" refers to bycatch from crab traps that is retained for sale. Total byproduct reported from "crab traps" is negligible (<50kg / annum total) although some byproduct reported from "lobster pots" probably originates from "crab traps". This means that we cannot separate byproduct from these two closely related fisheries. The only significant (>500 kg) byproduct from "lobster pots" reported in 2001/02 was octopus (total catch of 3.7 tonnes).

A trial to increase trap numbers from 50 to 100 was run during winter (June-August) in 2001 and 2002 with the aim of increasing the proportion of the quota taken during the period when beach price is highest. In addition, increasing the proportion of catch taken during this period would be expected to reduce the harvest of females as males form the bulk of the winter catch, while females form the bulk of the summer catch. Weather conditions and the economic viability of fishing during this period of the year play a large role in the magnitude of effort, and no trends in catch were observed for the duration of the trial. Total catch was similar to that taken prior to the issuing of special 100 trap permits. The sex ratio of the yearly catch of fishers participating in the trial included more females than males, but less so than for the remainder of the fleet. However, these fishers had a history of catches less skewed towards females prior to the issue of permits. Mean weight of individual crabs caught by fishers with permits for 100 traps was similar to that of the remainder of the fleet, which means that the total number of crabs taken per unit of quota would be unaffected.

An important concern for the resource is the movement of benthic trawling operations further inshore onto crab grounds along the west coast of Tasmania. There was a substantial increase in trawling activities shallower than 350m in 2001 – a region where very little trawl effort was expended previously. The issue is of concern on several levels including the loss of gear, restriction of fishing area, trawler bycatch of crabs, damage to discarded crabs, and habitat alteration.

In conclusion, this assessment of the resource is based on insufficient information to determine whether the TACC of 103t is sustainable in the long term. However, there is nothing in the data currently available to indicate that a decline in the fishery is occurring so the present TACC should remain until better and more information is available. Improved assessment techniques are being adopted along with the collection of a wider range of data concerning the fishery. Both of these will provide more complete assessments in the future.

Table of Contents

1. Introduction

This report is the second formal stock assessment of the Tasmanian giant crab resource and is an annual requirement of the Tasmanian giant crab management plan.

Giant crabs are taken in deeper water than most commercial crustacean species, with fishing effort concentrated around the edge of the continental shelf. The species is only found across southern Australia. Commercial exploitation was sporadic until the early 1990's due to their low market price. Commercial rock lobster fishers had identified regions with high giant crab density off Portland in Victoria by the 1880's and small numbers were marketed in Melbourne. The fishery was reassessed in Tasmania during the 1970's with the aim of establishing an industry based on picked flesh. This never eventuated due to low catches and prices.

Giant crabs collected as a bycatch to the rock lobster fishery continued to be marketed only occasionally in southern Australian States as most animals captured were discarded. The development of markets and techniques for live rock lobster enabled several processors and fishers to start developing markets for live giant crabs in 1991. This resulted in a rapid increase in price and volume of landed product so that fishers were able to target giant crab with steel traps on deeper ground than that for rock lobster. By 1994/95, catches in Tasmania had risen to 290 tonnes from less than 1 tonne in 1991 (Figure 1). Catches subsequently declined and a quota (total allowable commercial catch – TACC) of 103.5 tonnes was introduced in November 1999 as part of a new management plan for the fishery. The quota season is from March 1st through to the end of February, which is the same as for rock lobster. Other States have had a similar rise and fall in catches. The majority of the Australian catch (and TACC) is now taken around Tasmania.

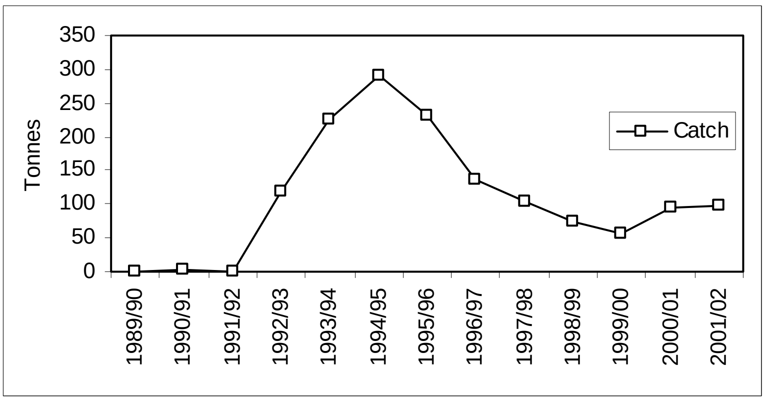

Figure 1. Historical giant crab catch in Tasmania. The Total Allowable Catch was set at 103.5 tonnes in November 1999. Catches in 1998/99 and 1999/00 were from partial fishing years due to an extended seasonal closure to allow revision of management arrangements.

The giant crab fishery is still closely associated with the rock lobster fishery with many participants shifting effort between the two species depending on catches and market price. The majority of the catch is taken by less than 10 boats specifically targeting giant crab. A few tonnes are also taken as bycatch by around 10 lobster fishers operating in deeper waters. Fishers targeting giant crab have altered their gear from traditional rock lobster gear to larger, heavier steel pots to overcome drag from the long buoy lines. Opening of other fisheries, particularly scallop, also influences effort directed at giant crab.

The giant crab industry is small by volume but valuable due to the high market price of the product. The direct value of the Tasmanian giant crab fishery is estimated to be between $3 and $4 million annually. Employment is generated in catching giant crabs and also in support of vessels through provision of fuel, boat maintenance, insurance, bait, etc. These flow-on benefits are typically a high percentage of the catch value in wild fisheries. Live holding and transport is critical for the giant crab industry and employment in processing facilities is also a significant benefit from the fishery. The integration of the giant crab fishery with the rock lobster industry assists both industries by enabling operators to improve efficiency by switching effort in response to markets.

Giant crab catch and fishing effort figures have been recorded by the industry throughout the duration of the fishery through the Tasmanian Department of Primary Industry, Water and Environment mandatory logbook program. Size-structure samples have been recorded on several occasions by Deakin University, the Tasmanian Aquaculture and Fisheries Institute (TAFI), and also by some fishers. Tagging has also been undertaken with the bulk of this work driven through Deakin University (Levings et al., 2001). Additional research has been conducted by various organisations on a range of other aspects such as larval biology, diet, reproductive biology and product handling.

A key step in giant crab assessment research was the production of a yield- and egg per recruit model in 1999 (McGarvey et al., 1999). This model incorporated data from a range of sources, primarily that described by Levings et al. (2001). This model provided estimates of the effect of different size limits on stocks under different fishing scenarios. Further development of this model is currently underway to allow a broader range of scenario testing, including different size limits for males and females (as per rock lobsters) and the harvest of non-berried females during winter.

While the model described by McGarvey et al. (1999) provided information on size limits, it was not intended to be an assessment model that would provide an ongoing measure of the state of the resource. The need for ongoing information on stock size was identified by the Tasmanian Giant Crab Fishery Advisory Committee during the process of formulating the draft management plan. As a result, a new project on the development of giant crab assessment techniques commenced in July 2001 with funding support from the Fisheries Research and Development Corporation. That project has begun to produce results that are included in this stock assessment report, but the project is not yet complete. Improvements to the stock assessment process for giant crab are expected to continue over the next few years.

2. Industry Stock Assessment Issues

Fishers interviewed through the course of the FRDC funded giant crab assessment project have identified several assessment issues that are beyond the scope of this present report. These issues are presented here as a guide for future research directions.

Fishers were asked about the incidence of crabs with black marks on their carapace from the east coast in the last 12 months. Blackening or melanization of the exoskeleton of crustaceans is a common response to a range of diseases or physical traumas (Paynter, 1989). Several fishers stated that had seen this problem, but only one fisher of the 11 who responded stated that they had seen an increase in the incidence of blackening in giant crabs.

When questioned about their opinion of the sustainability of the fishery, the majority of respondents (9) stated that they felt the fishery was sustainable at the current TAC. Three fishers were unsure and one was contemplating exiting the fishery as they considered it unsustainable. Several noted their concerns with habitat damage through trawling activities. Many giant crab fishers, particularly on the west coast, have observed increased activity of trawlers with many boats working ground fished by crab fishers. Industry is concerned that this trend is leading to gear interaction problems and may also affect giant crab habitat. Benthic video surveys appear to be an option for assessing this issue.

Most of the fishers interviewed stated that they had observed large numbers of small juveniles for the first time in the 1999/00 and 2000/01 seasons (Table 5, page 18). Many exploited crab populations have large variation in recruitment with occasional strong recruitment pulses. Sainte-Marie et al. (1996) considered these pulses to be a function of cannibalism with the reduction in biomass of larger crabs through fishing leading to pulses of recruitment. These cohorts of strong recruitment then act to suppress future year classes until they also enter the fishery and are fished down. A similar scenario is feasible with giant crab given that their natural diet has been shown to include smaller giant crabs (Heeren and Mitchell, 1997).

Both industry and management have identified the need to improve on our ability to evaluate alternative harvest strategies. Specific issues include the simulation of alternative TACs and methods to shift catch to higher value months. An example of this latter issue is the ability to evaluate the effect of permitting harvest of non-berried females during winter months.

3. Fishery Assessment

As noted earlier, this fisheries assessment report is the second to be conducted for the Tasmanian giant crab resource; information and analyses contained within the report are expected to improve over the next few years through research conducted with FRDC assistance on giant crab assessment techniques. In the last assessment report it was noted that error existed in the catch and effort data for a range of reasons. This has been a focus of our effort over the last year. As a result, our interpretation of change in catch rate in the fishery is quite different in this report to that presented last year.

Data is generally presented for years divided as per the current quota year: March to February. While this report relates specifically to the 2001/02 season, more recent data is included where possible. Although this will be for an incomplete quota year, it is of value for assessing the current status.

This report was prepared with industry and management consultation, however, there was no formal discussion with these groups in a stock assessment working group. The creation of a Giant Crab Stock Assessment Working Group is planned for review of the next assessment report.

Research currently underway will also result in changes to the next assessment report including: (a) the standardisation of catch rate to correct for biases from non-normal distribution and changes in fishing patterns; and (b) the development of the framework for stock assessment modelling.

3.1 Evaluation of trigger points

3.1.1 Catch per unit effort

The giant crab management plan defines two trigger points relating to catch per unit effort (CPUE):

- When CPUE for the state declines for two consecutive years;
- When CPUE for any region declines by a total of 20% in two years.

The data used in this analysis is drawn from commercial logbooks and has changed since the start of targeted giant crab fishing in 1992. Logbook data prior to January 1995 does not include a measure of effort (as number of traps) so that data cannot be used for calculation of CPUE.

From 1995 to 1999, giant crab data was stored in the general fish database and effort was recorded as the number of traps and the duration of deployment (soak time). Although this allowed the calculation of effort, no record was made whether fishers were targeting giant crabs or simply retaining bycatch while lobster fishing. CPUE would be expected to be quite different in these two cases.

In the previous report, we attempted to identify when fishers were targeting crabs by using data where the gear type was recorded as “crab trap” rather than “lobster pot”. This solution was clearly inadequate as only a small proportion of the reported catch was taken by “crab trap” (around 10%). From November 1999 onwards, fishers were asked to specify if they were targeting lobster or crab. We have used this information to develop rules for splitting historical catch data (1995-1999) into “targeted” and “non targeted” (based on factors including depth fished, soak times, catch of lobsters and fisher).

Other adjustments to catch and effort data include the identification and correction of errors from a range of sources such as data entry, or reporting of catch in numbers rather than weight. In more recent data, it has been possible to compare catch records recorded through the logbook system with those recorded through quota monitoring. Substantial changes have been made to the measures of effort in historical records, which has subsequently affected calculations of catch rate. These changes include correcting pot number where fishers have advised that they were using more traps than authorised under their permits. Records from some vessels were consistently erroneous. Where it was not possible to correct these, they have been excluded from calculations of catch rate (but not total catch).

Note that fishing practices for giant crab differ from that of lobsters as gear is generally set for periods of several days when targeting giant crab. To account for variability in soak time, catch rates are standardised to catch per 24 hours soak time (this assumes that there is no saturation of traps and that the presence of crabs in a trap does not influence entry of additional animals).

Statewide trends in CPUE

Seasonal patterns in statewide catch and effort data have become clearer since the process of database correction has been completed (Figure 2). These observations support the changes made through database correction as catch rate calculations now appear to better reflect changes in the fishery. Among changes more apparent are the higher catch rates during summer months. This affects the interpretation of annual changes in statewide catch rate because fishing seasons in 1998/99 and 1999/00 were incomplete. The 1999/00 season only lasted from November to February and did not include any winter months. The seasonal patterns in catch rate imply that this restriction has lead to estimates of annual catch rate that are biased higher for the 1999/00 season. As a result, the inclusion of winter fishing in the following year would be expected to lead to reduced catch rates, regardless of any change in the abundance of stocks.

Absolute values of statewide catch rate have changed since the last assessment report although the inter-annual trend is largely unchanged (Figure 3). Catch rates have declined since records became available in 1995, although they appear to have been stable between 2000/01 and 2001/02.

Last year, the trigger point that related to the statewide CPUE was breached, that is, statewide CPUE had declined for two consecutive years (Figure 3). This year, the catch rate has stabilised relative to the previous year - thus the trigger point is no longer activated.

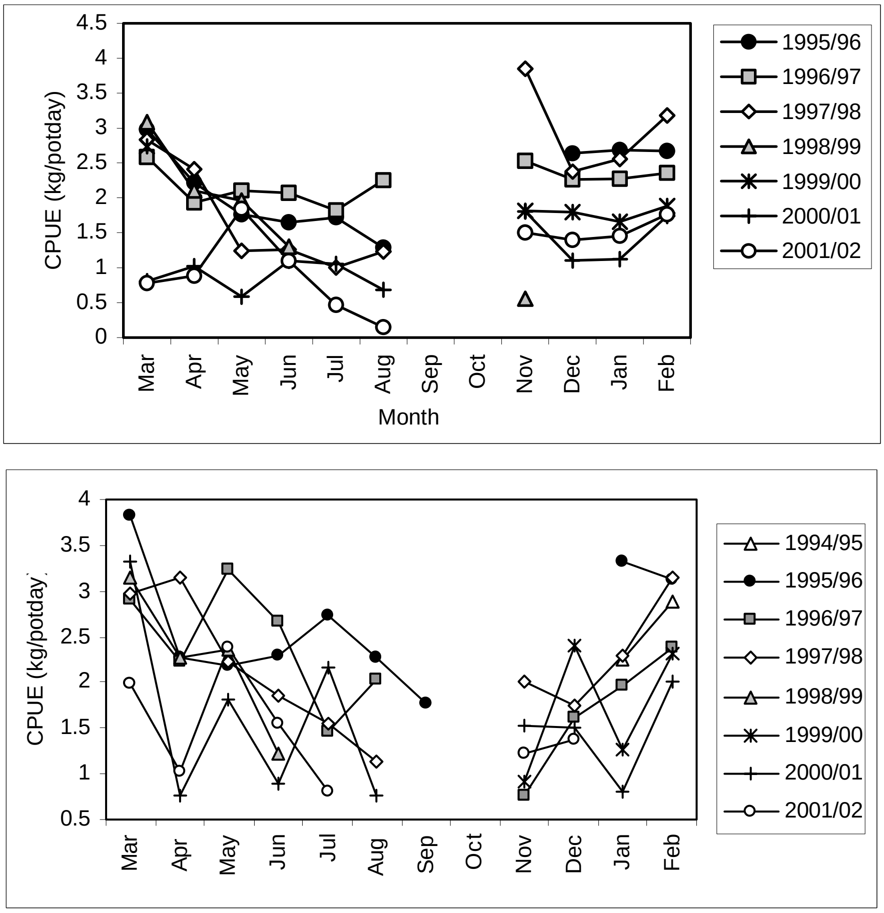

Figure 2. Seasonal patterns in CPUE since 1995. The upper plot shows values from data after correcting for database errors as described in text. The lower plot shows the same information, but generated with the catch and effort data available for the previous giant crab assessment. Note that the process of correction of errors has improved the signal to noise ratio – so that seasonal patterns more indicative of the biology of giant crabs have become apparent. For example, catch rates in November now appear higher, which is consistent with the opinion of fishers.

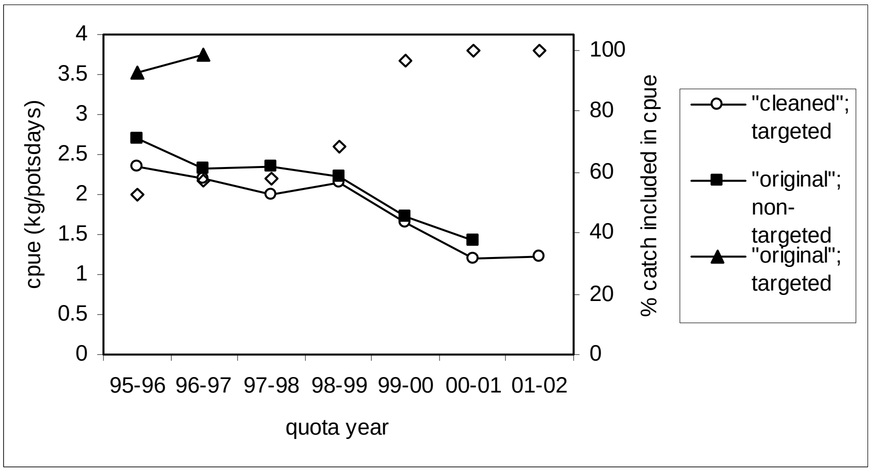

Figure 3. Trends in annual catch per unit effort statewide since 1995/96. Four sets of data are shown. Two are the "original" trends in catch per unit effort statewide as shown in the last stock assessment report (solid triangles and solid squares). These were split into data from fishers "targeting" crabs and "non-targeting" based on their recorded being "crab traps" or "lobster pots" respectively. Data was corrected over the last year and is plotted here as "cleaned" data for only those records where fishers were targeting crabs (based on depth, soak time and fisher; hollow circles). During the process of "cleaning" the data, some records could not be corrected and were excluded. The percentage of useable catch data that contributed to the corrected plot are shown by the hollow diamonds.

Figure 4 shows the frequencies of catch rates of individual records for each year since 1995. This figure is important in understanding the pattern of change in statewide CPUE for two reasons. First, the distribution of these data is clearly non-normal, which implies that the statewide values of CPUE presented here may be biased as they are calculated by arithmetic mean (that is, total catch divided by total effort). This bias is confirmed by a Q-Q plot of the residuals where the fit using arithmetic means is extremely poor (Figure 5). Research underway over the next year is directed to providing an improved system for tracking changes in time in CPUE that is suited to data with this type of distribution. Secondly, note that there is a clear pattern of change in the shape of these distributions through time; distributions become shifted to the left which implies reduced catch rates.

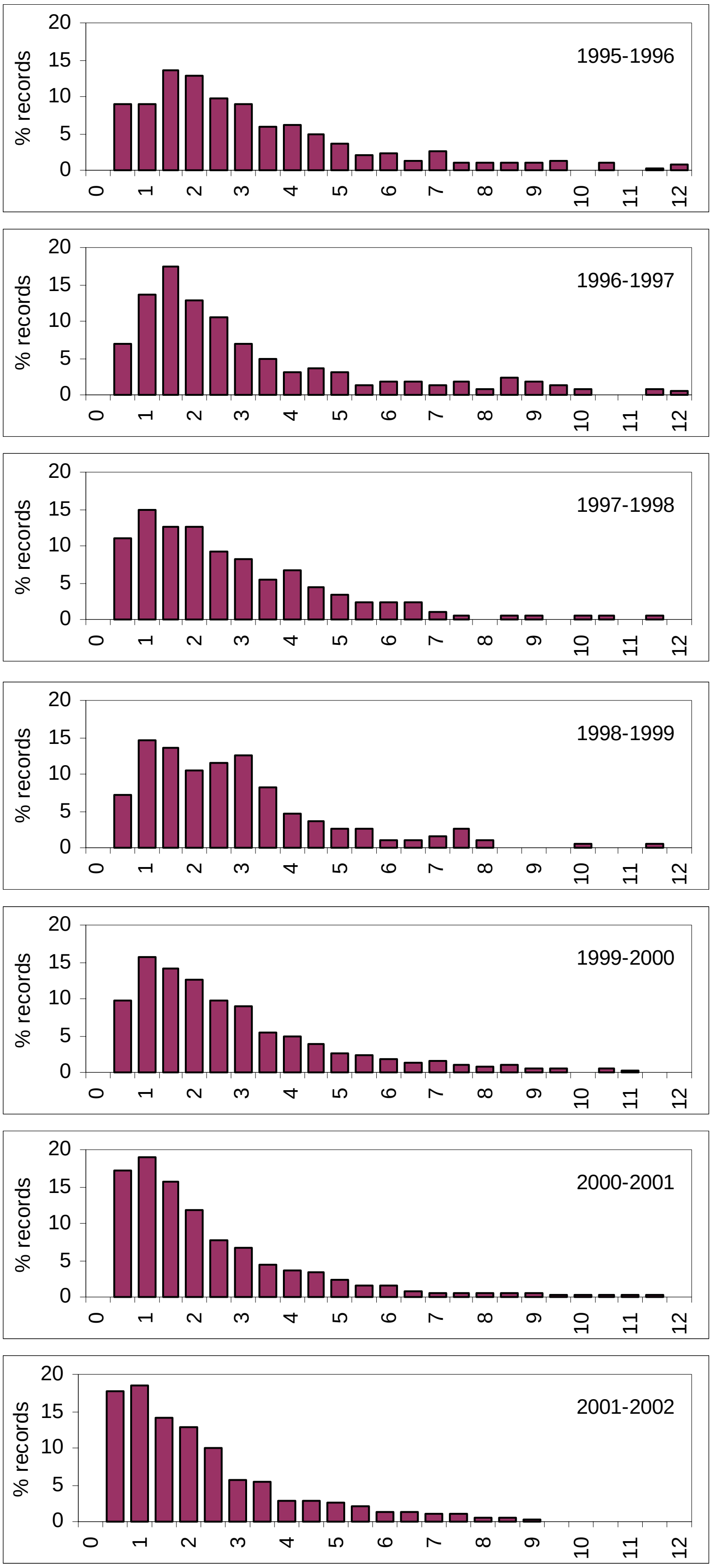

Figure 4. Frequencies of catch rate (x-axis; kg/potday) for individual records in fisher log book returns (split by quota years). Note that the distribution of these is not normal, which implies that the arithmetic means of catch rate will be biased. Also note that the distributions are shifting to the left through time, which indicates a shift towards lower catch rates. Frequencies of catch rates of zero crabs per shot are excluded.

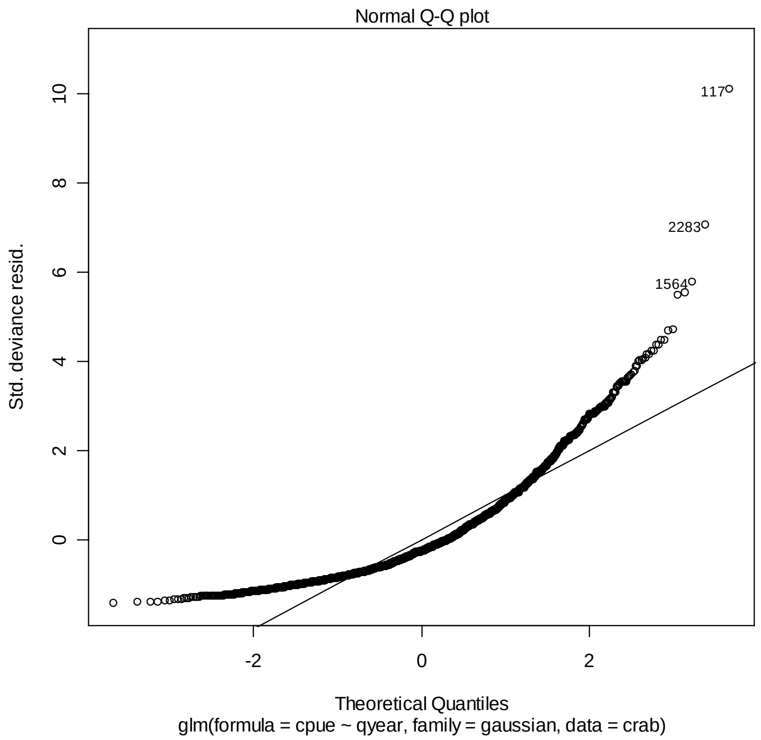

Figure 5. Distribution of residuals of catch rate (CPUE) data obtained by arithmetic mean by year (that is, total catch/total effort). The distribution of these residuals is curved, rather than straight, which indicates a poor fit from the arithmetic means. This implies that the performance indicators based on arithmetic means may not truly reflect changes in the fishery – work to address this problem by standardisation is underway and will contribute to the next stock assessment.

Regional catch rates

The second trigger concerning catch per unit effort (CPUE) relates to each of the 8 stock assessment regions as used for the rock lobster fishery (Figure 6). This trigger is stated as "CPUE for any region declines by a total of 20% in two years". Data is shown for only areas 2 to 7 as very little catch was reported for areas in the far south: 1 and 8. Catch rates for the year 1999/2000 are based on only a small amount of data due to the protracted fishery closure prior to the implementation of QMS. Consequently, care should be taken in interpreting data for this year.

Reported CPUE is highly variable between years with no clear pattern between regions (Figure 7). The trigger point of a total decline in CPUE of 20% in 2 years was breached in each assessment area except area 7 where catch declined by only 18% (Table 1). As noted earlier, the fishing season in 1999/00 was incomplete so this 2-year comparison is of limited value in 2001/02. Changes in catch rate since 5 years ago are strongly negative in all areas except area 2, where insufficient data is available for a valid comparison. Regional changes in catch rate for the last year is mixed, with declines seen in only 3 of the 6 assessment areas (4,5 and 7).

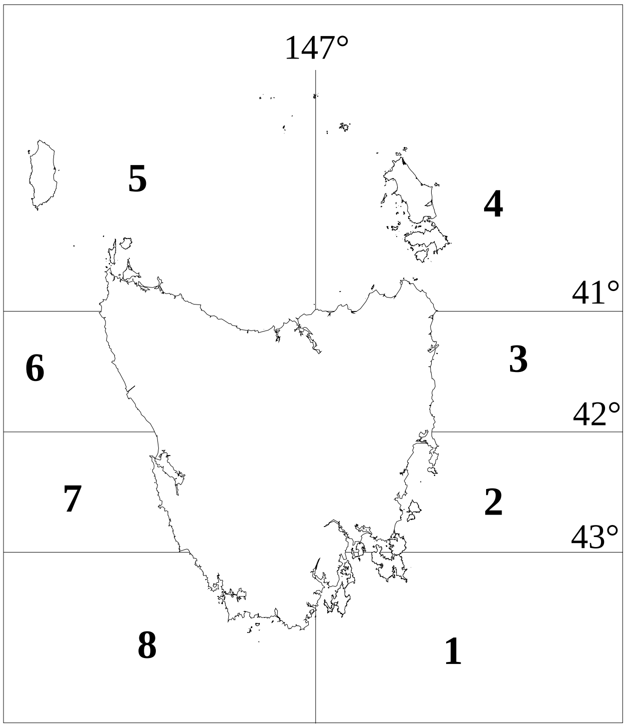

Figure 6. Regional stock assessment areas used for evaluation of regional catch rates. These are the same as those for rock lobster assessment.

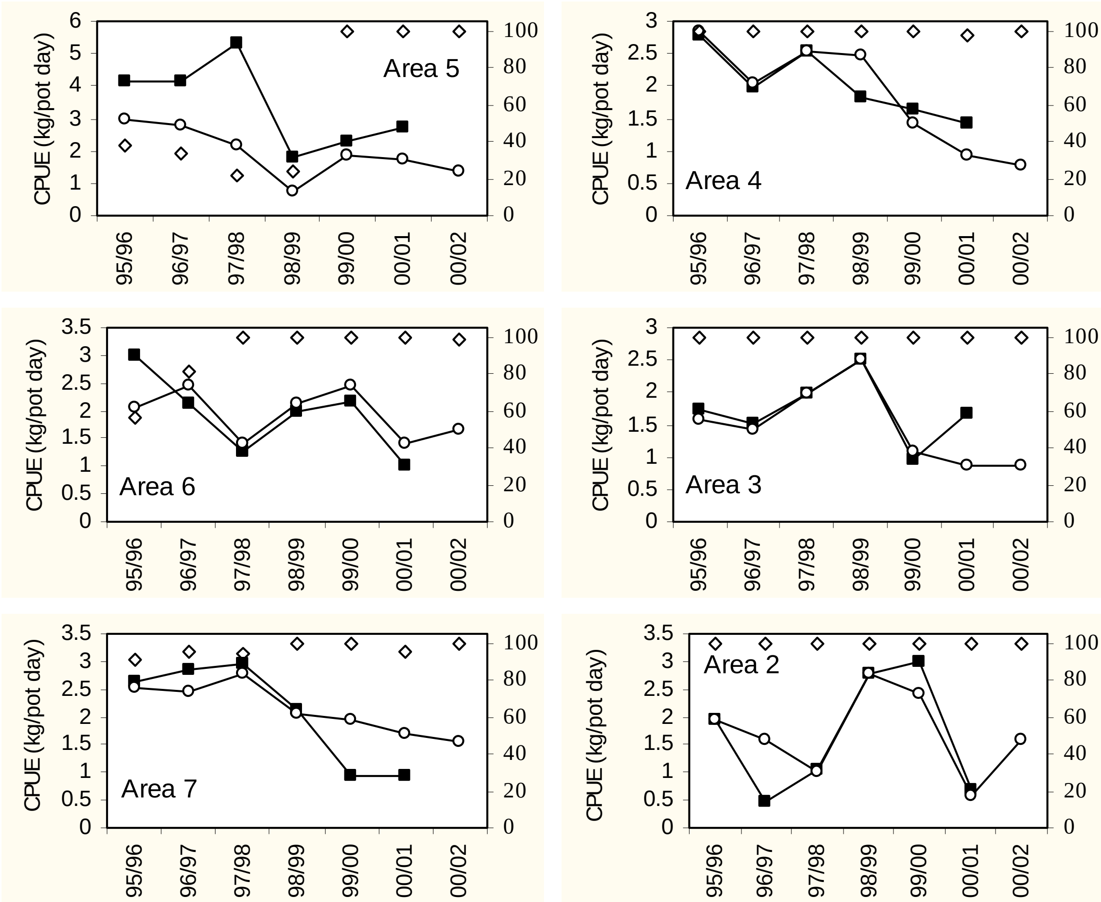

Figure 7. Trends in catch per unit effort (CPUE) from each of the 6 main assessment regions. Years are split by quota years (March –February). Effort is pot days. Each plot shows the CPUE trend as shown in last year's assessment report (black squares) and the corrected catch rate values as calculated for this year's assessment (hollow circles). In the process of correcting these data, some records of catch were associated with records of effort that could not be corrected; these data were excluded. The percentage of total catch data that was useable and could be incorporated into CPUE calculations are shown by the hollow diamonds measured against the right axis.

Table 1. Catch per unit effort (CPUE) in each assessment area for the 2001/2002 quota year relative to CPUE 5, 2 and 1 year ago.

Area	CPUE 96/97	CPUE 99/00	CPUE 00/01	CPUE 01/02	% Change 5 years	% Change 2 years	% Change 1 year
2	0.79*	2.42	0.59	1.58	101*	-35	168
3	1.23	1.09	0.87	0.87	-29	-21	0
4	2.02	1.36	0.91	0.77	-62	-43	-15
5	5.10	1.88	1.71	1.38	-73	-27	-19
6	2.47	2.46	1.40	1.64	-34	-34	17
7	2.22	1.89	1.69	1.55	-30	-18	-8

- Insufficient data was available for area 2 from 5 years ago (1996/97) so data shown here for comparison is from 4 years ago (1997/98).

3.1.2 Total annual commercial catch

Two triggers are based on the total annual commercial catch:

- The total yearly catch is not less than 90% of the TAC in any year;
- The bycatch of giant crabs taken by lobster fishers does not exceed 5 tonnes in any year.

Total yearly catch

Catch weight of giant crab is recorded at several stages, at the time of capture in commercial logbooks, at the time of landing through the quota audit system, and also by processors. Data presented here is from the quota audit system and the processors.

Total catch for the first quota year under the Tasmanian giant crab management plan (1999/00) was considerably less than the TAC of 103.5 tonnes because this quota year was abbreviated to run for only 4 months (Table 2). The weight of giant crab recorded by processors was less than that recorded through the fishers quota records in 1999/00 and 2000/01 but similar (58 kg) for 2001/02. This information from processors would be expected to underestimate total crab catch but is a useful second source of data on catch in that it provides a minimum estimate. The similar estimate of catch from both processors and fishers in 2001/02 indicates that all crab catch is now being recorded through these systems.

Total catch weight for the 2001/02 season was in excess of the 90 tonne trigger and thus does not indicate cause for alarm.

Table 2. Total catch of giant crab for quota years since introduction of the TAC. Catches recorded by fishers through the quota monitoring system are recorded as “QMS”. A secondary source of information on total catch is that reported by processors. These processor data provide a minimum estimate of catch as some animals harvested may not be recorded here.

Year	QMS Total catch (kg)	QMS Total N	Mean weight (kg)	Processor weight (kg)
1999/00	53054	16394	3.24	43938
2000/01	96226	28627	3.36	85588
2001/02	98188	27268	3.60	98246

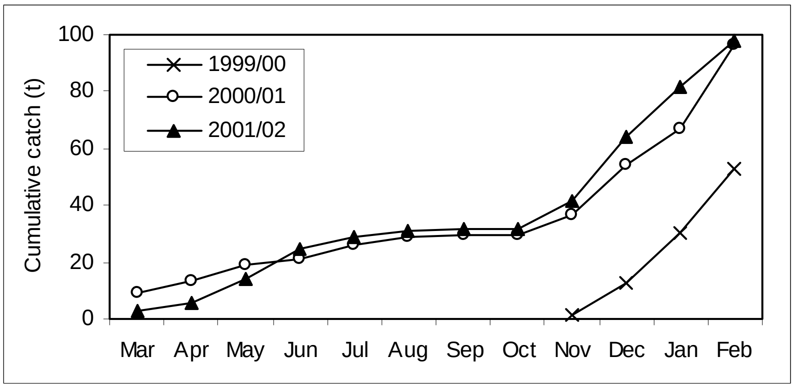

Figure 8. Cumulative catch by month for each quota year since introduction of QMS in 1999. Total catch exceeded 90 tonnes in each of the full quota years.

Catch taken as bycatch

Giant crabs can be captured by a range of methods that fall outside the giant crab quota management system. Crabs can be captured in standard rock lobster gear, and provisions in the management plan allow for the landing of a small number of crabs as bycatch. The management plan includes a performance indicator that relates solely to bycatch taken in rock lobster pots.

Fishers have also reported capturing giant crabs using set nets, baited hooks and trawl.

Reported giant crab catch taken by all gear types managed by the State of Tasmania are small relative to catches from crab traps with catches exceeding 100 kg only for graball nets in 1997/98 and shark nets from 1995/96 to 1997/98 (Figure 9). In 2001/02, only 5 kg of catch was reported from a fish trap, which was the only reported catch from a gear type other than a crab trap or lobster pot.

Several fisheries managed by the Commonwealth through the Australian Fisheries Management Authority (AFMA) also appear to catch and retain giant crab, although the species of crab is not generally recorded in this data. Bottom longline, dredge and gillnet fisheries from within the area bounded by 143 to 149 longitude and 39.12 to 44.5 latitude all report catches of “crabs”. Total retained catch of “crabs” by each of these methods was no more than 170 kg in any one year (Figure 10).

Total weight of retained crab species taken by Commonwealth managed trawl is more substantial with total catch in excess of 2 tonnes for each year over the last decade (Figure 11). Although catch by trawlers is simply reported as “crab”, it is possible to estimate the portion of this that was actually giant crab from data collected through observer programs from 1993 to 1997. Records from this program show that 55% of the crabs retained by trawlers from western Tasmania were giant crab while 85% of the crabs retained from eastern Tasmania were giant crabs. This information was collected from a small sample of a highly variable industry so it provides only a general guide. Nonetheless, the observer data shows that trawlers retain giant crabs and that catches are of sufficient magnitude to warrant continued monitoring in stock assessments.

Total bycatch of giant crabs taken by lobster fishers who did not hold giant crab quota is shown in Table 3. Reported bycatch of giant crab reached 1100 kg in 2000/01 but was only around half that amount (650 kg) in 2001/02. Bycatch of giant crab has been less than the trigger point of 5 tonnes in each year since the introduction of the management plan. Thus, this trigger has not been activated.

Table 3. Giant crab bycatch taken by lobster fishers without giant crab quota.

	Giant crab bycatch (t)	% of total landings
1999/00	0.87	1.61
2000/01	1.11	1.14
2001/02	0.65	0.66

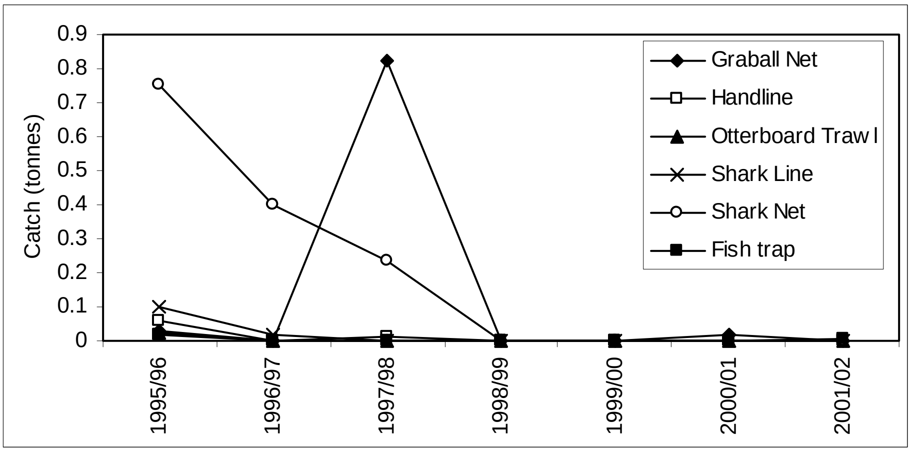

Figure 9. Giant crab catch reported through Tasmanian State managed fisheries for gear types other than giant crab traps or lobster pots.

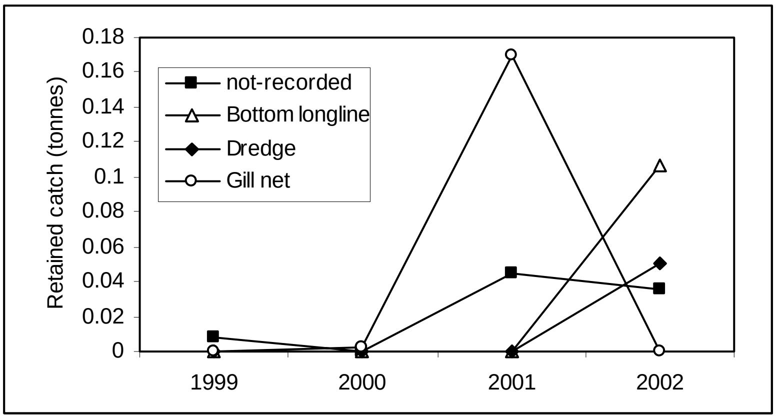

Figure 10. Grouped crab catch reported through Commonwealth (AFMA) managed fisheries for gear types other than trawl. Giant crabs are not differentiated from other crab species in this data so these retained catches may include other species such as spider crabs (Majidae) and king crabs (Lithodidae). Data for 2002 is for a partial year only.

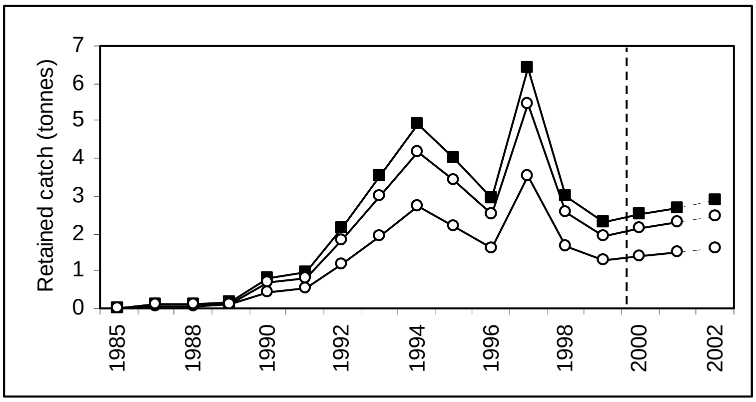

Figure 11. Grouped crab catch reported by commonwealth (AFMA) managed trawlers (solid squares). Crab catch in these data are not differentiated into different species so catches of species other than giant crab may be included here (such as spider crabs (Majidae) and king crabs (Lithodidae)). Observer data from trawlers operating in Tasmania provides some guide to the proportion of the catch that may be giant crab; the total catch of giant crabs by commonwealth managed trawlers is estimated to lay between the two lines marked by hollow circles that represent catch scaled by the proportion of giant crabs in the catch from eastern (85%) and western (55%) Tasmania, as recorded by observers. Catches prior to 2000 were recorded in the old South-east Trawl Database with less precision than recent data. Data for 2002 is for a partial year only.

3.1.3 Size distribution of the commercial catch

The size distribution of the commercial catch provides a guide to changes to the population as a result of fishing mortality and recruitment pulses. Information on size distribution is obtained from several sources including:

- voluntary measuring of catch (including undersize) by commercial fishers;
- mean weights from estimated catch and number data in commercial log books;
- mean weights from measured weight and number in quota audit data; and
- weights of crabs sold into different price category splits.

Trigger points in the current management plan relate to only the last of these with two triggers listed:

- The proportion of the catch above 5kg varies by more than 30% compared to the 1996/97 distribution;
- The proportion of the catch below 3 kg varies by more than 30% compared to the 1996/97 distribution.

The proportion of crabs falling in small (<3 kg) and large (>5 kg) size splits from sales of fishers to processors are shown in Figure 12. These data were drawn from information collected from both processors and fishers, with the majority of data originating from fishers who tend to work on the west coast. Note this data set does not include all crab sales, rather only those that can be obtained voluntarily from either fishers or processors (Table 4).

Table 4. Proportion of total landed catch included in analyses of processor size-split categories.

Year	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02
%	12.4	23.5	34.2	34.1	27.8	17.4	72.3	14.9

Comparison of the proportion of the size split in each category relative to the reference year of 1996/97 is shown in Figure 13. Both these triggers were activated for the previous 3 years but not in 2001/02. This measure appears to be quite unstable with the trigger activated in different directions in previous years.

Note that the individual fishers that are included within these samples influence conclusions, and proportion of the total catch included in data sets over the last year is low. The need for a large data set is illustrated in Figure 14. A solution to this problem may be the mandatory reporting of crab weight splits by processors as part of normal returns.

Although no trigger point relates directly to data on the mean size of landed crabs collected through the quota audit process, these are useful for observing patterns in the size distribution of the population. Figure 15 shows the mean monthly weight of landed crabs since the introduction of QMS in 1999. No trend is apparent in these data, which suggests stability in size structure of the landed catch.

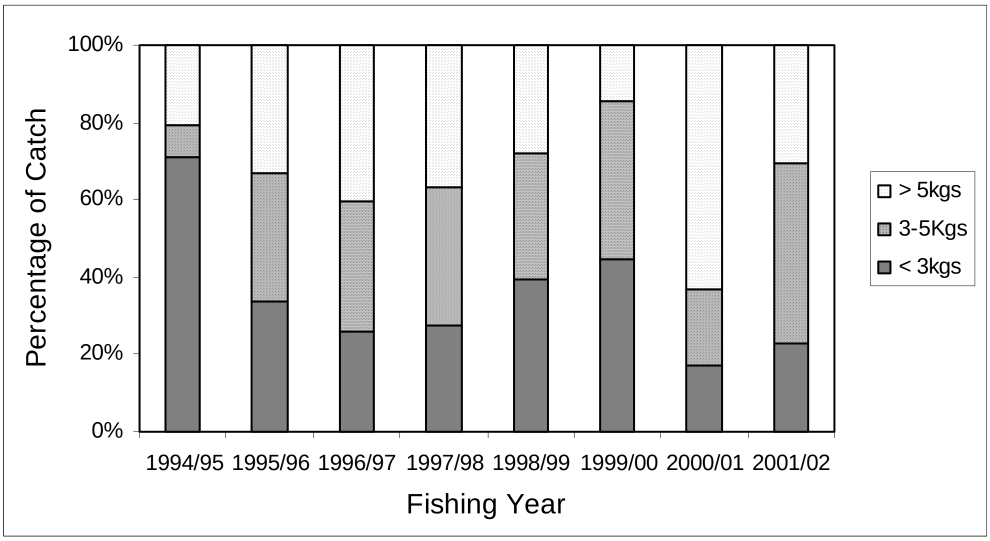

Figure 12. Proportions of commercial processor size-split categories in the landed catch.

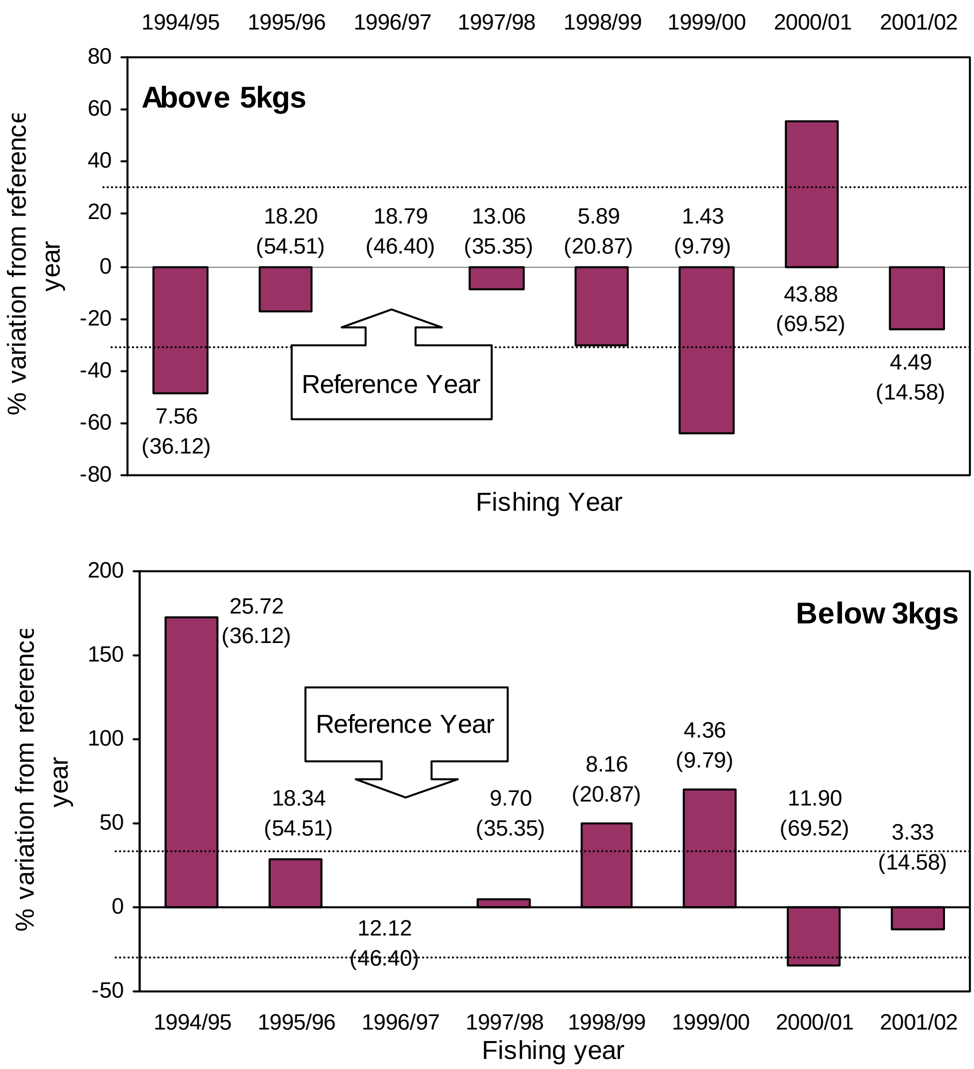

Figure 13. Percentage difference of the proportion of the catch in large or small size splits relative to the reference year of 1996/97. Total weight of catch in each size split is shown next to each column, with the total catch weight that data is available for in parentheses. Dotted lines represent 30% differences.

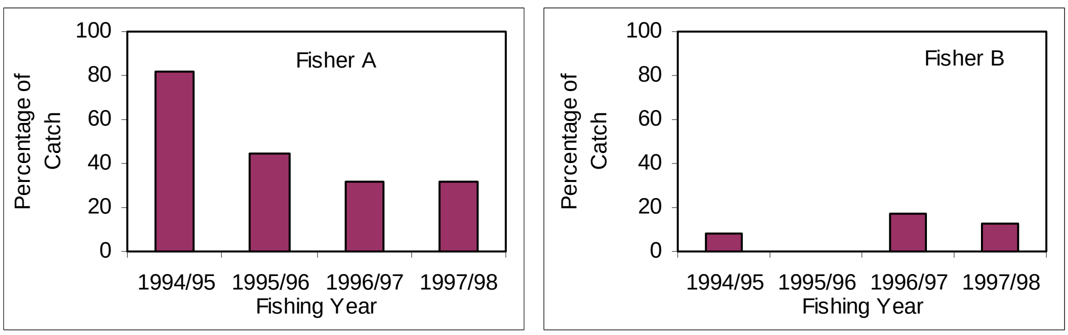

Figure 14. Comparison of the proportion of the catch of two different fishers falling in the <3 kg size bin. This highly variable catch composition between different fishers implies that grouped data may be biased by the fishing patterns of individual fishers. This risk is reduced by increasing the size of the data set, with bias and precision improving as the proportion of the total catch sampled increases.

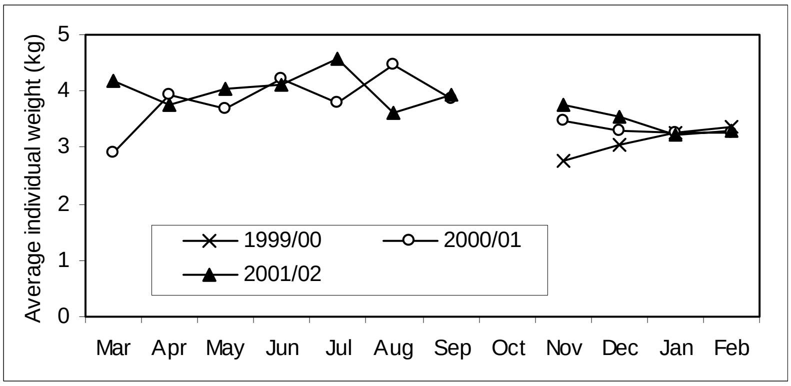

Figure 15. Average weight of crabs landed by month for each year since the introduction of quota management. These data are drawn from numbers and weights reported through the quota audit process.

Fishers were also interviewed over the last year to gain their impression of changes in the fishery and stocks. A part of these interviews focused on changes in size structure in broad categories of under-size, legal-size, over-size and damaged (1-armed) animals. As these data are based on recollections, the time period of recalled changes tends to be imprecise so they were asked to describe broader changes. Their responses indicated a decline in the abundance of legal sized animals since quota was introduced compared to earlier years. Many reported an increase in the abundance of undersized animals and some also reported an increase in one-armed animals.

Table 5. Fishers impression of change in the abundance of size groups in catches 2001/02 compared to pre-quota. Fishers responses were recorded by interview and includes only those fishers targeting giant crabs.

	much less	less	same	more	many more
Abundance of legal sized animals		5	5		
Proportion of undersize animals			6	3	3
Proportion of oversized animals	1	1	7	1	
Proportion 1-armed animals			7	2	

3.2 Other analyses

3.2.1 Bycatch

Information on bycatch species taken by crab fishers will be recorded as part of catch sampling conducted for the FRDC funded projected on the development of giant crab assessment techniques. Bycatch data were presented in the previous stock assessment report. In summary, that report noted that few species were recorded as bycatch with the most numerous being the antlered crab *Paromola petterdi*. Hermits crabs (*Strigipagurus strigimanus* and *Dardanus arrosor*) were the next most common species followed by pink ling *Genypterus blacodes*. All hermit crabs and over 90% of antlered crabs were observed to be released apparently unharmed. These animals do not contain air spaces and thus show no apparent effect of the pressure change experienced during hauling to the surface. In contrast, finfish bycatch was moribund.

3.2.2 Byproduct

Byproduct differs from bycatch in that it is retained for sale. Information on bycatch is collected through the general fish log book and can be traced back to giant crab fishing where the fisher specifies their gear type as “crab traps”. Crab fishers have reported very little byproduct since recording commenced in 1995. The only byproduct type recorded from crab traps is octopus, with less than 20 kg recorded in 98/99 and 99/00 (Figure 16).

The distinction between crab traps and lobster pots is ambiguous and it is probable that some crab fishers recorded byproduct but reported their gear type as lobster pots. Byproduct from lobster pots is generally low with total catches of most fish species less than 500 kg per annum from the entire lobster fleet (Figure 17). Cod catches have declined from a peak of 3 tonnes in 1996, which is most likely due to the reduction in market acceptance of this low-quality species. Octopus form the bulk of byproduct from lobster pots but no clear trend is evident from records of this byproduct type.

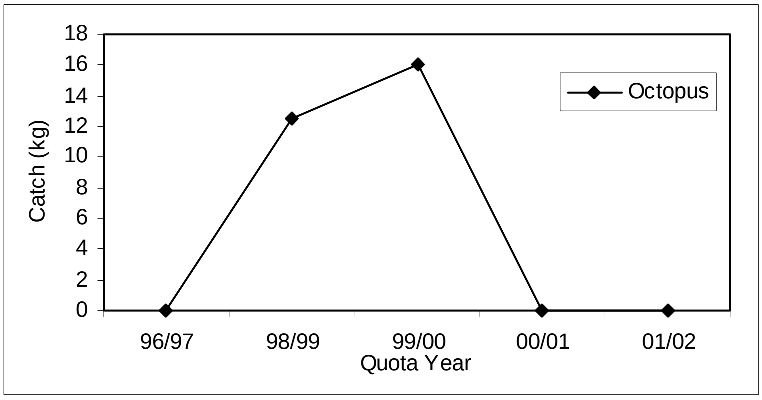

Figure 16. Byproduct reported from fishers using “crab traps”. The only reported byproduct type was octopus and this was only recorded in 2 years since 1995. The distinction between “crab trap” and “lobster pot” gear types is ambiguous so some bycatch from crab fishing operations may not be shown here.

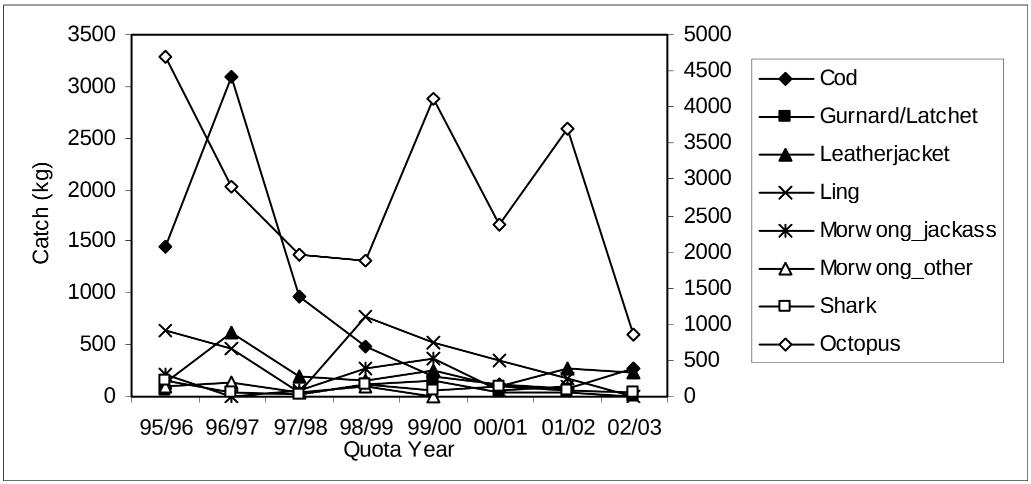

Figure 17. Significant (>100 kg in any one year) byproduct reported from rock lobster pots, January 1995 to August 2002. Data is grouped into quota years (March to February) so annual catches are incomplete for the 1995/96 and the 2002/03 quota years. Values for catches of octopus are shown on the right-hand axis of the lower plot, all other species are shown at left.

3.2.3 Protected species interactions

No interactions between fishers and protected species were reported over the last year, although this information is currently collected in an ad-hoc manner by encouraging fishers to report interactions. Benign interactions with seabirds and other protected species have inevitably occurred during this period, but have not been reported. To assist with data collection on this issue, a revised logbook has been drafted which includes a component on protected species.

3.2.4 Trial of increased trap numbers in winter

A trial evaluating the use of increased traps during winter was undertaken during 2001/02 and has been repeated in 2002/03. This was done under special permit with 5 issued in the first year and seven issued in the second. Permit holders were allowed to fish 100 traps during June, July and August 2001, rather than the standard 50 traps. The aim of these permits was to allow fishers to take more of their quota allocation during the period when prices are higher.

Total catch by fishers with the special permits did not appear enhanced relative to catches in 2000 when no permits were issued (Figure 18). Fishers report that weather conditions tend to have a greater impact than pot number on the total catch during winter months. Although catch during winter did not increase dramatically as a result of these permits, it is logical that under different weather conditions, doubling the number of traps during winter must lead to an increase in catch during this period. Under a quota management system, this should not lead to a change in the total number of crabs harvested. However, it may lead to a shift in the sex ratio of the total harvest, or the mean size of animals harvested.

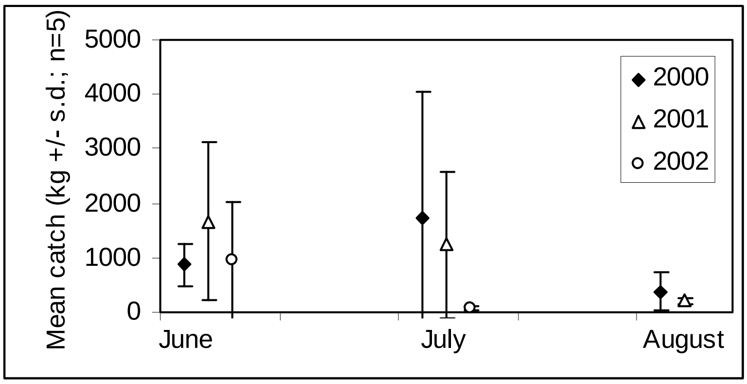

Figure 18. Catches for the vessels fishing with special permits for each year since the introduction of quota management. The permits allowed the use of an additional 50 traps during the months of June, July and August in 2001 and 2002; no permits were issued in 2000 so this serves as an index.

The number of animals harvested varies seasonally, with most animals being harvested in summer. The sex ratio of these catches also varies with season with females forming the bulk of the summer catch, and males forming the bulk of the winter catch (Figure 19). This suggests that the use of special permits to increasing fishing during winter months should act to increase the harvest of males, and reduce the harvest of females. That is, the 100-pot special permits would be expected to act to conserve egg production.

Actual sex ratios of the catch from the fishers with special permits support this hypothesis with their catches tending towards a more even 1:1 split between males and females than the rest of the fleet (Table 6). Note however that these individuals had a tendency to harvest more males than the rest of the fleet even in 1999/00, before the issuing of 100-trap permits.

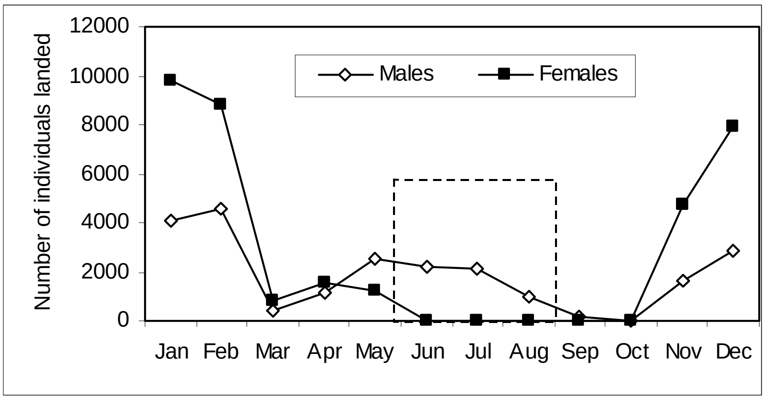

Figure 19. Seasonal changes in the number of males and females harvested (data is pooled for 2000 and 2001). The period during which the permits for the use of an additional 50 traps is marked within the dashed box. Males form the bulk of landings during this period.

Table 6. The ratio of males to females in harvests of giant crab by fishers with a portion of their quota taken under special permit to use 100 traps.

The ratio shown is males to females, so a ratio of 0.5 equates to 1 male captured for every 2 females, and a ratio of 0.66 equates to 2 males captured for every 3 females. Standard deviation is shown in parentheses for holders of the 100 pot permits (n=5). No permits were issued in the first two years shown so these serve as indices.

	Sex ratio	
quota year	whole fleet	100 pot permit holders
1999/00	0.38	0.56 (0.27)
2000/01	0.69	0.82 (0.51)
2001/02	**0.67**	**0.92 (1.39)**

If the sex ratio of the total catch taken by fishers with 100-trap permits varies from that of the rest of the fleet, then this may also influence the mean size of crabs harvested as males grow larger than females. Under a quota based management system, an increase in the mean size of animal harvested equates to a reduction in the total number of animals harvested. The mean size of animals harvested by fishers with the 100-trap permits and the remainder of the fleet was similar for the last 3 quota years (Figure 20).

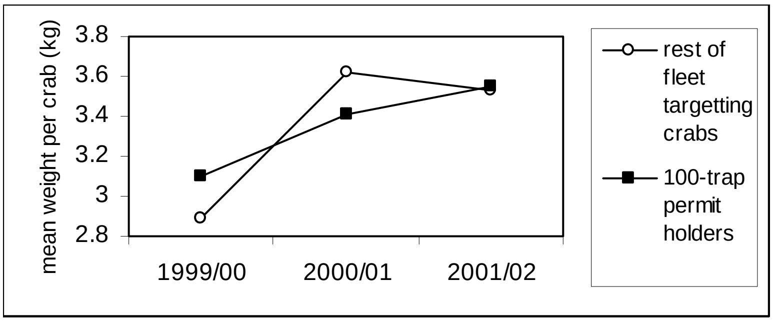

Figure 20. Mean weight of crabs harvested by fishers with special permits to use 100 traps compared to the remainder of the fleet (excluding catches where crabs were not targeted). No permits were issued in 1999/00 so this serves as a reference. The minimum legal size of a giant crab equates to around 2.8 kg – the origin on the y-axis.

In conclusion, the use of increased trap numbers has not had any clear impact on the magnitude of catches taken by crab fishers over the 2 years of the trial. This is presumably due to other factors such as weather; at some stage, greater effort must lead to higher catches than would have been taken otherwise. Under quota management, the main issue with the increased trap numbers during winter is - what effect does this have on the composition of the catch? As the sex ratio of the catch in winter is skewed towards males, we would expect the use of increased traps during this period to increase the proportion of the catch that is male, and thus reduce the proportion that is female. This should be a positive effect given that the harvest at other times targets females disproportionately. Female crabs tend to be smaller than males, so shifting effort towards males will reduce the total number of crabs harvested.

3.2.5 Spatial distribution of catches

The spatial distribution of effort is shown in Figure 21. The majority of the effort is directed north of 42ºS, although fishing grounds extend south of this into Area 7 on the west coast and Area 2 on the east coast. Spatial distribution of catch is shown in Figure 22. Spatial distribution of catches in the first year of quota management was quite different to that of later years, presumably due to the restricted season (November to February). Distribution of catch in the last two years of quota management have been similar, although there appears to have been some shift away from area 3 (E) to area 4 (NE) and area 2 (SE) between 2000/01 and 2001/02.

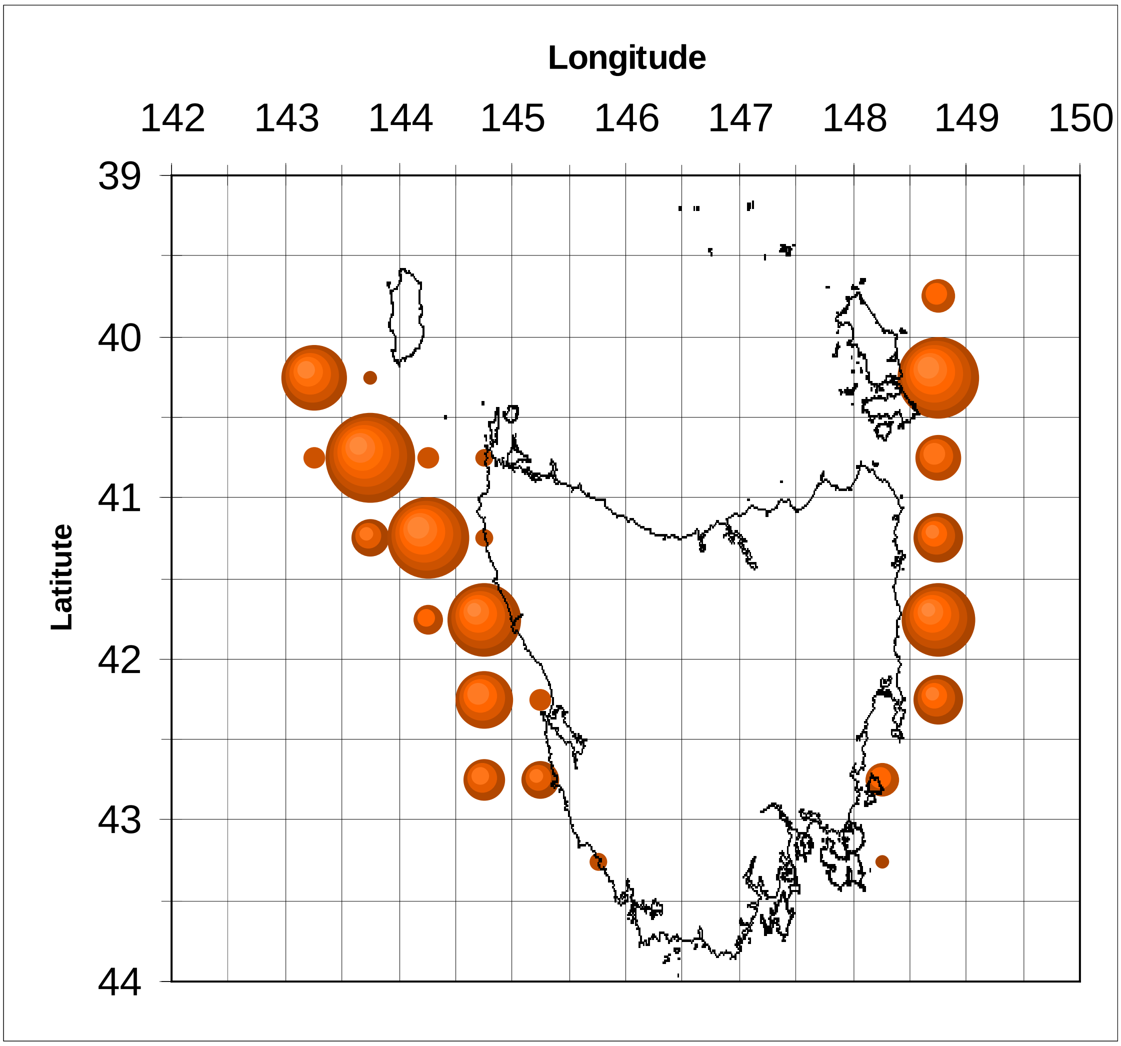

Figure 21. Spatial distribution of effort of fishers targeting crabs from 1999 to 2002; larger circles denote greater effort. Effort is measured as number of shots and grouped by assessment blocks.

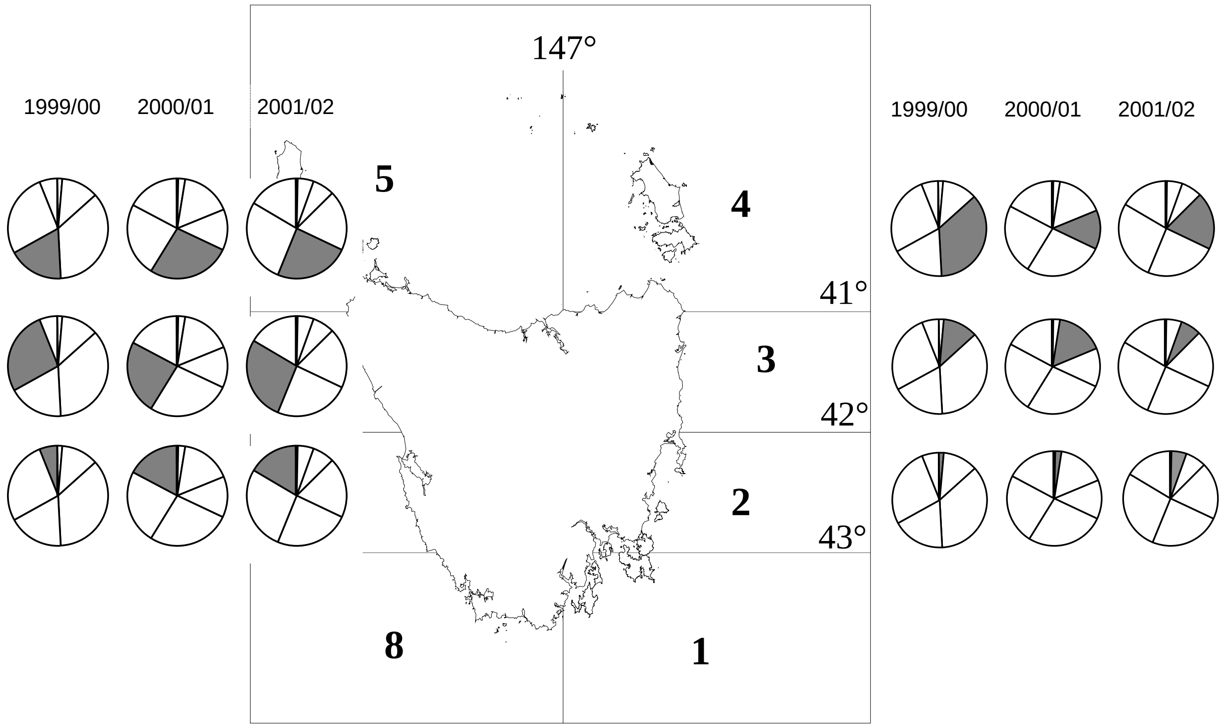

Figure 22. Distribution of legal-sized, retained catch between assessment areas (as percentage of total number of animals taken around the State). Catch from areas 1 and 8 represent less than 1% of total catch.

3.2.6 Structure of catches: proportion undersize, female/male, and discarded

Following the introduction of a new logbook in November 1999, fishers now provide details of the structure of their catch in terms of the number of males and females retained, the number of undersize crabs discarded, and the number of animals discarded for other reasons (eg oversize, damaged or berried). This information will provide a valuable guide to changes in the fishery in the future and will assist in interpreting changes in catch rate. Data is only available for 3 seasons at this stage so temporal trends are difficult to identify (some preliminary data is also presented from the 2002/03 season). Note also that one of these three seasons was incomplete (Nov 1999 – February 2000).

Seasonal patterns

As noted in Section 3.1.1 (page 4) catch per unit effort varies seasonally with highest catch rate from November to March. This period corresponds to those months where a large proportion of the retained catch is female (approximately 2-3 females for each male retained; Figure 23). The proportion of females in retained catch declines in autumn, as females become ovigerous or berried.

The legal minimum size limit for the crabs is 150 mm carapace length, with a maximum of 215 mm. The proportion of undersize in catches (Figure 24) and other discarded crabs (possibly damaged or one-armed; Figure 25) appears relatively stable across all months, although the proportion of discarded crabs from both groups was marginally higher in August and September. It is noteworthy that the decline in the proportion of female crabs in retained catch during autumn (Figure 23) does not translate into an increase in the proportion of discarded crabs (Figure 25), which indicates reduced catchability while berried. Also note that no clear pattern is evident between years in the number of crabs discarded (Figure 25). This indicates that the release of larger and one-clawed animals is not leading to an increased proportion of these animals in the population. Two options that could explain this are that recruitment is sufficiently large to mask any accumulation of discard animals, or the mortality of these discarded animals is high.

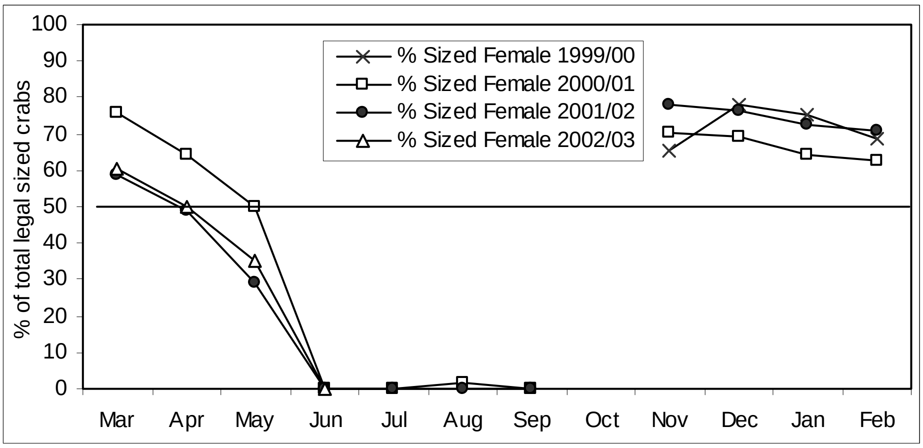

Figure 23. The proportion of retained giant crabs that were female for each month since November 1999. Note these proportions are based on number of individuals, not weight, and that a proportion of 0.75 equates to catch comprised of three females for every male. The horizontal line at 50% represents the proportion where equal numbers of males and females were taken. Data for 2002/03 is incomplete.

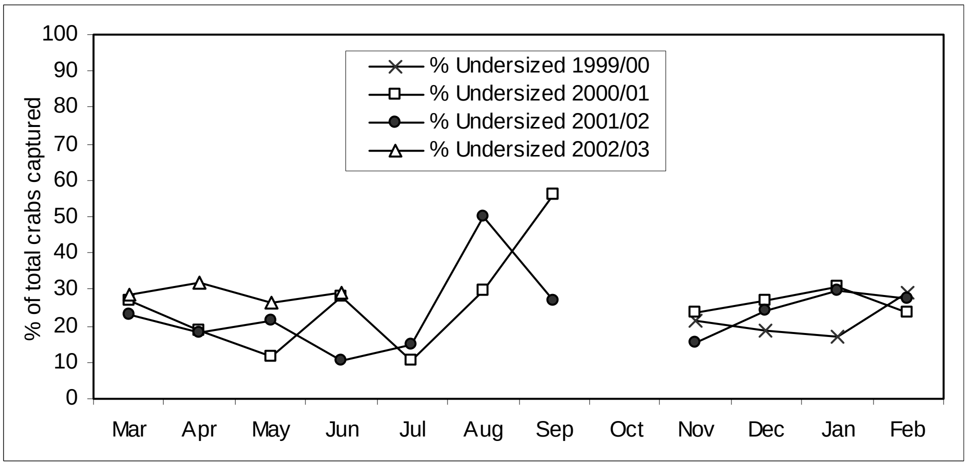

Figure 24. The proportion of giant crab catch that was undersize for each month since November 1999. Note these proportions are based on the number of individuals, not weight. Data for 2002/03 is incomplete.

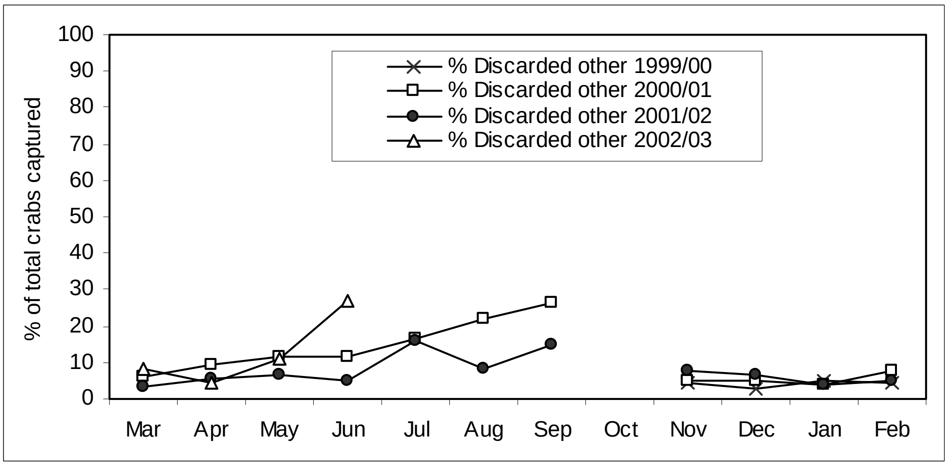

Figure 25. The proportion of giant crab catch that was discarded, but not undersize, for each month since November 1999. Crabs in this category include berried females, males larger than the maximum legal size of 216 mm, and animals with only one claw, which are usually discarded due to their low market value. Note these proportions are based on the number of individuals, not weight. Data for 2002/03 is incomplete.

Interannual patterns

Information on the change in the proportion of females and undersize crabs in catches will be of value for future monitoring of annual changes in giant crab stocks. Data collected since November 1999 is presented here, although as noted earlier, data is available for only two full years.

The proportion of undersize crabs in catches appears stable since 1999/00, and the proportion of females in the retained catch appears stable between 2000/01 and 2001/02 (Figure 26).

Regional patterns are shown in Figure 27 although the significance of temporal changes is difficult to assess with such a limited time-series of data. Catches on the east coast tend to include a higher proportion of females than those from the west.

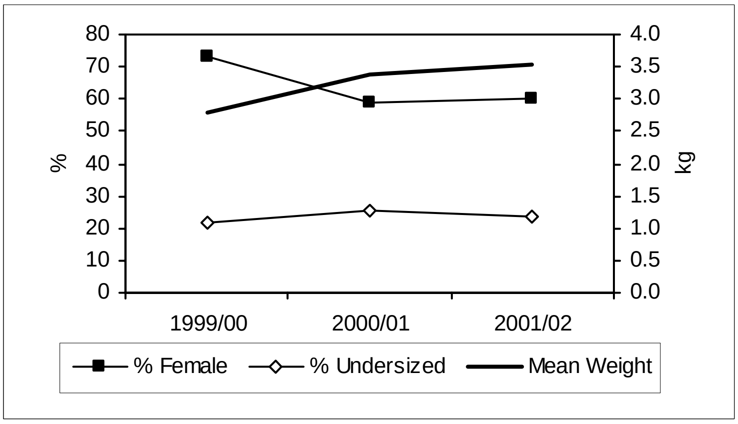

Figure 26. Statewide, interannual trends in the proportion of retained catch that was female, proportion of undersize in catch, and the mean weight of retained crabs.

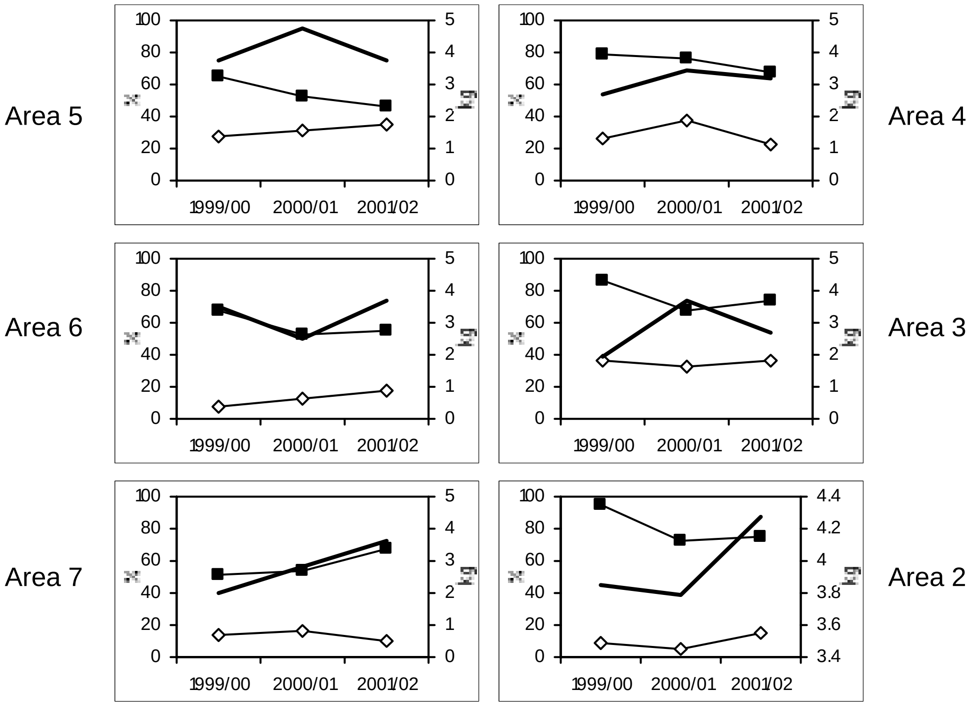

Figure 27. Interannual change in the proportion (based on numbers of individuals) of females in retained catch (solid squares), proportion of undersize in catch (hollow diamonds), and mean weight (heavy line) for each assessment area. Areas 1 and 8 are omitted due to low catches.

3.2.7 Interaction with benthic trawling operations

Crab fishers on the west coast of Tasmania have reported increased effort by benthic trawlers in shallower ground (<350 m) over the last year. These reports are supported by a change in the depth fished by commonwealth managed trawlers in 2001 (Figure 28). Given that these two fisheries are located adjacent to each other along the shelf break, any change in depth of trawlers can be expected to impact on the crab fishery (Figure 29). There are several reasons for concern including:

- gear interaction/loss by trawlers passing through sets of crab traps;
- harvest of crabs by operators not bound by Tasmanian State regulations such as size limits;
- potential for damage to crabs discarded or coming in contact with trawl gear;
- potential for long-term damage to habitat required for sustainability of crab populations and the fishing industry.

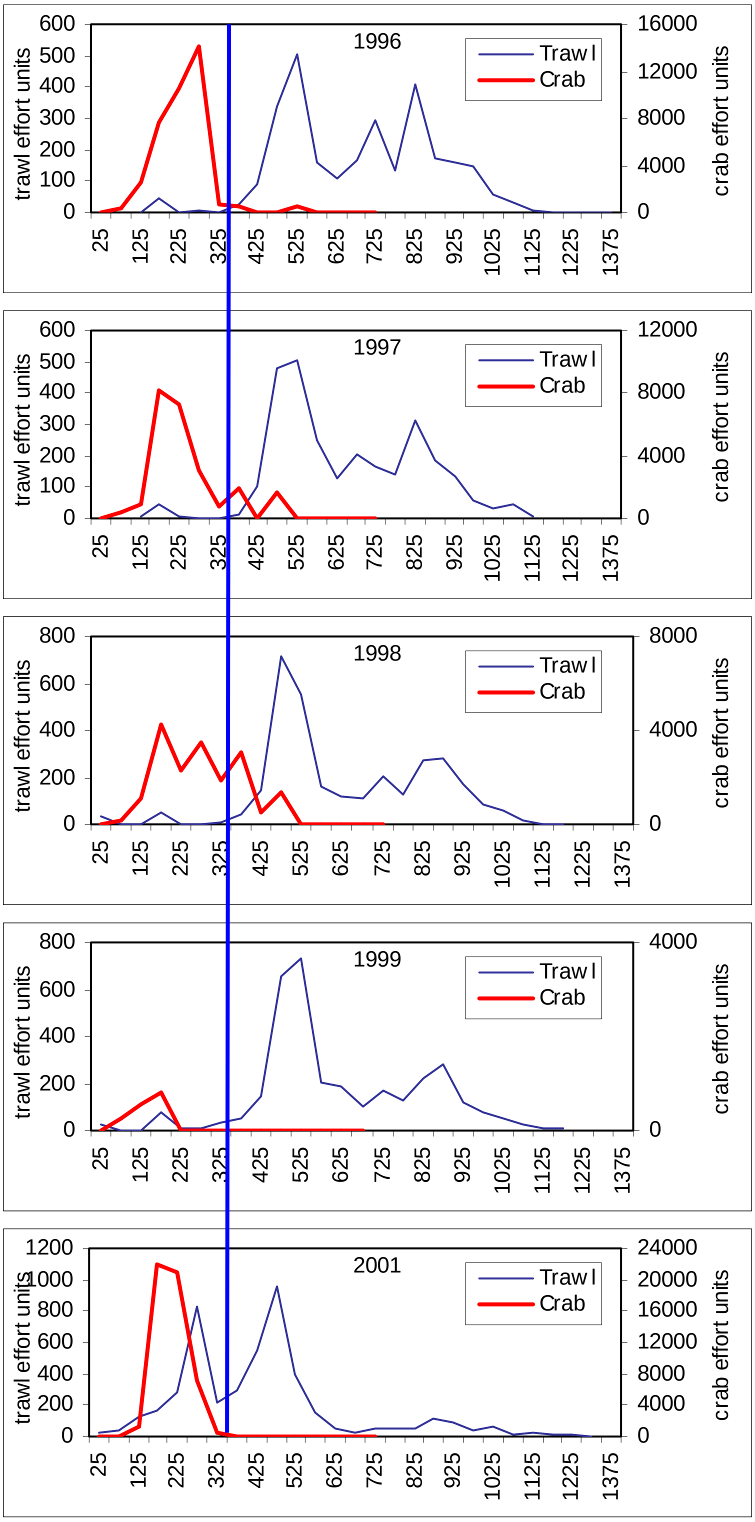

Figure 28. Depth of benthic trawling and crab trapping operations off western Tasmania 1996-2001 (no data were available for 2000). A sharp rise in effort by trawlers in shallower water (<350 m) is apparent in 2001.

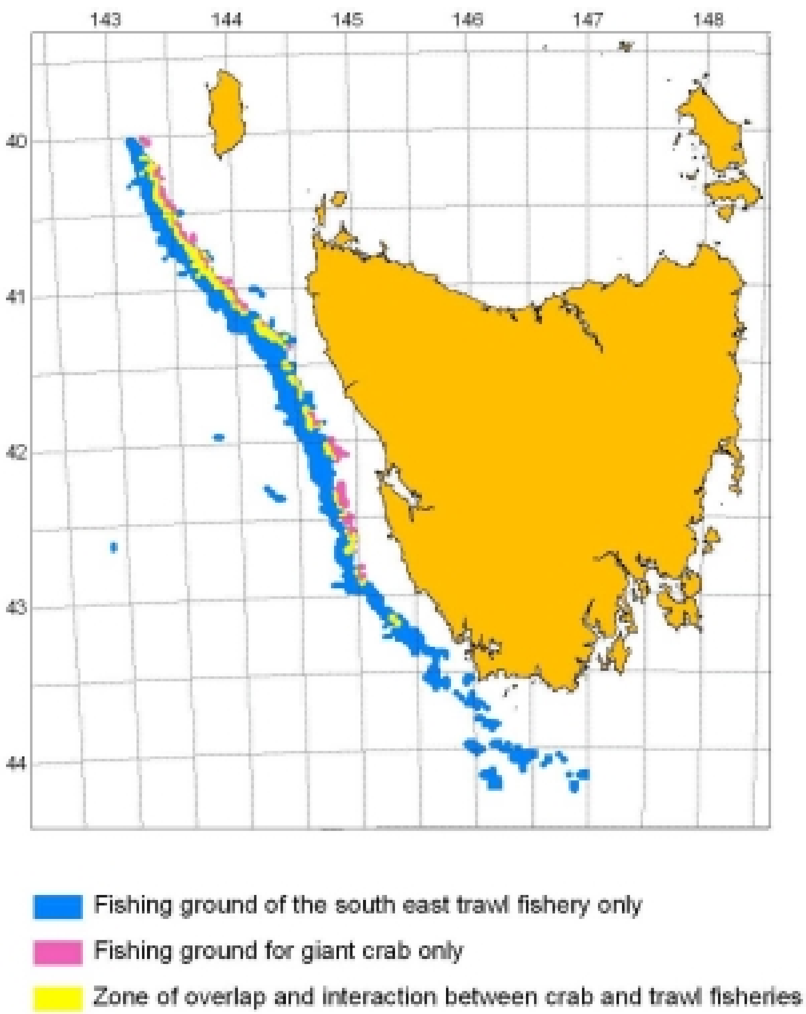

Figure 29. Distribution of crab and benthic trawling effort off western Tasmania, 2001.

4. Acknowledgments

This report was improved with the advice and contributions of Brian Cheshuk, Malcolm Haddon, Paul Burch, David Mills and Stewart Frusher and the staff of the DPIWE Quota Audit Unit. Several processors contributed, especially Stanley Fish and Galaxy. John Garvey of AFMA provided bycatch data from Commonwealth managed fisheries. Dr Andrew Levings contributed information presented in Appendix 1. The substantial changes made to the giant crab assessment over the last year was only possible through the assistance of most of the fishers targeting giant crabs, both through the provision of data in voluntary programs and also through providing advice on a range of aspects. Funding from FRDC supported research into aspects of this report.

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6. Appendix 1. Summary of FRDC project: Fisheries Biology of the Giant Crab

A large project on giant crabs was completed recently, titled the "Fisheries biology of the giant crab (*Pseudocarcinus gigas*)". A summary of the final report provided to FRDC by Andrew Levings (Deakin University) is reproduced here.

*Levings, A., Mitchell, B. D., McGarvey, R., Matthews, J., Laurenson, L., Austin, C., Heeren, T., Murphy, N., Miller, A., Rowsell, M. and Jones, P. (2001). Fisheries biology of the giant crab (*Pseudocarcinus gigas*). Final report to the Fisheries Research and Development Corporation, 93/220 and 97/132.*

7.1. Biology

Broadscale and enduring trends in the southern Australian oceanic environment have for 35 million years supported the evolution of *P. gigas* to present day. The crabs are "poikilotherms" which lack internal temperature control mechanisms, but live where the hydrology and steep terrain of the continental margin offers easy access to a cooler or a warmer environment. Their growth and reproduction are inherently linked with the food resources and physical character of where they live. Downslope movement into cooler water is advantageous for energy conservation through a slowing down of metabolism during moulting or extrusion and brooding of eggs, when they cannot feed. Upslope movement provides access to more abundant benthic food resources at other times.

Allozyme and then DNA techniques indicated a genetically homogeneous *P. gigas* stock structure. Another commercially exploited crab *H. acerba,* which occupies similar substrates but favours warm temperate waters is genetically the closest to *P. gigas* of all the species examined. *H. armata* an almost identical species to *H. acerba* occurs in Japanese waters and may be a clue that indicates a common Tethyan or West Indo-Pacific ancestor. Perhaps, in the Southern Hemisphere *P. gigas* evolved divergently from *H. acerba*, adapting to the cooler conditions caused by the opening of the Drake passage and the beginning of the Antarctic circumpolar current.

P. gigas occur in a temperature range of 11-17˚C, are well adapted for travel compared to many other crab species, and forage by following the scent of prey carried to it by water movement. Its cardiac and respiratory organs are of sufficient size to provide a large aerobic capacity and legs are protected from wear by broad hard surfaces at the tips.

At any given time fishers report the crabs are at a particular depth across many miles of ground. As temperature bands do occur at similar depths over large areas and as the crabs are poikilotherms, a plausible explanation for the fishers'observations is to propose that the crabs occupy a thermal niche. As the niche boundaries move, the crabs move within the niche, shallower or deeper. Excepting carrion, food boundaries are static and a function of substrate composition, but temperature is not and varies in a seasonal cycle to which the crabs growth and reproduction is synchronized.

Females are captured in greatest abundance on the narrow zone of bryozoan rich substrates which begin at a depth of approximately 120 meters. This type of substrate lies beyond the scouring effects of wave action and becomes progressively muddier until at about 300 metres it grades into all mud. It extends along the entire southern margin of Australia. Circumstantial evidence suggests the females move onto the mud when they moult.

Males are captured across a broader depth range than females. Most of the crabs taken as a by-catch of the lobster fishery, from the wave scoured rocky reefs in waters shallower than 120 metres, are of this sex. In the autumn when the oceanic hydrology changes from summer upwelling to winter downwelling, the water becomes warmer and the males move outward, over the shelf into deeper, cooler water. Thus their movement is synchronised with seasonality in a biorhythm that facilitates mate selection in the Autumn and copulation in the Winter when the females have moulted and are in a soft shelled state.

Despite the crabs' largeness and hard shell acting as a deterrent to predators and so eliminating the need for a physical shelter, the boundaries to their occurance are defined by the abundance of food and a temperature suited to their physiology. During moulting the crabs are soft and vulnerable, but their movement to deeper cooler waters to do this, reduces their availability to predators. As their environment becomes less than optimum towards the limits of their range, there is a decrease in moult increment and the maximum size attained.

A major output was the development of a cheap and effective tag that was applied in large numbers by fishers. At the end of the study nearly 18,000 crabs had been tagged and 1,700 recaptured. Their movement was along-shelf into the current; to the north off both sides of Tasmania, tending northwesterly off western Victoria and then westerly off South Australia. Off Bremer bay in West Australia the movement was along shelf to the southwest. Off Augusta where the shelf break begins its northerly orientation adjacent Cape Leeuwin movement increasingly reversed to be southerly, away from the warm temperate environment further northward where its range ends. Journeys of up to 400 km were recorded off West Australia and Victoria/South Australia.

Movement into the prevailing current means the millions of larvae they produce are carried back in the opposite direction to replenish the fishing grounds. The timing of hatching, the duration of larval lifetime and the onset of summer upwelling events, maximize the effectiveness of this reproductive strategy. For example: the Bonney upwelling illustrated in chapter 4 creates a peak in phyto-plankton production and within the 14ºC to 16ºC temperature range, concentrations of zoo-plankton including krill. While assisting larval nutrition the upwelling also reverses the direction of the current and broadcasts them further westerly during these episodic events. Settlement subsequently occurs and is demonstrated by the presence of juvenile crabs observed in lobster traps between 45 to 75 fathoms (or ~ 80 to 140 meters) below the location of the well defined thermocline at the outer edge of the upwelling.

This project established the female size at maturity for crab populations off each of the states. In the early stages of the fishery's development, an interim size limit of 150 mm was set in the eastern states in 1994. This was deliberately conservative and aimed for a target of 50% for the conservation of virgin egg production, double the 25%

international benchmark. Hence females are well protected by the current size limit, as it is set well above the average size at which maturity occurs. The crabs are highly fecund, store sperm and usually spawn in the years when they do not moult. There is a trend in declining fecundity with increasing size and age in the East Tasmanian population where there is a low abundance of males. In West Australia where the crabs mature at a smaller size and over a lifetime do not grow as large as those of the eastern states, a smaller legal minimum length of 140mm was adopted in 1996. Western Australian fishers voluntarily observed size limits of 135mm off Albany and 150 mm off Augusta prior to this.

While legal minimum length was based on egg production estimates from the female section of the population, the issue of male maturity and an appropriate size at which to harvest is problematic. Physiological maturity does not automatically mean the male can achieve reproductive success because males must also become dominant over other rivals to secure a mate and function as an adult. During the transition to functional maturity the morphology of the large chela in relation to carapace length starts to exhibit allometric growth. We have described the point at which this occurred and found from an overall population sample of 80,000 crabs, that in the Autumn the increase in male mean size was due to a greater abundance of individuals that were larger than the size where allometric growth began. These larger sizes were also present at the same locality where most newly moulted females were observed, therefore we propose they are the functionally mature section of the population. We also recognize that the onset of functional maturity is likely to be a dynamic relationship that can change. Variability is to be expected due to innate individual differences and varying population dynamics reflected in each crab’s development.

The fact that male *P. gigas* grow to more than double the size of females may be attributed to the advantages provided by having a huge chela, because it allows the crushing of larger prey and so provides access to a wider range of prey compared to females. As these larger prey are more abundant to shore-ward this difference provides an explanation why males have a wider distribution than females and in an evolutionary sense how a maximization of growth, attainment of giantism and an optimised chance to survive is manifest in the creature we observe today.

7.2. Preliminary Stock Assessment

Although the moult increment is large, growth is primarily mediated by a reduced frequency of moulting as age increases. Intermoult period estimates for *P. gigas* vary from 3-4 years for juvenile males and females (80-120 mm), with rapid lengthening in time between moulting to approximately 7 years for females and 4.5 years for males at legal minimum length of 150 mm. The female preference to aggregate on the narrow strip of bryozoan substrates means that the relative abundance of egg bearers in the sections of the population above and below minimum legal size can be clearly observed in the data and are an artefact of prior fishing history. The implication of the long intermoult, particularly for females, is that the population structure of the commercial fishery will tend to change, older and larger sizes becoming less abundant, with smaller sized recruits that have moulted from below the legal minimum length taking their place. In areas fished prior to a minimum size being introduced, or subject to illegal removals, full recovery of the population to the size structure that was intended will take about a decade.

Size distribution is stratified by depth (P =<.0001) and there are also other highly significant differences in size which can be attributed to season and sex (P =<.0001). Target depths can range from 75 - 250 fathoms(140 - 450 metres), but fishing operations are usually modified to ensure that the gear can be retrieved consistently. In areas subject to strong currents the depth at which the gear is set may be shallower than the optimum depth for the largest catch. As there are multiple factors that can significantly affect catches, regular communication with fishers is an important precondition for clear interpretation of trends in fishery statistics.

It has not been possible to confidently predict the crab biomass because of the broader dispersal of males out of the target fishery area and the historical inadequacy of catch and effort systems. In order to remedy this a pro-forma catch and effort form was designed to capture information at a whole fishery level and to date has been incorporated in all state fishery agency systems except Victoria.

Management of the crab fishery is a state responsibility, however the Commonwealth controls other fisheries which impact on it. The fishery can be detrimentally affected by the Commonwealth demersal trawl and mesh-netting fisheries which are conducted in the same depth range. Demersal trawl destroys the bryozoan substrate which is the framework for the benthic ecology and mobilises bottom sediments previously held in place by these organisms, making recolonisation difficult.

P. gigas is taken as a by-catch by trawl and meshnet methods. Southeast Fishery trawl operators are restricted to a by-catch of 5 crabs per trip, but no limitations have yet been placed on meshnet operators in regard to crab by-catch. This is significant because there is strong anecdotal evidence about damage to crab stocks off eastern Tasmania and southern Western Australia by deep water mesh netting operations. The accounts primarily concern circumstances where strong tides cause the net to come into contact with the bottom and delay retrieval. The eastern Tasmanian account deals with events over a decade ago when blue eye Trevalla were targeted. The vessel and the fishing method in that area were subsequently banned. The western Australian account is current, with crab fishers in Esperance and Albany attributing the cause of damage to crabs to be from deepwater meshnetting for dogshark and scalefish and the loss of nets which have subsequently ghostfished.

These sort of problems have occurred elsewhere in the world. Comments about the Northern Pacific king crab *Paralithodes camtschaticus,* where the early fishery was mostly based on trawl and tangle nets, are illuminating.

> "American king crab fishermen are forbidden to use tangle or trawl nets in the crab fishery, because the nets, the tangle net especially, make it difficult to return females and sub-legal males to the sea without injury". (Browning et. al., 1974).

This project could not have been possible without a large investment of research funds in training and the provision of extension materials to an Australia wide network of fishers. Combined with their material resources, existing lines of command and employment structures, consistent quality data was collected across the species range.

The data which consists of many discrete snapshots of fishing events within the targeted fishery was used to develop an individual based yield, egg and value per recruit model. The model has a user friendly interface "crabsim" which allows a user to key in their management choices. The choices are integrated with biological and economic information to provide outcomes. The ability to canvas multiple scenarios helps the formulation of management and improves industry confidence. The model has wider application and is also being applied in Western Australia to the *H. acerba* fishery.

Giant crab is a small "boutique" fishery, but the large demand for the species is evident in the year 2000 price maximum of $57 per kg for smaller commercial sizes. The need for sound management practices is paramount. As the fishery generates only a small volume of a valuable commodity, continuity of supply is essential to keep up demand. It is vital that exporters are involved in formulation of future management plans to ensure the best use is made of the product.

7.2.1. Management recommendations

- That the legal minimum size of 150mm in the eastern states and 140mm in West Australia provides adequate conservation of sexually mature females to maintain high levels of egg production for resource sustainability.

- That the size at sexual maturity for males should be further researched with a view to re-assessment of the present legal minimum length for this sex. This reassessment should be considered a priority in Western Australia where the ecology combined with the male preference for shallower substates has rendered it comparatively more vulnerable to fishing mortality than females.

- That annual surveys take into consideration that the giant crab population is not fixed to a specific location and should therefore incorporate movement information gained from tagging, into choice of sampling location.

- That a bycatch, even if only 1 or 2 crabs a trip be allowed for rock lobster fishers to assist the return of tag recapture information and provide information about migration from the shelf break to shallower waters to shoreward.

- The consequence of illegal removal of undersized crabs from the Victorian - Tasmanian border region is a decade of damage. The migratory nature of crabs indicates the damage is not limited to this area. Strong measures by the state of Victoria are required to rectify this situation.

- The issues which arise from the impacts of other fisheries may be controversial and may generate conflict between resource access holders and designated management authorities. Nonetheless they should be carefully addressed.
  The issues are;
  a/ Degradation of habitat by demersal trawling.
  b/ The effects of deepwater meshnetting.

- That the tool of 3 dimensional mapping be used to assist in a fuller description of marine ecosystem dynamics and the resolution of multiple use issues.

- Optimisation of the benefits of exploitation of giant crab requires careful integration of ;

  a/ The need for continuity of supply to overseas buyers.

  b/ The need to supply premium quality product

  c/ The timing of biological events that affect quality.

  It is therefore essential to include exporters as well as fishers, biologists and managers, in discussions of this nature and work towards an integration of these issues for the best result.

7. Appendix 2. Juvenile Growth and Development

7.1 Summary

Little information has been recorded on the biology of juvenile *P. gigas* but interest in these life stages has increased recently due to industry concern about the impact of commercial activities, including benthic trawling, on presumed juvenile habitats. The nature of early juvenile habitat has yet to be established, although McNeill (1920) reported a catch of two early-stage juvenile *P. gigas* in sponge trawled from 120-200 m depth. In more recent work, Levings *et al*. (2001) noted that the size of animals retained in crab traps decreased with depth, and that bryozoan communities from the continental slope across southern Australia are rich in juvenile prey items. They reasoned that this habitat was likely to be important for the settlement and growth of early stages of *P. gigas*.

To assist with future ecological research on these early juvenile stages, the juvenile stages were described from laboratory reared juveniles (Figure 30; Gardner and Welsford, submitted). Additionally, information gained from the rearing of juvenile through from the egg in the laboratory provided information on the growth of juveniles through to crab 7. While recognising the risk in extrapolating from this data from the laboratory to the growth of juvenile *P. gigas* in nature, our data may provide a useful guide to broader patterns of growth, in the absence of data from the field.

This work indicated that growth to legal size of 150mm CL is likely to take many years as juveniles only reached stage crab 7 (24 mm CL) after almost 2 years since hatch (Figure 31). This rate of growth is similar to that of several commercially important king crab species from high latitude areas. For instance, Loher *et al.* (2001) estimated that red king crab *Paralithodes camtschaticus* from Kodiak, Alaska reach 9mm CL after 1 year and 23 mm CL 2 years after settlement. Similarly, brown king crab *Paralithodes brevipes* from Japan reach around 10 mm CL, 1 year after settlement (Torisawa *et al*., 1999). A pattern of slow growth in juveniles is consistent with information available on adults from tag-recapture (McGarvey *et al*., 2002) and radiometric shell ageing (Gardner *et al*., 2002) where intermoult period of animals around the minimum legal sizes ranges between 4 and 7 years, depending on sex. McGarvey *et al*. (2002) found that moult increments were constant with length, based on tag-recapture data from a sample with most crabs larger than 100 mm. It appears that the early stage juveniles in this study had not yet developed this growth pattern, as they had increasing moult increment with size.

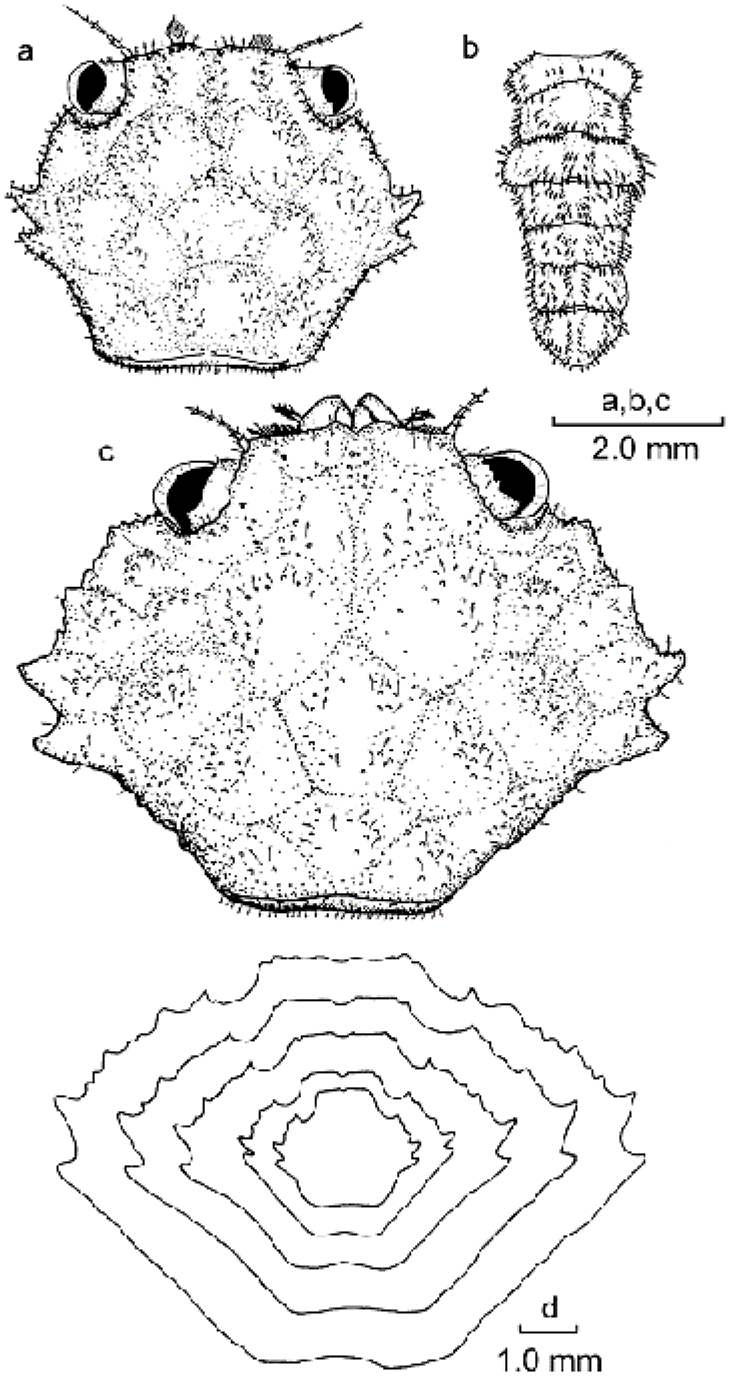

Figure 30. Carapace and abdomen development in juvenile *Pseudocarcinus gigas*. a crab 1 carapace; b crab 1 abdomen; c crab 2 carapace; d nested outlines of carapaces from the first 5 crab stages.

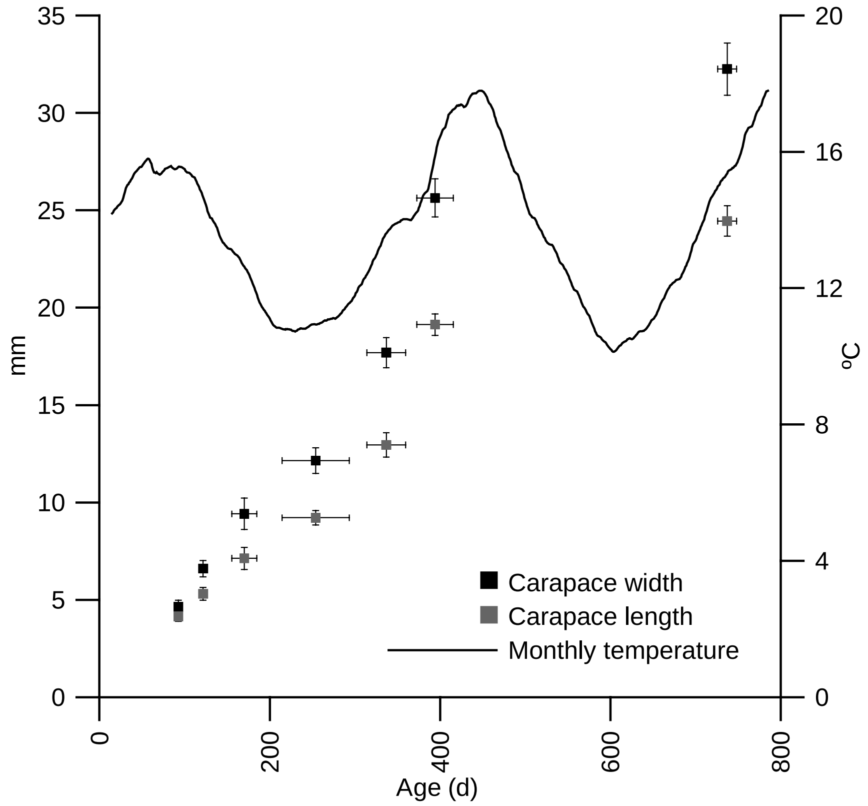

Figure 31. Water temperature and mean carapace width and length at age of moulting of *Pseudocarcinus gigas* for the first 7 crab stages. Error bars are +/- sd. Water temperature is 30 day running average.

7.2 References

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8. Appendix 3. Summary of rules for the Tasmanian Giant Crab Fishery

Table 7. Summary of rules for the Tasmanian Giant Crab Fishery.

COMMERCIAL	
Management zone	one management zone for the State (since January 1997)
Limited entry	106 licences (approximately 1/3 of the rock lobster licences in the state).
Limited seasons	Open season: 1st March -30th September, 11 November – 23rd February (both sexes).
Limits of pots on vessels	minimum of 15 pots, maximum of 50 pots
Quota	Total allowable catch of 102.3 tonnes
Restrictions on setting pots	pots cannot be set for more than 48 hours in less than 120m depth
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 (as per rock lobster pot)
Size limits	minimum of 150 mm CL and maximum of 215 mm CL for both sexes
Berried females	taking of berried females prohibited

RECREATIONAL	
License requirements	rock lobster potting licence (recreational) - 1 recreational pot per person,
Daily limit	1 per recreational license holder
Limited seasons	In 2000: closed season 1st September-10th November (both sexes).
Restrictions on setting pots	as per commercial fishers
Restrictions on gear	as per commercial fishers
Escape gaps	as per commercial fishers
Size limits	as per commercial fishers
Berried females	as per commercial fishers
Sale or barter of lobsters	prohibited