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Quantification of changes in recreational catch and effort on blue swimmer crabs in Cockburn Sound and Geographe Bay

FRDC Project No 2001/067

N.R. Sumner and B.E. Malseed



Department of
Fisheries



Australian Government
**Fisheries Research and
Development Corporation**



Fish for the future

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Fish for the future

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Research programs conducted by the Fisheries Research Division and laboratories investigate basic fish biology, stock identity and levels, population dynamics, environmental factors, and other factors related to commercial fisheries, recreational fisheries and aquaculture. The Fisheries Research Division also maintains the State data base of catch and effort fisheries statistics.

The primary function of the Fisheries Research Division is to provide scientific advice to government in the formulation of management policies for developing and sustaining Western Australian fisheries.

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FRDC 2001/067 Quantification of changes in recreational catch and effort on blue swimmer crabs in Cockburn Sound and Geographe Bay

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OBJECTIVES

1. To estimate the boat-based and shore-based recreational catch, fishing effort and size composition for blue swimmer crabs in Cockburn Sound and Geographe Bay during 2001/02.
2. To report on the relative recreational and commercial catch shares for 2001/02 and to compare the results with earlier years.
3. To quantify and evaluate changes in the recreational catch, catch rates and fishing effort following resource-sharing changes since the previous survey in 1996/97.
4. To compare the length frequency data of the recreational catch of blue swimmer crabs relative to commercial catches in these areas.

NON TECHNICAL SUMMARY

OUTCOMES ACHIEVED

Cockburn Sound

The estimated recreational catch of blue swimmer crabs from Cockburn Sound and Owen Anchorage for the period from September 2001 to August 2002 was 18.5 tonnes. The recreational fishing effort for blue swimmer crabs was 19,100 fisher days from boat-based fishers. The catch and effort from shore-based fishers was negligible.

The proportion of the total catch taken by recreational fishers has increased from 8% (28.4 tonnes of 357.1 tonnes) in 1996/97 (Sumner *et al.*, 2000) to 15% (18.5 tonnes of 122.1 tonnes) during 2001/02. Most (94%) of the recreational catch was taken between January and March. The commercial catch has shown a declining trend over the past five years, decreasing from 328.7 tonnes in 1996/97 to 103.6 tonnes during 2001/02, due to lower levels of effort and variable recruitment into the fishery.

The size composition of the recreational and commercial catch was similar. However, the recreational catch comprised predominantly male crabs (97%) and the commercial catch comprised more female crabs (57%) due to the differences in the spatial and temporal nature of fishing activities for the two sectors.

Geographe Bay

The estimated recreational catch of blue swimmer crabs from Geographe Bay for the period from December 2001 to November 2002 was 28.6 tonnes. Almost all the catch was taken by boat-based fishers (27.0 tonnes) rather than shore-based fishers (1.6 tonnes). The recreational fishing effort for blue swimmer crabs was 21,500 days. This comprised 19,400 days from boat-based fishers and 2,100 days from shore-based fishers.

The proportion of the total catch taken by recreational fishers has increased from 51% (17.5 tonnes of 34.0 tonnes) in 1996/97 (Sumner *et al.*, 2000) to 66% (28.6 tonnes of 43.5 tonnes) during 2002. However, the 1996/97 survey only included the boat-based recreational catch. During 2002, most (82%) of the recreational catch was taken between July and October. Over the past six years the commercial catch has fluctuated due to changing levels of recruitment into the fishery. For the two years the surveys were completed, the commercial catch was 16.5 tonnes in 1996/97 and 14.9 tonnes during 2002.

The size composition of the recreational and commercial catch was similar. The majority of crabs kept by both commercial and recreational fishers were female (85% and 81% respectively). Both sectors target crabs in shallow water close to the shore where female crabs are more abundant.

Information on the size of the recreational catch was required to address resource allocation issues between recreational and commercial crabbers in Cockburn Sound and Geographe Bay. Management measures designed to allocate more of the catch to the recreational sector were put in place prior to this study at both locations. Estimates of the recreational catch were required to evaluate the effectiveness of these new management measures by comparing the catch shares with a survey conducted in 1996/97.

A 12-month creel survey of recreational boat-based and shore-based crabbing in Cockburn Sound was conducted between September 2001 and August 2002 and in Geographe Bay between September 2001 and November 2002. During the surveys 1,235 interviews were conducted at boat ramps in Cockburn Sound and 929 in Geographe Bay. An additional 619 shore-based fishing parties were interviewed in Cockburn Sound and 444 in Geographe Bay.

The bus route method, where a survey interviewer visits all boat ramps in a pre-determined area on the one day, was used to estimate the total catch and fishing effort for persons crabbing from recreational trailer boats launched at boat ramps. A roving creel survey was used to estimate the catch and fishing effort from shore-based crabbers using drop nets or wire scoop nets from the shore.

Both the recreational and commercial catch of blue swimmer crab from Cockburn Sound was lower in 2001/02 than 1996/97 due to a lower level of recruitment. Recreational and commercial catch rates and effort were also lower. The increased size limit of 130mm for commercial crabbers resulted in 16.6 tonnes of crabs being returned by commercial fishers to be potentially available to the recreational sector. However, results show that only 2.2 tonnes of crabs kept by recreational boat-based fishers have a CW of 127-129mm, which is less than the commercial minimum size of 130mm. Since the recreational and commercial sectors have different spatial and temporal fishing activities it is unlikely that the recreational sector benefited substantially from the higher size limit for commercial fishers.

The recreational catch of blue swimmer crabs from Geographe Bay was larger in 2001/02 than 1996/97 primarily due to an increase in recreational fishing effort. There was a slight decrease in the commercial catch between the two years. It is difficult to determine the effect of the individual components of the new commercial management measures since these are confounded with changes in fishing effort, gear type and recruitment (and hence abundance) between the years surveyed. However, the new management measures and higher profile of crabbing in the area may have contributed to the increase in recreational crabbing effort.

For Cockburn Sound and Geographe Bay there is considerable variation in the commercial catch and catch rates from year to year due to the level of recruitment into the fishery. Furthermore, the corresponding variations in the recreational catch may be magnified by increased effort in years where catch rates are high and reduced effort in years when catch rates are low. This will exacerbate the variation in recreational catch resulting from recruitment fluctuations.

The fishing season for crabs in each location is affected by the time at which crabs reach legal size relative to the timing of fishing effort. In Cockburn Sound, the commercial and recreational effort peaks together in Summer, following the spring closed season for commercial fishers with the result that crabs are fished at about 2 years of age. The commercial fishery continues at a lower level through Autumn and Winter when recreational fishing is minimal. In contrast for Geographe Bay, both the commercial and recreational fisheries operate year round but peak in winter/spring when most crabs first reach legal size at about 18 months of age. Lower catches in summer, the main tourist season, reflects the heavy fishing pressure in spring and possibly an offshore movement at that time.

This research has provided important catch and effort information on the recreational sector by season and location. Estimates of the recreational catch, since the introduction of new management measures, were not previously available for the Cockburn Sound and Geographe Bay recreational fisheries and this study has addressed this shortfall. Catch and effort data for this survey and an earlier survey conducted in 1996/97 has now been collated and presented in a single document along with the commercial catch for the same periods. The results show that the recreational catch share in both locations has increased, which was the objective of the recently introduced management measures.

Ongoing catches by the commercial sector, coupled with high and increasing recreational pressure, indicates that stocks of blue swimmer crabs in Cockburn Sound and Geographe Bay are in need of continued monitoring for management decision purposes.

KEYWORDS: Recreational Fishing, Blue Swimmer Crabs, Cockburn Sound, Geographe Bay, Creel Survey

1.0 Background

General

Blue swimmer crabs (*Portunus pelagicus*) is the most important inshore species for recreational fishing in the South West of Western Australia in terms of the number of animals caught (Sumner and Williamson, 1999; Sumner *et al.*, 2000 (FRDC 98/119)). This activity has been in direct competition with the commercial crab fishery in Cockburn Sound and Geographe Bay, which expanded during the early 1990's (Potter *et al.*, 2001 (FRDC 97/137)). As a consequence, management action was taken to reallocate definite shares of crab catches in Cockburn Sound and Geographe Bay to the recreational sector.

While there have been a number of instances in W.A. (and elsewhere) where management measures have been introduced to allocate additional catch to the recreational sector, there has generally not been data available for both before and after the management change to assess it's success. The existence of comprehensive recreational survey data preceding the management change therefore presented an ideal opportunity to gather data following the management measures to enable an assessment of the success of the strategy.

This opportunity related to two specific and independent fishing areas i.e. Cockburn Sound and Geographe Bay.

Cockburn Sound

The boat-based recreational catch of blue swimmer crabs in Cockburn Sound and Owen Anchorage (Figure 1) was estimated as 119 tonnes in 1978 (Dybdahl, 1979). A later study (Sumner and Williamson, 1999) estimated the boat-based recreational catch as 28.4 tonnes during 1996/97. Different methods of data collection and catch and effort calculations were used by the two surveys. However, the trend of a declining recreational catch and greatly expanding commercial catch is probably realistic. Recreational catches were managed by a size limit of 127mm and bag limit of 24 crabs per person or 48 per boat. The shore-based recreational catch had not been assessed although it was considered to be relatively small.

The annual commercial crab catch for Cockburn Sound has steadily increased from 98 tonnes in 1991/92 to 347 tonnes in 1996/97 before declining to 104 tonnes in 2001/02. The efficiency of commercial fishing increased substantially with the change from drop nets to specifically designed crab traps in 1994.

The two sectors have agreed, through a mediation process, to resource sharing in Cockburn Sound with the intention that 5/8 (62.5%) of the catch be allocated to commercial fishers and 3/8 (37.5%) to recreational fishers. This was to be achieved by a commercial effort reduction (800 trap limit) and a higher size limit of 130mm for commercial fishers from December 24, 1999. The commercial fishery was also closed from 1st October to the 30th November (the breeding season) from 1995 onwards.

Geographe Bay

Recreational fishing in Geographe Bay (Figure 2) has a very high profile. The total boat-based recreational catch of blue swimmer crabs in Geographe Bay was estimated as 17.5 tonnes during 1996/97 (Sumner and Williamson, 1999). Recreational catches were managed by a size limit of 127mm and bag limit of 24 crabs per person or 48 per boat. The shore-based recreational catch was not estimated although it was considered to be relatively small.

The annual commercial crab catch has increased from 1.6 tonnes in 1989 to 14.9 tonnes in 2002 with a peak catch of 17.3 tonnes in 1997. The overall crabbing effort has also increased, however, it is difficult to compare effort between these years due to the change from using drop nets prior to 1999 to primarily traps in more recent years.

The management measures introduced in June 1999 included spatial closures to exclude commercial fishers from areas frequented by recreational fishers, temporal closures and a higher size limit of 128mm for commercial operators. Catch shares for Geographe Bay were not specified, although a reallocation towards the recreational fishery was envisaged.

2.0 Need

A current estimate of the recreational catch and fishing effort for blue swimmer crabs was needed following the recent introduction of management measures designed to change the commercial/recreational composition of the catch in Cockburn Sound and Geographe Bay. The size of the recreational and commercial catches and fishing effort for these embayments were specifically needed to assess the performance of these reallocation packages. Information on the total catch and fishing effort (recreational and commercial) was needed to enable the refinement of the management packages for these fisheries to maintain agreed resource shares.

This assessment was also required to determine, for the two fishing sectors, whether the management methodology adopted has achieved its objectives. The project will become a case study for use by the Resource Sharing Advisory Committee recently set up by the Department of Fisheries as part of the Integrated Coastal Fisheries Initiative.

Fishing in these embayments has been the source of considerable debate and controversy between recreational and commercial fishers. The major obstacle to the resolution of fishery management and resource sharing issues in Cockburn Sound and Geographe Bay was the lack of current data on the recreational catch.

3.0 Objectives

The objectives of the project were to estimate the annual harvest of blue swimmer crab made by recreational fishers in Cockburn Sound and Geographe Bay.

Specifically, the objectives were:

1. To estimate the boat-based and shore-based recreational catch, fishing effort and size composition for blue swimmer crabs in Cockburn Sound and Geographe Bay during 2001/02.
2. To report on the relative recreational and commercial catch shares for 2001/02 and to compare the results with earlier years.
3. To quantify and evaluate changes in the recreational catch, catch rates and fishing effort following resource-sharing changes since the previous survey in 1996/97.
4. To compare the length frequency data of the recreational catch of blue swimmer crabs relative to commercial catches in these areas.



Figure 1. Cockburn Sound.

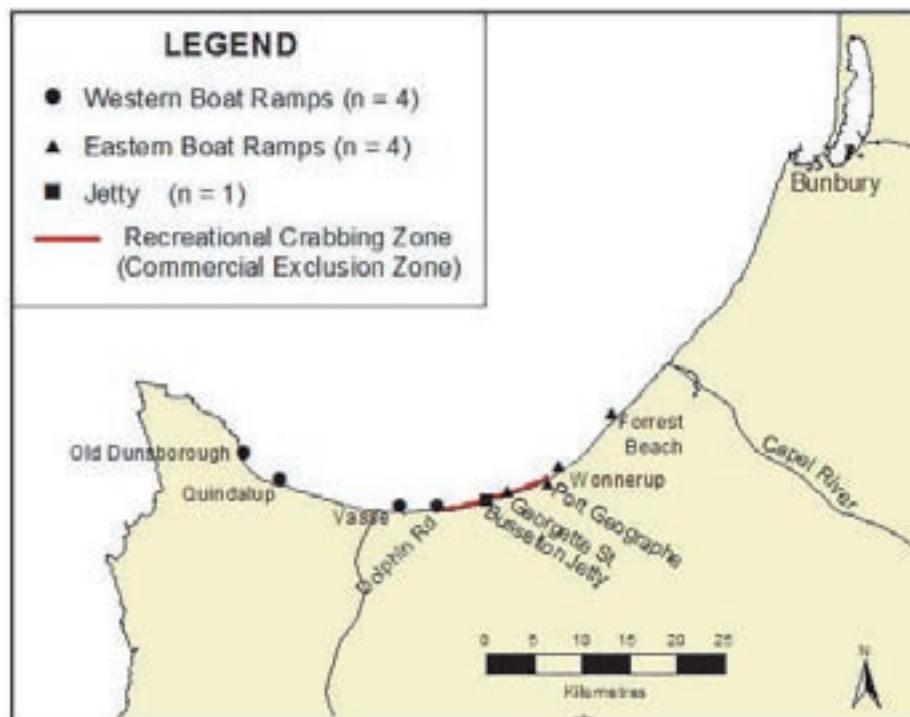


Figure 2. Geographe Bay.

4.0 Methods

Information on the shore-based and boat-based recreational catch and fishing effort was obtained from creel surveys. Commercial catch and effort data were obtained from compulsory monthly records provided by these fishers.

4.1 Recreational Fishing Survey Design

Two creel survey methods were used to estimate the recreational catch of blue swimmer crabs for boat-based and shore-based fishers. The bus route method (Robson and Jones, 1989; Jones *et al.*, 1990), where a survey interviewer visits all boat ramps in a district on the one day, was used for trailered boats launched from public boat ramps. A roving creel survey was used to estimate the catch and fishing effort from shore-based crabbers using drop nets or wire scoop nets from the shore.

4.2 Spatial and Temporal Stratification

The survey of Cockburn Sound spanned a 12 month period, commencing in September 2001 and concluding at the end of August 2002. In Geographe Bay the survey also commenced in September 2001. This survey, however, was extended until the end of November 2002. This enabled a complete crabbing season, which in Geographe Bay occurs during winter and spring, to be surveyed.

Both surveys were stratified by season (spring, summer, autumn or winter), time of day (morning or afternoon) and weekdays or weekends (including public holidays). Separate

total catch estimates were made for each of these 16 strata (4 seasons \times 2 for mornings and afternoons \times 2 for weekends and weekdays). The boat fishing effort estimates were further stratified by ramp. This ensured that corrections could be made to account for the varying proportion of boats at each ramp, which were crabbing or angling within Cockburn Sound or Geographe Bay, fishing outside Cockburn Sound or Geographe Bay or not fishing at all. These estimates were then combined to obtain the total recreational catch and effort during the survey period.

Each interviewer worked one shift (morning or afternoon) on each of the scheduled survey days. We chose to divide the day into two shifts so that the interviewer would not have to work longer than 6.5 hours. In Geographe Bay during spring and summer shifts were 6 hours, either 7:00 am to 1:00 pm or 1:00 pm to 7:00 pm. This was reduced to 5.5 hours, 7:00 am to 12:30 pm or 12:30 pm to 6:00 pm during autumn; and then further reduced to 4.75 hours 8:00 am to 12:45 pm or 12:45 pm to 5:30 pm during the winter months. In Cockburn Sound during spring and summer shifts were 6.5 hours. This was reduced to 5.5 hours during autumn and 4.5 hours during winter.

For Cockburn Sound, a separate roving creel survey of shore-based crabbers was conducted by the survey interviewers. The day was divided into 6 hour morning and afternoon shifts. Morning shifts were conducted between 7am and 1pm while afternoon shifts were conducted between 1pm and 7pm.

4.3 Sampling Design

Boat-based fishing - bus route method

Boat-based crabbers used drop nets to catch crabs. This is an active device consisting of two rings joined by a mesh net. The lower ring also has a mesh net base to which bait is attached. When the net is retrieved the top ring is raised effectively trapping crabs within the device.

For Cockburn Sound, one bus route was sufficient to cover all major boat ramps in the Sound. The number of shifts conducted per month depended upon the season. More shifts were allocated to the seasons where most effort occurred, based on prior information on recreational crabbing patterns (Sumner and Williamson, 1999). The prior information suggested that mornings were more popular than afternoons during the summer crabbing season. More shifts were therefore allocated to summer mornings. An equal proportion of shifts were allocated to weekdays and weekends (including public holidays). The number of survey shifts allocated per month varied from eight to 14, which is effectively four to seven full days (Table 1).

For Geographe Bay, two bus routes were set up (referred to as “eastern” and “western”) to cover all major boat ramps and caravan parks where boats are launched in the embayment. Since crabbing was thought to occur throughout the year in Geographe Bay an equal number of shifts were conducted each month. An equal proportion of shifts were allocated to eastern and western ramps, mornings and afternoons and weekdays and weekends (including public holidays). The number of survey shifts allocated per month was 16, which is effectively 8 full days.

Table 1. Monthly Allocation of Survey Shifts for Cockburn Sound.

Month	Number of morning shifts	Number of afternoon shifts	Total number of shifts
January	8	6	14
February	8	6	14
March	6	6	12
April	6	6	12
May	6	6	12
June	4	4	8
July	4	4	8
August	4	4	8
September	4	4	8
October	4	4	8
November	4	4	8
December	8	6	14

The bus route schedules were constructed as described by Pollock *et al.* (1994). The start, travel and wait time at boat ramps were rounded to the nearest minute. A Mathcad (Anonymous 1999) worksheet was developed by the authors to generate the randomised schedules.

The starting boat ramp and direction of travel for the bus route was chosen randomly. The bus route commenced either between ramps or at a ramp. However, due to the large distances between boat ramps, travel time and cost involved, starting at a ramp and returning to the same ramp to complete the route at the end of the shift was inefficient. Furthermore, removing this last leg of the bus route allowed more time to be spent at the boat ramps collecting data rather than travelling. For this reason, the bus route method was constrained so that a shift could not commence part way through the wait time at a ramp although the probability of commencing at a ramp or travelling remained unchanged. It was likely that each boat ramp was visited during all hours of the day by the end of a season. McGlennon and Kinloch (1997) used a similar modification of the bus route method for a survey conducted in South Australia where boat ramps were also separated by large distances.

The allocation of wait time to each ramp (Tables 2 and 3) was proportional to ramp use by crabbers based on a previous survey (Sumner and Williamson, 1999).

Within each season, a random sample of survey days was chosen. When it was not possible for recreational anglers to fish due to severe weather conditions the survey was not conducted and it was assumed that there was zero catch and effort for the shift. The survey interviewer made this decision on the day after assessing the weather conditions. It was assumed that the number of days when recreational fishing was not possible due to severe weather was representative of each season.

Table 2. Allocation of Time to Survey Ramps for Cockburn Sound.

Ramp	Prop. of Time
Leeuwin	0.11
Woodman Point	0.35
Sutton Road	0.05
Kwinana Beach	0.09
Palm Beach	0.15
Causeway	0.25

Table 3. Allocation of Time to Survey Ramps for Geographe Bay.

Area	Ramp	Prop. of Time	Area	Ramp	Prop. of Time
East	Busselton Jetty	0.16	West	Dolphin Road	0.28
East	Georgette Street	0.20	West	Vasse	0.24
East	Port Geographe	0.35	West	Quindalup	0.33
East	Wonnerup	0.12	West	Old Dunsborough	0.15
East	Forrest Beach	0.17			

The interviewer followed a pre-determined schedule specifying the boat ramps to visit and the sampling time for each boat ramp. Catch, effort, biological and demographic information were collected from boat-based fishers when they returned to the boat ramp. A form was used to record the environmental conditions, boat launches and retrievals while the interviewer was at a boat ramp (Appendix 3). Only recreational boat trailers were counted at the boat ramps; these could be distinguished from trailers used by professional fishers. A second form was used to record the time-spent fishing, catch and other information for individual boats (Appendix 4). For boat-based fishers the catch was recorded at the completion of the day's fishing and represented the entire catch for the duration of the trip. The catch of crabs was counted, measured and where possible the sex recorded. The carapace width (CW) from spine point to point was measured to the nearest millimetre.

Field staff were instructed, where possible, to measure all crabs that were seen during interviews. However, since it was more important to collect as much basic catch information from as many fishers as possible, when several boats returned to a ramp at the same time it was not always possible to measure all the crabs in the catch. When this happened, a random sample of the crabs kept were measured. A random sample, rather than all of the catch, was also measured when fishers were in a hurry to leave the ramp.

Shore-based fishing - roving creel survey

A roving creel survey was used for the survey of shore-based crabbers. These included crabbers wading through shallow water with wire scoop nets or using drop nets from the jetties in Cockburn Sound or Busselton Jetty in Geographe Bay.

For Cockburn Sound, a random sample of four survey days was chosen each month (two morning and two afternoon). On these days the interviewer visited each of the 16 jetties or shore based fishing locations indicated in Figure 1. An instantaneous count of crabbers was made on arrival at each location before interviews were undertaken using the interview questionnaire shown in Appendix 4.

For Geographe Bay, catch and effort information for shore-based crabbers was collected during the bus route surveys. Progressive counts of shore-based fishers were made while the interviewer drove from one boat ramp to the next according to a randomised time schedule. The Busselton Jetty was included as a stop in the bus route survey design to ensure that there was enough time to count and interview shore based crabbers at this popular location. The schedule design allowed time for a small number of interviews between check points. This enabled shore-based crabbers to be interviewed when encountered. The boat ramps (including Busselton Jetty) were used as checkpoints along the route. Separate interviews of shore-based crabbers were conducted. The interview questionnaire used for boat-based fishers (Appendix 4) was also used to record time spent fishing, catch and other information for shore-based fishers.

4.4 Estimation of Total Catch and Effort for Boat-based Recreational Fishers

The fishing effort was estimated from counts of the number of trailers at the boat ramps. This was then converted to fisher days by taking into account the average number of fishers per boat and average length of fishing trip. Catch rates were estimated from information on the time spent fishing and catch obtained by interviewing fishers when they returned to the boat ramp at the completion of the fishing trip. The total catch was estimated by multiplying the catch rate by the estimate of fishing effort in boat hours (Appendix 5).

The measure of fishing effort for each season was adjusted to correct for the number of recreational boats not involved in crabbing activities. The correction was made by multiplying the trailer counts by the proportion of boats interviewed that were participating in recreational crabbing.

Fishing effort by boats that were launched before the start of a morning shift (7:00am or 8:00am in winter) and returned after the start of a morning shift was also taken into account. The ratio of effort occurring prior to the start of a morning shift to that occurring after the start of a morning shift was estimated and a correction factor (f) applied to the effort estimate in the mornings for each season (Appendix 5).

The total number of crabs both kept and released was estimated. The standard error associated with the estimate of the number of fish kept $SE(\hat{c})$ was calculated for each species. Assuming a student t distribution, the $(1-\alpha)$ percent confidence interval for the number kept (\hat{c}) was calculated from the standard error as follows:

$$\hat{c} \pm t(1 - \alpha / 2; n - 1)SE(\hat{c})$$

$$\hat{c} \pm 1.96 SE(\hat{c})$$

where $\alpha = 0.05$ for the 95% confidence interval and n is the number of boats surveyed (sample size). The estimates reported in the results (Section 5) have been rounded to reflect the level of precision.

The whole weight of the catch, in tonnes, was estimated using the following carapace width (CW) (mm) to body weight (W) (g) relationships developed by Potter *et al.* (1983).

$$\text{males } \log_{10} W = \log_{10} 2.56 \times 10^{-5} + 3.260 \log_{10} CW$$

$$\text{females } \log_{10} W = \log_{10} 5.97 \times 10^{-5} + 3.056 \log_{10} CW$$

4.5 Estimation of Total Catch and Effort for Shore-based Recreational Fishers

For Cockburn Sound, the fishing effort for the day was estimated by multiplying the instantaneous counts by the average number of hours in the fishing day. For Geographe Bay, the fishing effort for the day was estimated by multiplying the progressive counts by the average number of hours in the fishing day. Catch rates were estimated from information on the time spent fishing and catch obtained by interviewing fishers while they were still fishing. The total catch was estimated by multiplying the catch rate by the estimate of fishing effort in fisher hours (Appendix 6).

The whole weight of the catch, in tonnes, was estimated from the length-weight relationships described in Section 4.4.

4.6 Estimation of Total Catch and Effort for Commercial Fishers

The commercial catch and effort for Cockburn Sound and Geographe Bay was obtained from compulsory returns provided by individual operators. The returns were entered into the Commercial Catch and Effort database from which aggregated summaries of total catch and effort over a 12-month period were reported.

5.0 Results/Discussion

5.1 Cockburn Sound

During the survey 1,235 interviews were conducted at boat ramps. Of these, 134 boats had been crabbing and 601 angling in Cockburn Sound (43 were both crabbing and angling). Of the remainder, 350 boats had been fishing outside Cockburn Sound and 193 were not involved in any fishing activity.

A further 38 boats were interviewed at yacht clubs whilst undertaking the shore based roving creel survey. None of these boats had been crabbing.

Blue swimmer crabs were targeted by 18% of recreational boat-based fishers interviewed in Cockburn Sound. Boat-based fishers also targeted species such as squid, King George whiting, Australian herring and pink snapper.

In addition to the interviews at boat ramps, 619 shore-based fishing parties were interviewed. Eighteen of these groups were crabbing and 614 were angling (13 were both crabbing and angling).

5.1.1 Recreational Crabbing Effort

Recreational Boat-based Crabbing Effort

Results indicate that most fishing occurred during the two survey periods of the day, referred to as a morning or afternoon shift. However, fishing also occurred both before and after the survey periods as indicated by the boat launch and retrieval times recorded by the survey interviewers. The ratio of effort occurring prior to the start of a morning shift to that occurring after the start of a morning shift was estimated and a correction factor (f) applied to the effort estimate in the mornings for each season (Table 4 and Appendix 5).

Table 4. Correction factor for effort occurring before the start of a morning shift.

Season	Ratio of effort prior to and after start of daily survey period	Correction factor (f)
Spring	0.187	1.187
Summer	0.319	1.319
Autumn	0.168	1.168
Winter	0.288	1.288

Most boats had returned to the ramp before the end of an afternoon shift. The number of boats returning after this time of the day, based on the number of trailers remaining, was relatively small (around 7 per ramp on average during summer) (Figure 3).

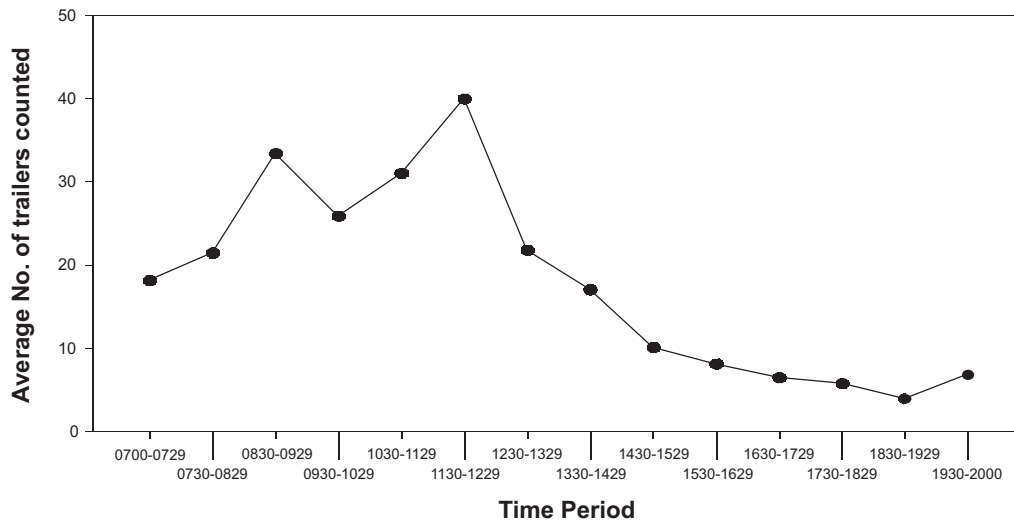


Figure 3. Average number of trailers counted on arrival/departure at all ramps during summer.

Boat-based crabbers used drop nets or caught crabs by hand whilst diving or snorkelling. The recreational boat-based crabbing effort was greatest in summer with 63% of the annual crabbing effort (12,000 fisher days) occurring during this period (December to February) (Figure 4). Autumn was the next most popular season for boat-based crabbing followed by spring. No crabbing took place during winter. The majority of boat-based crabbing took place in the morning. Recreational effort occurred during the months when weather conditions were favourable for social activities such as crabbing.

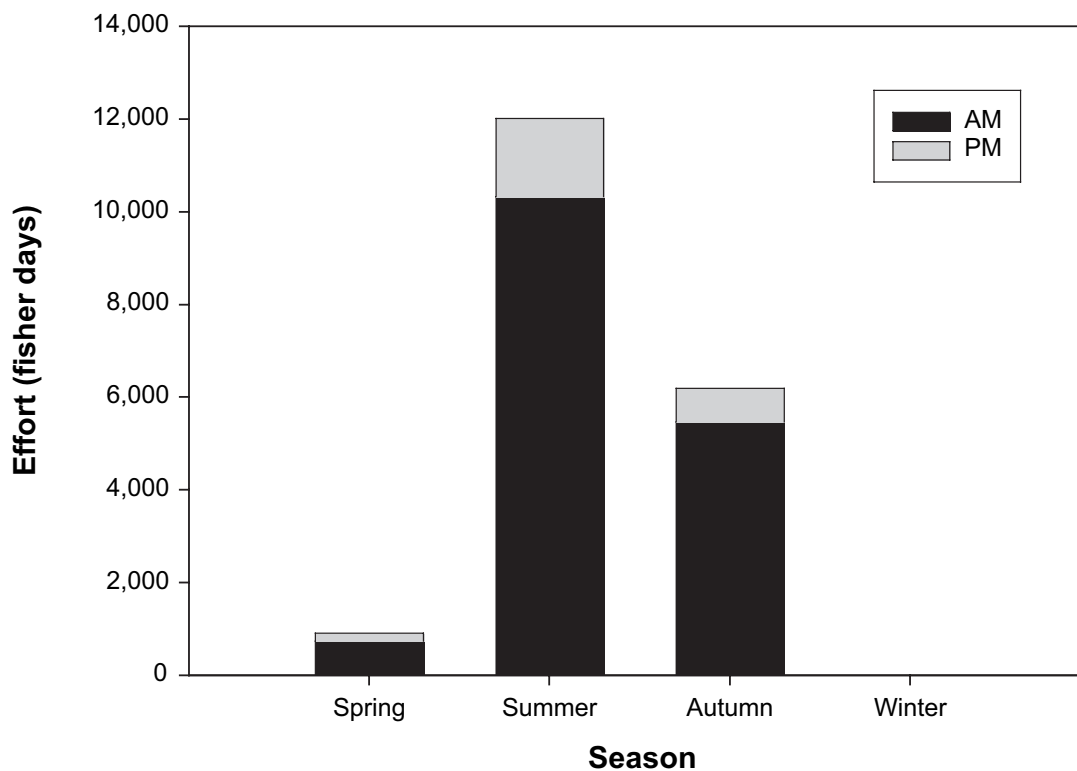


Figure 4. Recreational boat-based crabbing effort in Cockburn Sound.

The estimated total annual recreational boat-based crabbing effort for Cockburn Sound was 19,000 fisher days (28,000 boat hours).

Spatial Distribution of Recreational Boat-based Crabbing Effort

Boat-based crabbing effort was greatest in the Mangles Bay area between Palm Beach and the Causeway. Boat-based crabbing was also popular along the inside of Garden Island and north of Woodman Point (Figure 5).

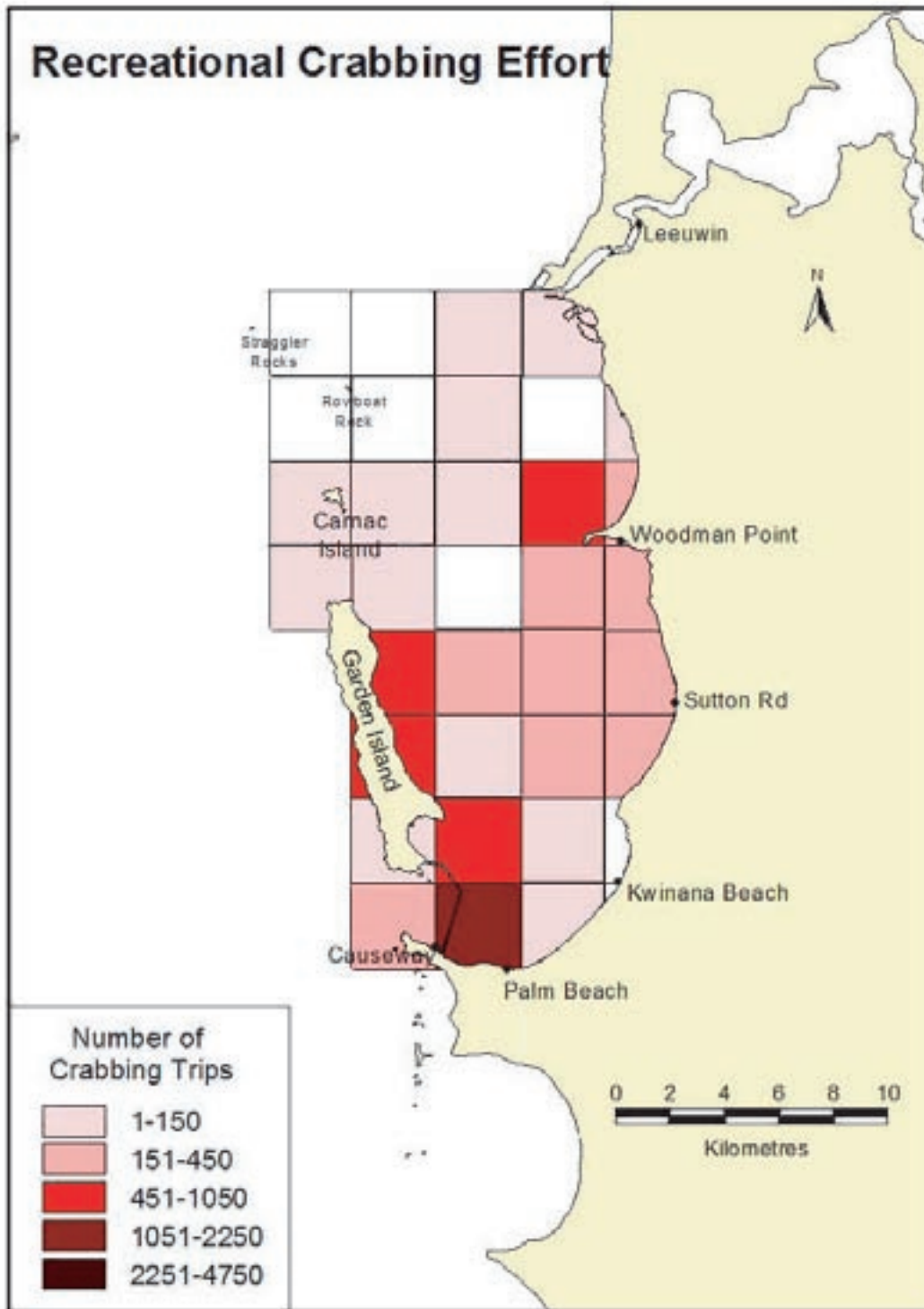


Figure 5. Spatial distribution of recreational boat-based crabbing effort in Cockburn Sound.

Recreational Shore-based Crabbing Effort

Shore-based crabbers targeted crabs with drop nets from jetties and by hand whilst diving and snorkelling. During summer the shore-based crabbing effort was estimated to be 800 fisher days (Figure 6). There was very little shore-based crabbing effort recorded throughout the remainder of the year and none during spring although the survey continued during this period.

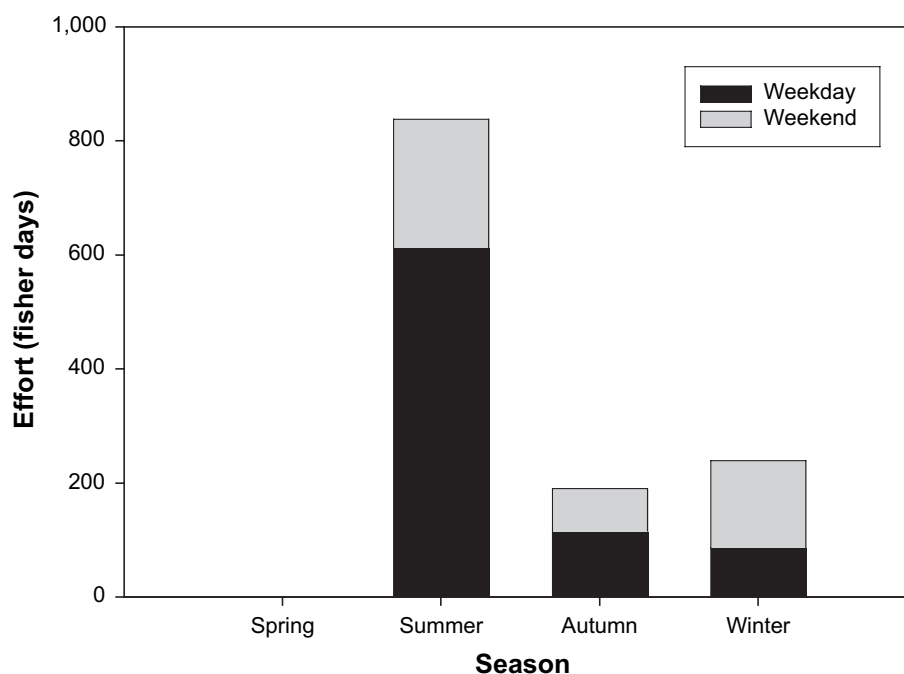


Figure 6. Recreational shore-based crabbing effort in Cockburn Sound.

The estimated total annual recreational shore-based crabbing effort for Cockburn Sound was 1,200 fisher days (3,700 fisher hours).

5.1.2 Recreational Crabbing Catch

Recreational Boat-based Catch of Blue Swimmer Crabs

Where the sex of the crabs was recorded, of those kept, 97% (1,278) were males and 3% (43) females. Of the crabs released, 82% (354) were males and 18% (80) females.

Table 5. Estimated catch of blue swimmer crabs by recreational boat-based fishers in Cockburn Sound.

	Total	Standard Error
Number kept	77,300	5,300
Number released	22,300	1,800
Weight kept (tonnes)	18.5	1.3
Catch rate (crabs/boat/trip)	9.9	1.0

An estimated 77,300 crabs were kept (74,800 males and 2,500 females) and 22,300 released (18,200 males and 4,100 females) by boat-based crabbers during 2001-02 (Table 5).

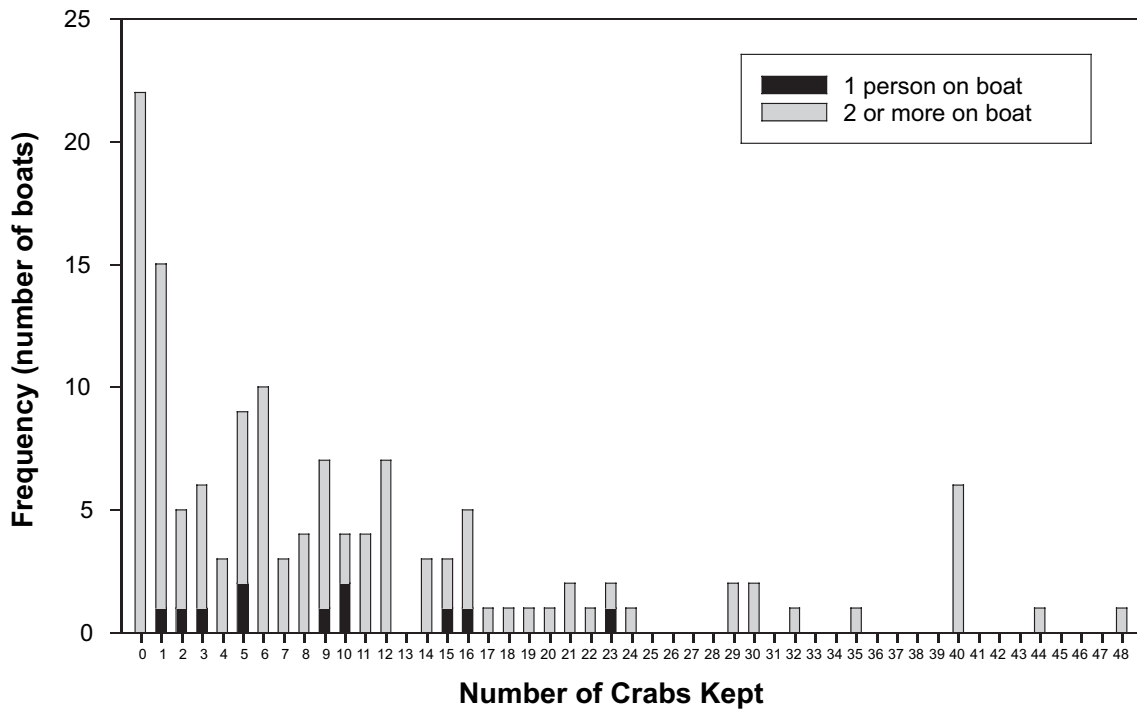


Figure 7. Frequency of crabs kept per boat in Cockburn Sound.

Only one of the 123 boats interviewed with two or more on board achieved the boat limit of 48 crabs and only one of the 11 boats with only one person on board achieved the daily bag limit of 24 crabs. Half of the boats targeting crabs (52%) caught six or less crabs, with 16% of boats not landing any crabs at all (Figure 7).

Catch rates were greatest between January and March (Figure 8). No crabs were recorded as having been kept during September and October or from May to August (Figure 8 and 9).

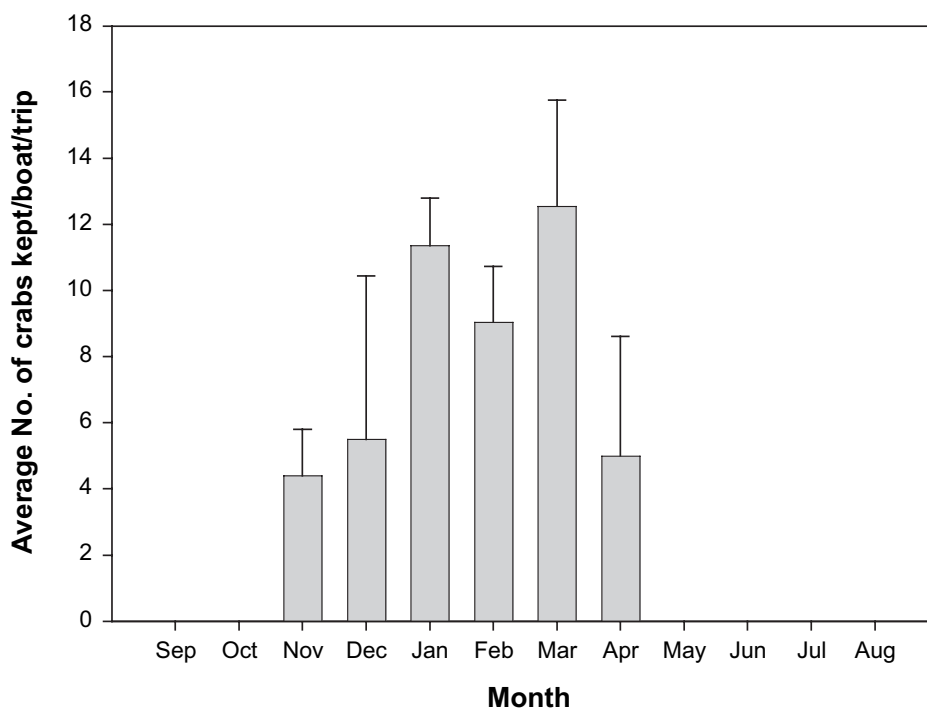


Figure 8. Crab catch rates by month for boat-based fishers in Cockburn Sound.

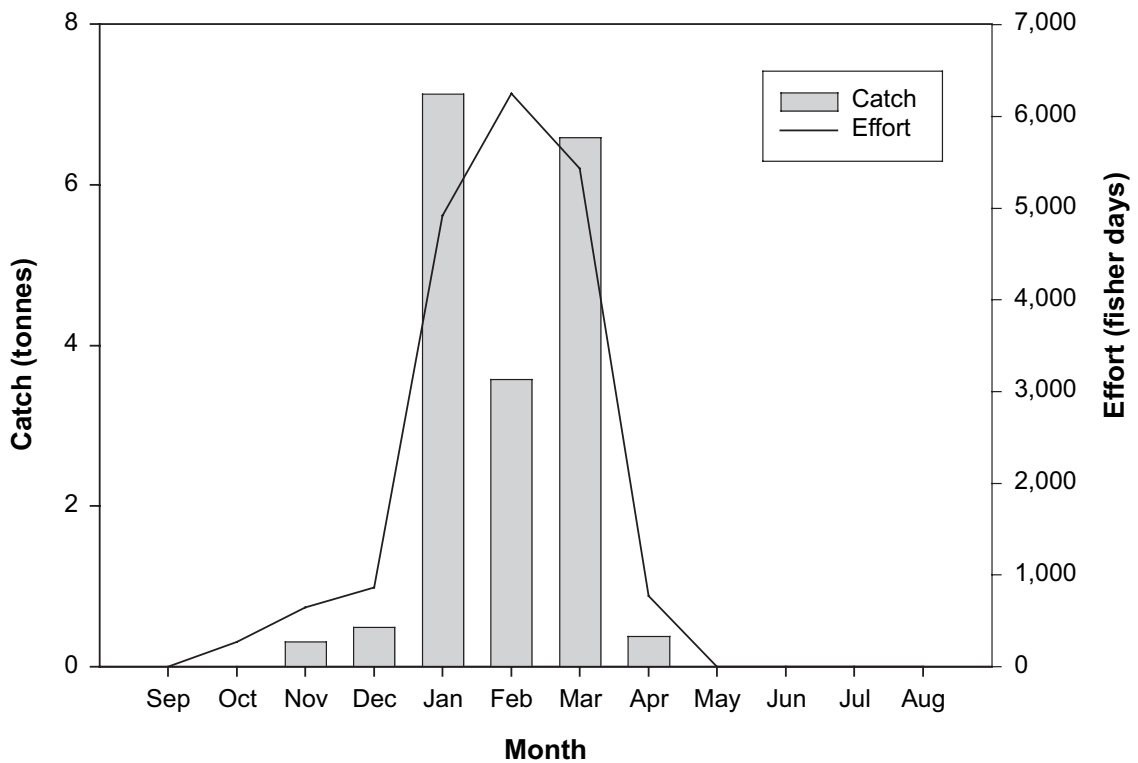


Figure 9. Estimated crab catch and effort per month for boat-based fishers in Cockburn Sound (Sept 2001 to Aug 2002).

Most (94%) of the recreational crab catch was caught between January and March. The majority of effort (87%) also occurred during this period (Figure 9).

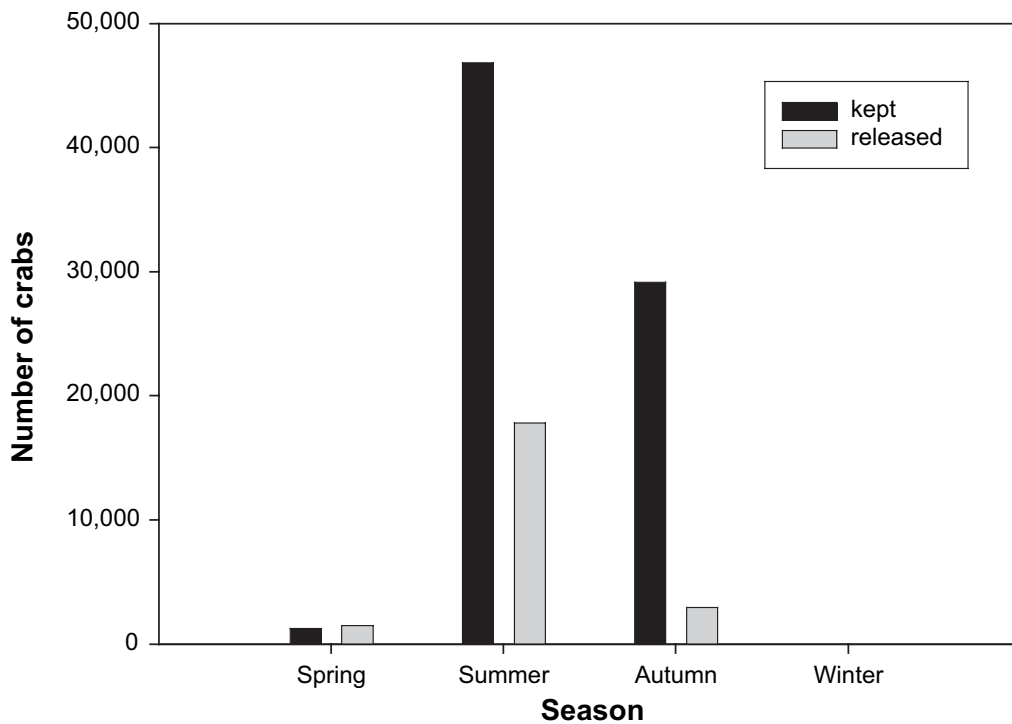


Figure 10. Estimated number of crabs kept and released per season from Cockburn Sound.

The majority (78%) of crabs caught in Cockburn Sound were kept. Only in spring, when very few crabs were caught, were there more crabs released than kept (Figure 10).

The total estimated annual weight of crabs kept by recreational boat-based crabbers in Cockburn Sound was estimated to be 18.5 tonnes (18 tonnes of males and 0.5 tonnes of females) (Table 5).

Recreational Shore-based Catch of Blue Swimmer Crabs

The shore-based catch of blue swimmer crabs in Cockburn Sound was found to be negligible. Only three groups of shore-based crabbers interviewed during the 12-month survey had kept crabs. The catch is therefore too small to estimate. Most of the effort (800 fisher days) comprised anglers fishing from jetties opportunistically using one or two crab nets to supplement their catch of fish.

Total Recreational Catch of Blue Swimmer Crabs

The total recreational harvest of blue swimmer crabs from Cockburn Sound for the 12 month period between September 2001 and August 2002 is estimated to have been 18.5 tonnes (77,300 crabs). Boat-based crabbers took almost all the catch since the catch from shore-based crabbers was negligible. It is also estimated that 22,300 crabs were released by recreational fishers during the 12 month period (Table 6).

Table 6. Estimated total recreational catch of blue swimmer crabs from Cockburn Sound.

	Boat	Shore	Total	Standard Error
Number kept	77,300	0	77,300	5,300
Number released	22,300	0	22,300	1,800
Weight kept (tonnes)	18.5	0	18.5	1.3

5.1.3 Size Frequency of Recreational and Commercial Catch

Size Frequency of Recreational Catch

The size frequency for blue swimmer crabs displayed in Figure 11 shows the carapace width (CW) range for crabs kept by recreational boat-based crabbers.

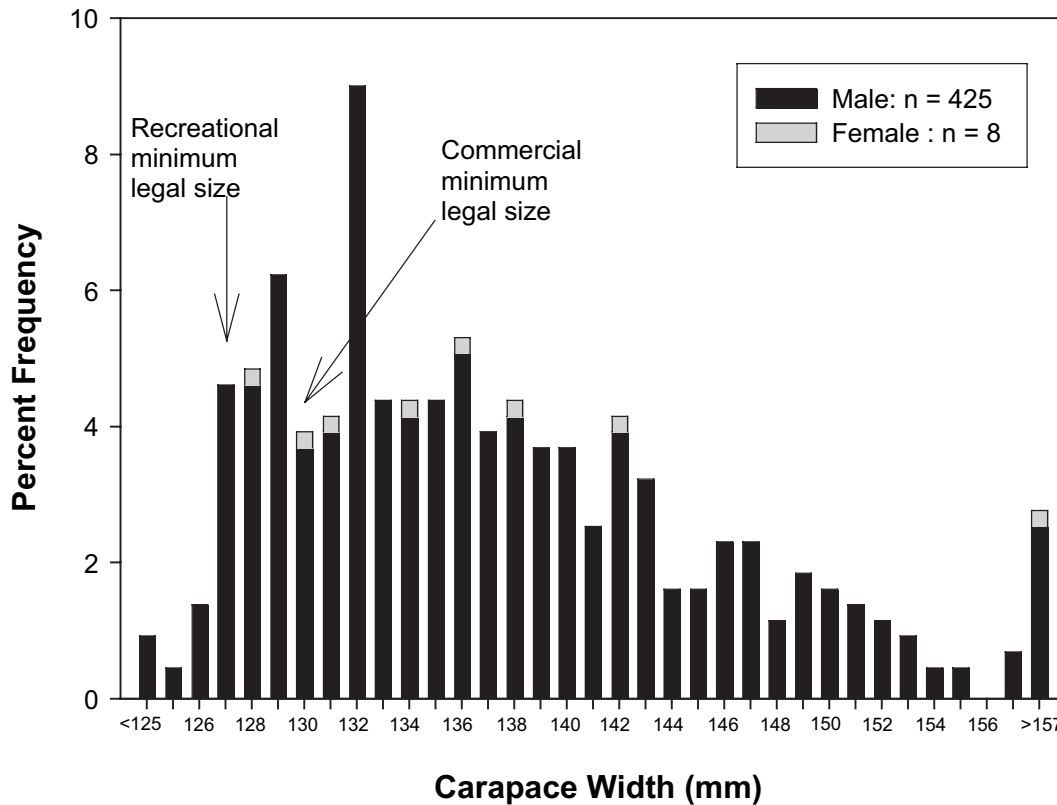


Figure 11. Size frequency for blue swimmer crabs kept by recreational boat-based fishers from Cockburn Sound (2001/02).

There was a relatively even distribution of crabs from the legal size of 127mm up to 143mm. Many crabs (22,300) were released, predominantly because they were smaller than the legal minimum CW of 127mm. Crabs as small as 120mm CW and as big as 177mm CW were kept by recreational crabbers. Very few female crabs were recorded (Figure 11). It should also be noted that 12% of the weight (2.2 tonnes) of crabs kept by boat-based fishers had a CW of 127mm, 128mm or 129mm, which is less than the commercial minimum size of 130mm.

Size Frequency of Commercial Catch

During January to March 2002 the commercial catch comprised predominantly male crabs (Figure 12b). At other times (April to June, July to September and December) the commercial catch comprised predominantly female crabs (Figure 12a,c & d). The reasons for this are not fully understood, however, possible causes include the higher abundance of male crabs in the areas fished between January and March, targeting of male crabs to avoid berried females, the release of females in breeding condition and reluctance of females in breeding condition to enter traps.

The distribution of CW changed during the year as the crabs progressed through various moult stages (Figure 12). The catch comprised predominantly smaller crabs during December. The size of crabs gradually increased during the following months (January to March, April to June and July to September). No data was available for October and November due to closure of the fishery at this time of the year.

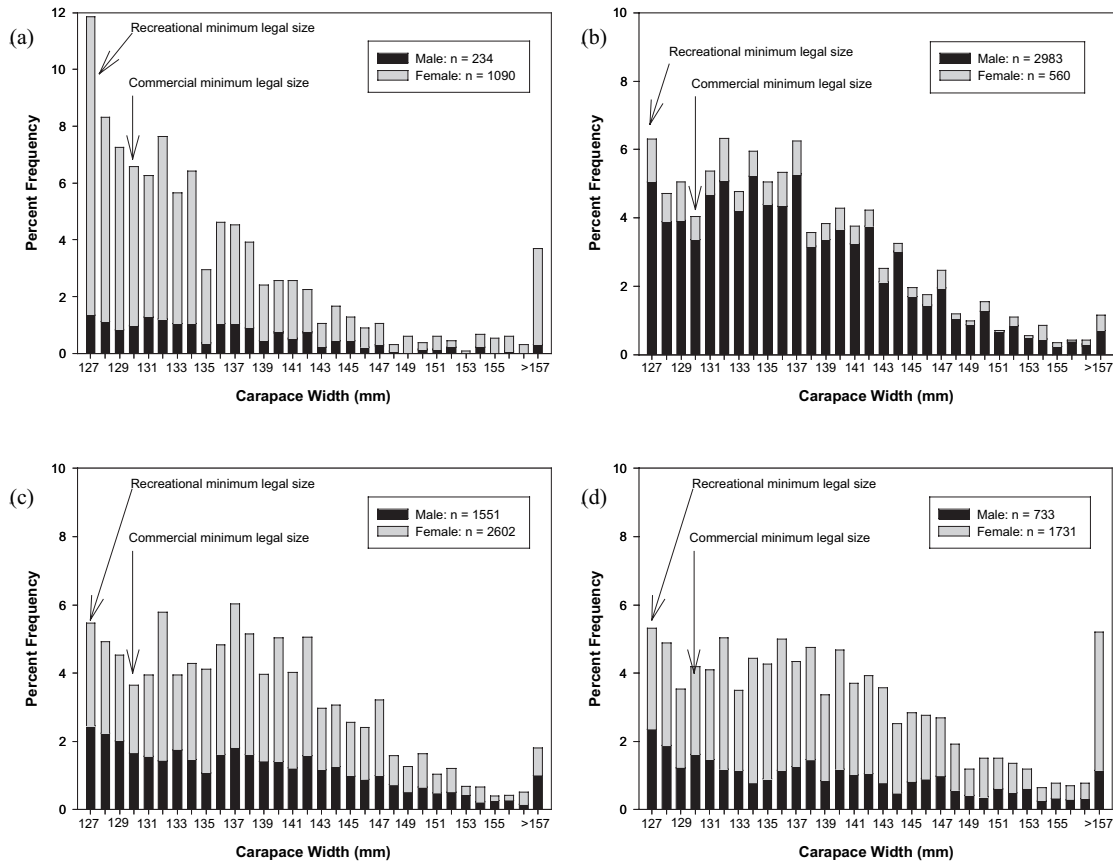


Figure 12. Size frequency for blue swimmer crabs ≥ 127 mm caught by commercial fishers from Cockburn Sound from December 2001 (a), January to March 2002 (b), April to June 2002 (c), and July to September 2002 (d).

The size composition of crabs caught in commercial traps between January 2002 and March 2002 (Figure 12b) was similar to the recreational catch (predominantly January 2002 to March 2002 (Figure 11)), although crabs below 130mm were discarded. There was a relatively even distribution of crabs from the legal size of 130mm up to 137mm. The ratio of male to female crabs between the commercial catch from January 2002 to March 2002 (Figure 12b) and the recreational catch (Figure 11) was slightly different. Almost all (97%) of the crabs kept by recreational fishers were male while 85% of the crabs kept by commercial fishers were male. However, the sex ratio of the commercial catch was distinctly different at other times of the year comprising 65% females from April to June, 75% females from July to September and 80% females during December.

Commercial crabbers only kept crabs with a CW of 130mm or larger due to the larger minimum legal size. Crabs of 127mm, 128mm and 129mm, which were released by commercial crabbers to make them available to the recreational sector, comprised 14% of the potential commercial crab catch. During 2001/02 commercial crabbers released 16.6 tonnes of crabs in these size classes of which 56% were males (although the sex ratio varied considerably throughout the year with 80% males from January to March, 45% males from April to June, 40% males from July to September and 12% males during December). However, few of these crabs were caught by the recreational sector since only 2.2 tonnes of crabs kept by recreational fishers had a CW of 127mm, 128mm or 129mm. Furthermore, there is little fishing effort from the recreational sector outside of January, February and March.

It is also unlikely that the recreational sector benefited from crabs of 127mm, 128mm and 129mm, which were released by commercial crabbers and made available to the recreational sector following the moult that occurs towards the end of the year (November/December). These predominantly female crabs did not noticeably increase the recreational (or commercial) catch between January and March. The sex composition for crabs of 127mm, 128mm and 129mm released by commercial crabbers in December (88% females) was very different to crabs caught by the recreational sector between January and March (98% males).

5.1.4 Comparison of Recreational and Commercial Catch and Effort

The commercial catch has shown a declining trend over the past five years, decreasing from 328.7 tonnes in 1996/97 to 103.6 tonnes during 2001/02 (Figure 13), due to lower levels of effort and variable recruitment into the fishery. There is considerable variability in the commercial catch from year to year reflecting changes in effort and different levels of recruitment into the fishery indicated by catch rates. The proportion of the total catch taken by recreational fishers from Cockburn Sound and Owen Anchorage has increased from 8% (28.4 tonnes of 357.1 tonnes) in 1996/97 (Sumner *et al.*, 2000) to 15% (18.5 tonnes of 122.1 tonnes) during 2001/02.

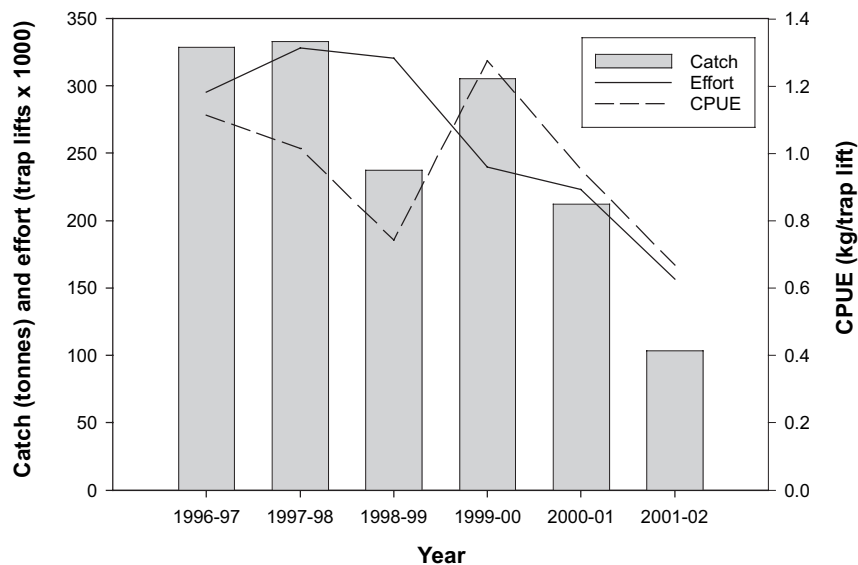


Figure 13. Annual commercial catch and effort for blue swimmer crabs in Cockburn Sound (1996-97 to 2001-02).

The commercial effort has decreased substantially from 295,000 trap lifts in 1996/97 to 156,000 trap lifts in 2001/02. The recreational effort decreased slightly from 23,000 fisher days in 1996/97 to 19,100 fisher days during 2001/02.

Both the commercial and recreational catch rates were higher in 1996/97 than 2001/02. The commercial catch per unit effort dropped from 1.11 kg/trap lift in 1996/97 to 0.66 kg/trap lift in 2001/02 due to a decrease in recruitment and increase in minimum size from 127mm to 130mm. A similar decrease from 14.4 crabs/boat in 1996/97 to 9.9 crabs/boat during 2001/02 was observed in the recreational sector. The catch rates for 2001/02 were 60% and 69% of the 1996/97 values for the commercial and recreational sectors respectively. This suggests that there is likely to be a positive correlation between catch rates for the two sectors. This is not surprising since the catch rates for both sectors will be related to recruitment, however, several years of recreational catch data would be required to prove this statistically.

5.2 Geographe Bay

During the survey, 929 interviews were conducted at boat ramps. Of these, 206 boats had been crabbing and 621 angling in Geographe Bay (79 were both crabbing and angling). A further 181 were not involved in any fishing activity.

The majority of the boat-based crabbers (57%) were local residents from the Busselton/Dunsborough region or from elsewhere in the south west (31%) (Figure 14).

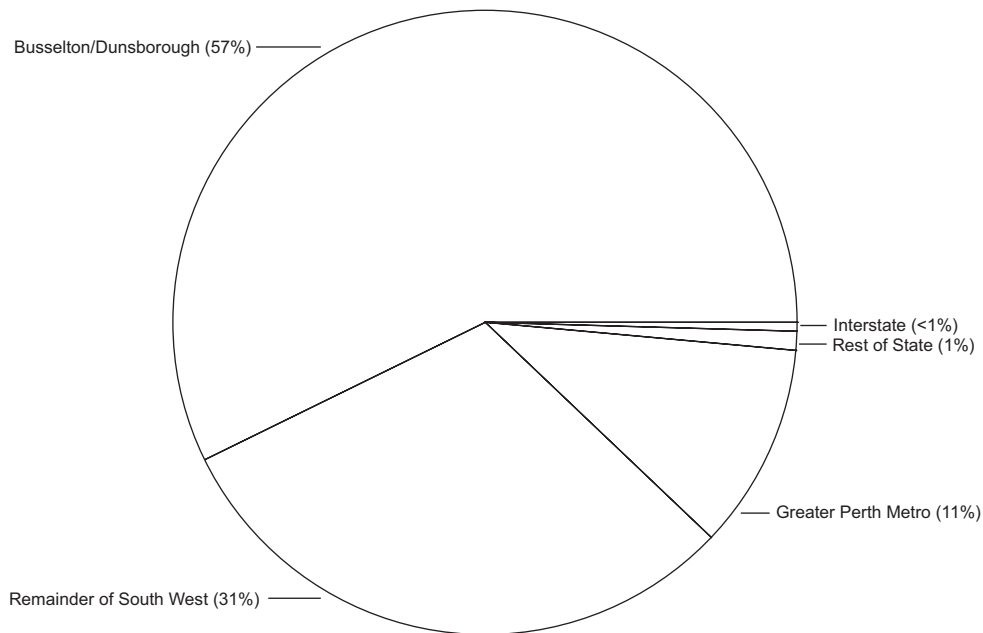


Figure 14. Boat-based crabbers' places of residence for Geographe Bay.

Blue swimmer crabs were the target species for 25% of recreational boat-based fishers interviewed in Geographe Bay. The remaining 75% of boat-based fishers targeted fish such as King George whiting, dhufish and skipjack trevally.

In addition to the interviews at boat ramps, 444 shore-based fishing parties were interviewed at the Busselton Jetty or between boat ramps. Of these groups, 52 were only crabbing, 331 were only angling and 61 were both crabbing and angling.

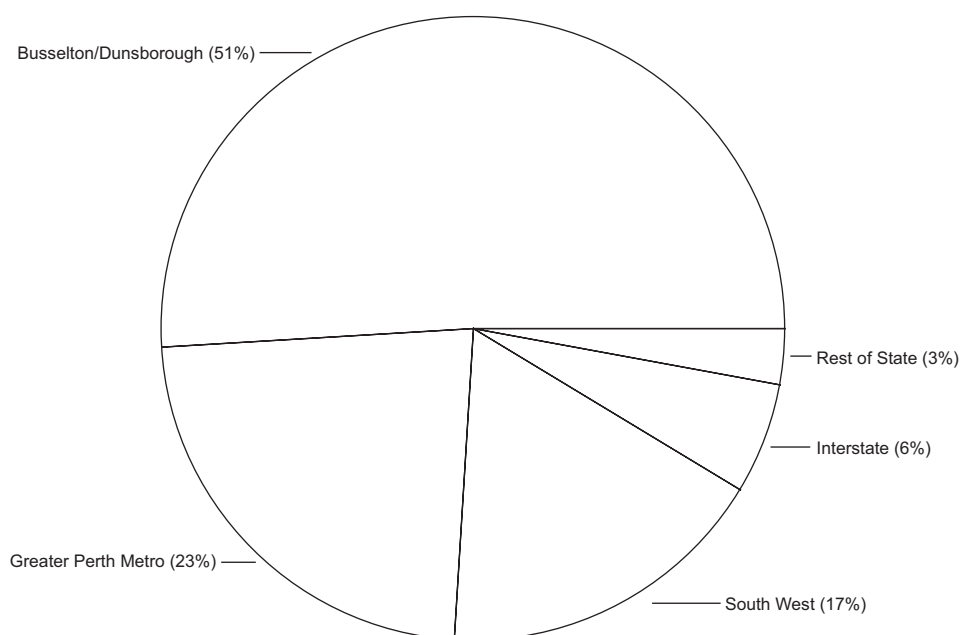


Figure 15. Shore-based crabbers' places of residence for Geographe Bay.

Although most (51%) shore-based crabbers were local residents from Busselton and Dunsborough, many (23%) were also from Perth (Figure 15).

5.2.1 Recreational Crabbing Effort

Recreational Boat-based crabbing effort

Most fishing occurred during the two survey periods of the day referred to as the morning or afternoon shift. However, some fishing also occurred both before and after the survey periods as indicated by the boat launch and retrieval times recorded by the interviewers. The ratio of effort occurring prior to the start of a morning shift to that occurring after the start of a morning shift was estimated and a correction factor (f) applied to the effort estimate in the mornings for each season (Table 7 and Appendix 5).

Table 7. Correction factor for effort occurring before the start of a morning shift.

Season	Ratio of effort prior to and after start of daily survey period	Correction factor (f)
Spring 2001	0.052	1.052
Summer	0.113	1.113
Autumn	0.022	1.022
Winter	0.014	1.014
Spring 2002	0.086	1.086

Most boats had returned to the ramp before the end of an afternoon shift (7pm during spring and summer, 6pm during autumn and 5:30pm during winter). The number of boats returning after this time of the day, based on the number of trailers remaining, was relatively small (around 1 per ramp on average during spring and summer) (Figure 16).

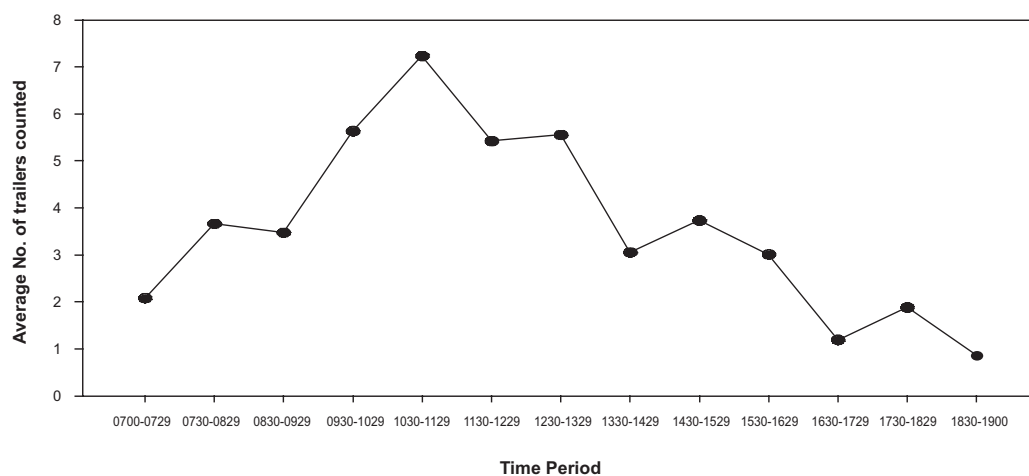


Figure 16. Average number of trailers counted on arrival/departure at all ramps during spring and summer.

Spring 2002 (September to November) was the most popular season for recreational boat-based crabbing in Geographe Bay with an estimated 10,500 fisher days (Figure 17). While, during 2001 spring, with 6,200 fisher days, was less popular than spring 2002 for boat-based crabbing. Crabbing effort continued throughout the year but at a lower level during summer, autumn and winter. The lowest effort occurred in autumn with 2,300 fisher days. The majority of boat-based crabbing took place in the morning.

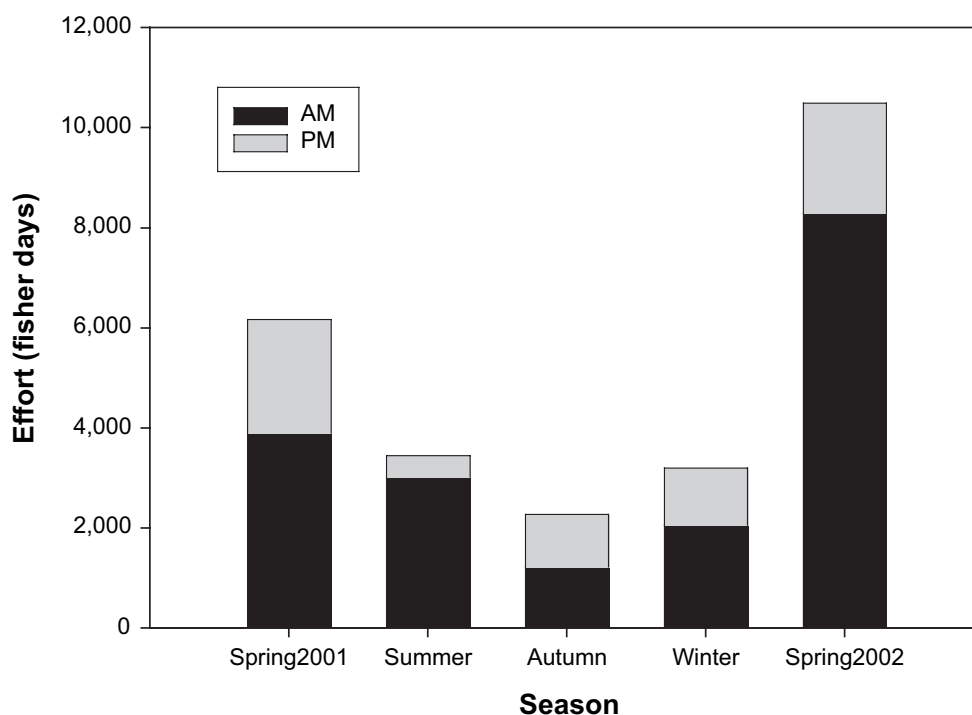


Figure 17. Recreational boat-based crabbing effort in Geographe Bay.

The estimated total annual recreational boat-based crabbing effort for the 2002 Geographe Bay crabbing season is 19,400 fisher days (22,800 boat hours). This effort does not include spring 2001, which was part of the 2001 crabbing season.

Spatial Distribution of Recreational Boat-based Crabbing Effort

Boat-based crabbing effort was greatest in the area adjacent to Port Geographe between Wonnerup and the Busselton Jetty. Boat-based crabbing was also popular between the Busselton Jetty and Vasse boat ramp (Figure 18).

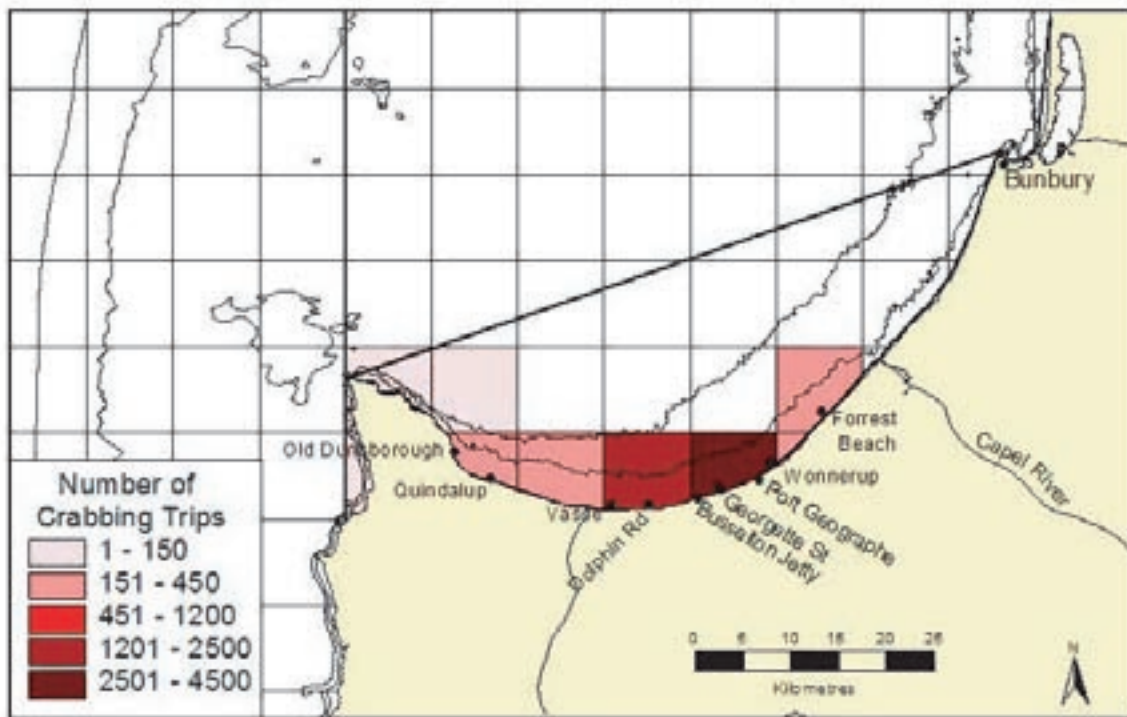


Figure 18. Spatial distribution of recreational boat-based crabbing effort in Geographe Bay.

Recreational Shore-based Crabbing Effort

Spring 2002 was the most popular season for shore based crabbers with an estimated fishing effort of 1,100 fisher days. Winter 2002 was also popular. Spring 2001 had less than one third of the effort of Spring 2002 (333 fisher days) (Figure 19).

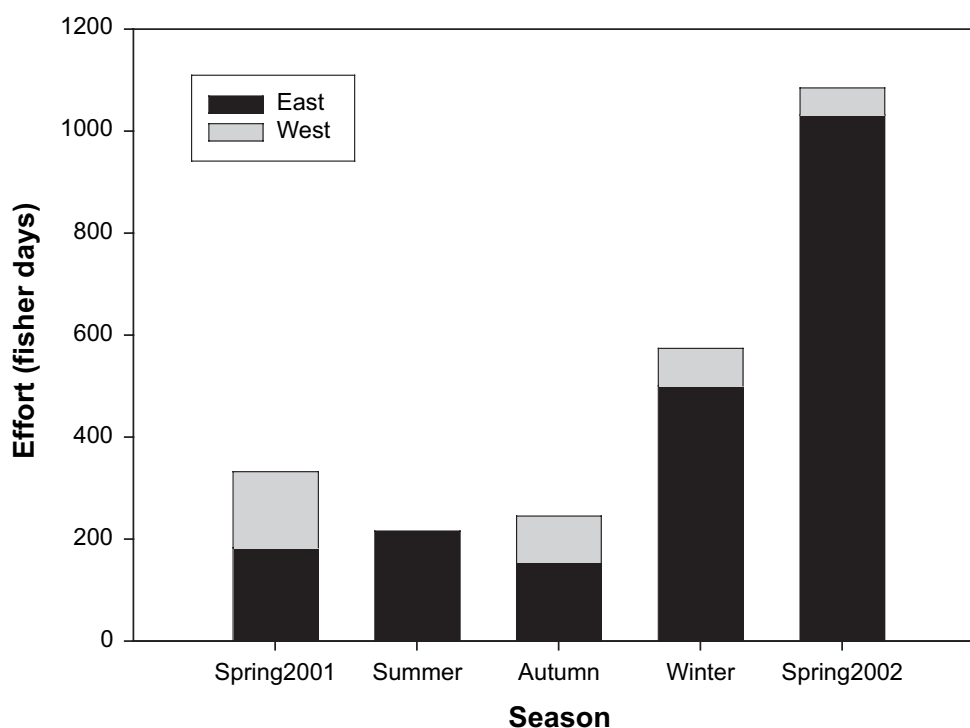


Figure 19. Recreational shore-based crabbing effort in Geographe Bay.

The eastern region of Geographe Bay had most of the shore based crabbing effort throughout the year (Figure 19). This is explained by the fact that the Busselton Jetty, which accounts for 79% of shore-based crabbing effort, was part of the eastern survey.

It was estimated that the total annual recreational shore-based effort for the 2002 crabbing season in Geographe Bay was 2,100 fisher days (6,600 fisher hours). This effort does not include spring 2001, which was part of the 2001 crabbing season.

5.2.2 Recreational Crabbing Catch

Recreational Boat-based Catch of Blue Swimmer Crabs

Where the sex of the crabs was recorded, of those kept 81% (2,517) were females and 19% (579) males. Of those released, 72% (3,594) were females and 28% (1,387) males.

Table 8. Estimated annual catch of blue swimmer crabs by recreational boat-based fishers in Geographe Bay (2002 crabbing season).

	Total	Standard Error
Number kept	131,500	13,600
Number released	219,200	23,200
Weight kept (tonnes)	27.0	2.8
Catch rate (crabs/boat/trip)	16.3	1.3

An estimated 131,500 crabs were kept (106,900 females and 24,600 males) and 219,200 released (158,200 females and 61,000 males) by boat-based crabbers (Table 8).

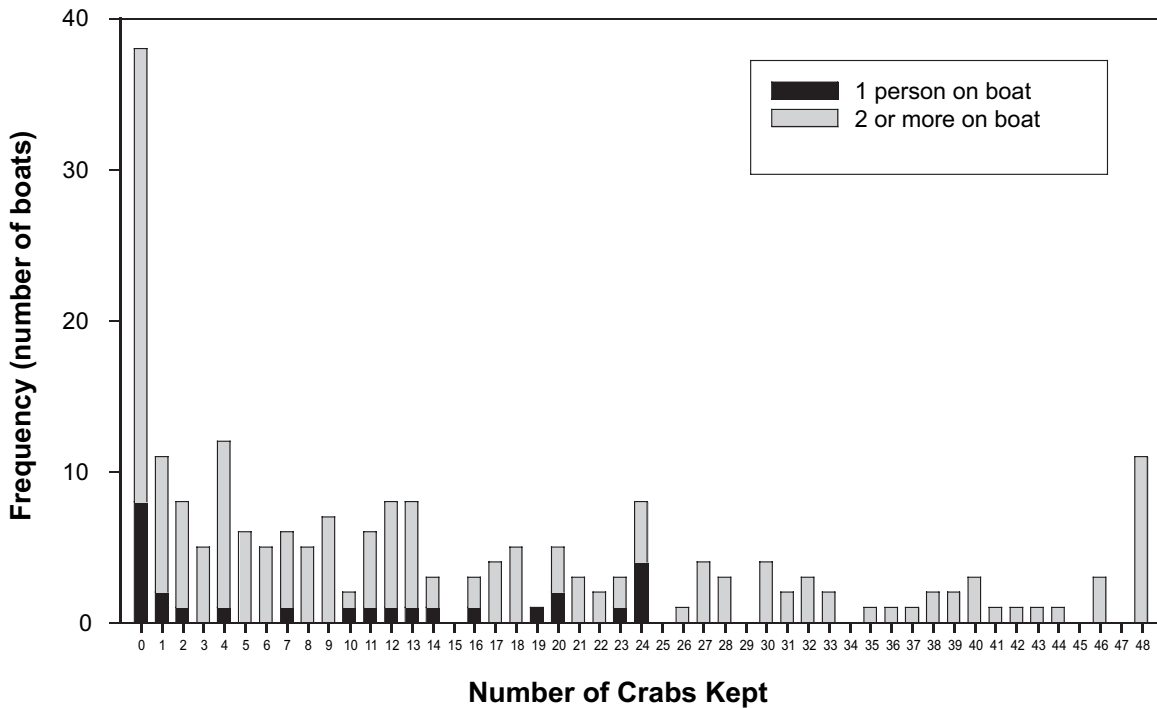


Figure 20. Frequency of crabs kept per boat in Geographe Bay.

Only 6% of recreational boats with two or more fishers on board achieved the boat limit of 48 crabs. However, 15% of boats with only one person on board achieved the bag limit of 24 crabs. Eighteen percent of boats targeting crabs did not land any crabs at all (Figure 20).

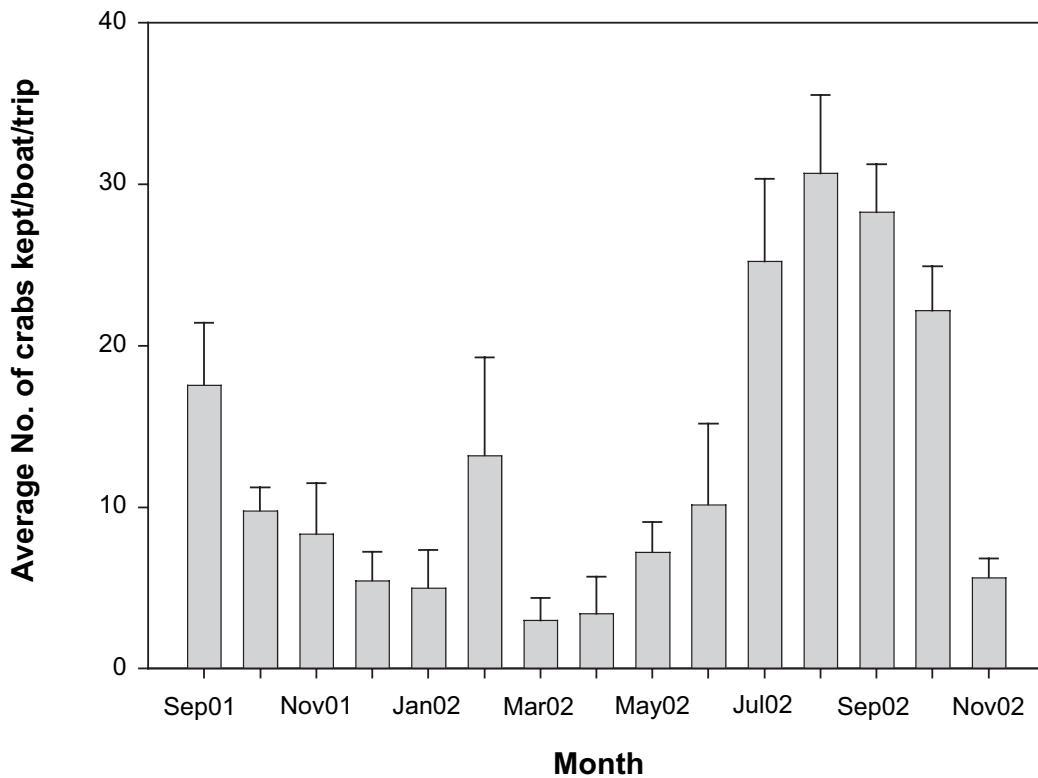


Figure 21. Crab catch rates per month for boat-based crabbers in Geographe Bay.

Catch rates peaked at just over 30 crabs per boat per trip during August 2002. Catch rates were slightly lower but steady at between 22 and 28 crabs per boat per trip for the rest of the 2002 crabbing season (July to October). Catch rates were much lower at all other times and during the two months of the 2001 crabbing season (September and October), which were also surveyed (Figure 21).

The majority of the crab catch was made between July and October (Figure 22). During 2002, the peak recreational catch (9 tonnes or 33%) and effort occurred in October.

Female crabs comprised around 90% of the crabs kept from May to November. However, when crabs were less abundant, particularly between December and April, female crabs only comprised around 30% of the crabs kept (Figure 22). The cycle of catch rates (Figure 21) and catches (Figure 22) relates directly to the timing of spawning in Summer and growth rates, which results in most crabs reaching legal size in Winter and Spring at about 18 months of age. There is a natural peak in abundance of legal size crabs during Winter and Spring and resulting heavy fishing pressure by predominantly local recreational and commercial fishers. There are few legal size crabs being available in Summer and Autumn due to heavy fishing pressure in previous months. Mature crabs, particularly females, may also move offshore into deeper water during Summer months and become less accessible to the fishery.

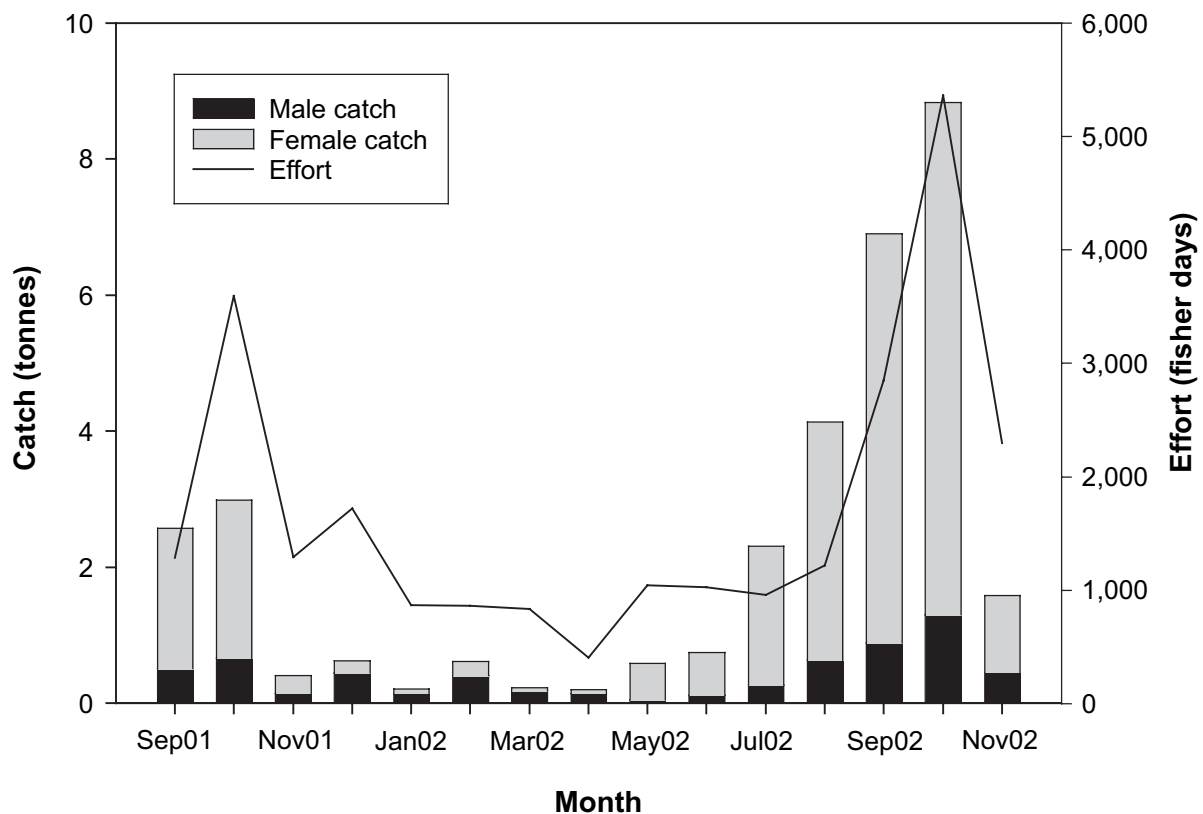


Figure 22. Estimated crab catch and effort per month from Geographe Bay.

The total annual weight of crabs kept by recreational boat-based crabbers for the 2002 Geographe Bay crabbing season was estimated to be 27 tonnes (21.6 tonnes of females and 5.4 tonnes of males) (Table 8). This catch does not include spring 2001, which was part of the 2001 crabbing season.

Catch rates are related to recruitment success with high catch rates in years of good recruitment and low catch rates when recruitment has been poor. The recreational catch (Figure 22) and catch rates (Figure 21) for September and October 2002 were larger than the same months during 2001, which indicates there is considerable variability in recruitment from year to year. For this reason, comparisons between the recreational and commercial catches must be made using results for the same year.

Furthermore, the variation in the recreational catch from year to year will be magnified by increasing effort (September and October 2002) in years where catch rates are high and reduced effort (September and October 2001) in years when catch rates are low (Figure 22). This will accentuate the variation in the recreational catch shares relative to the commercial catch where effort is effectively limited.

Recreational Shore-based Catch of Blue Swimmer Crabs

Of the crabs kept for which sex was recorded, 291 (80%) were females and 73 (20%) males. The sex of crabs released was also recorded where possible; of these 473 (61%) were females and 301 (39%) males. An estimated 8,100 crabs were kept and 19,400 released by shore-based crabbers (Table 9).

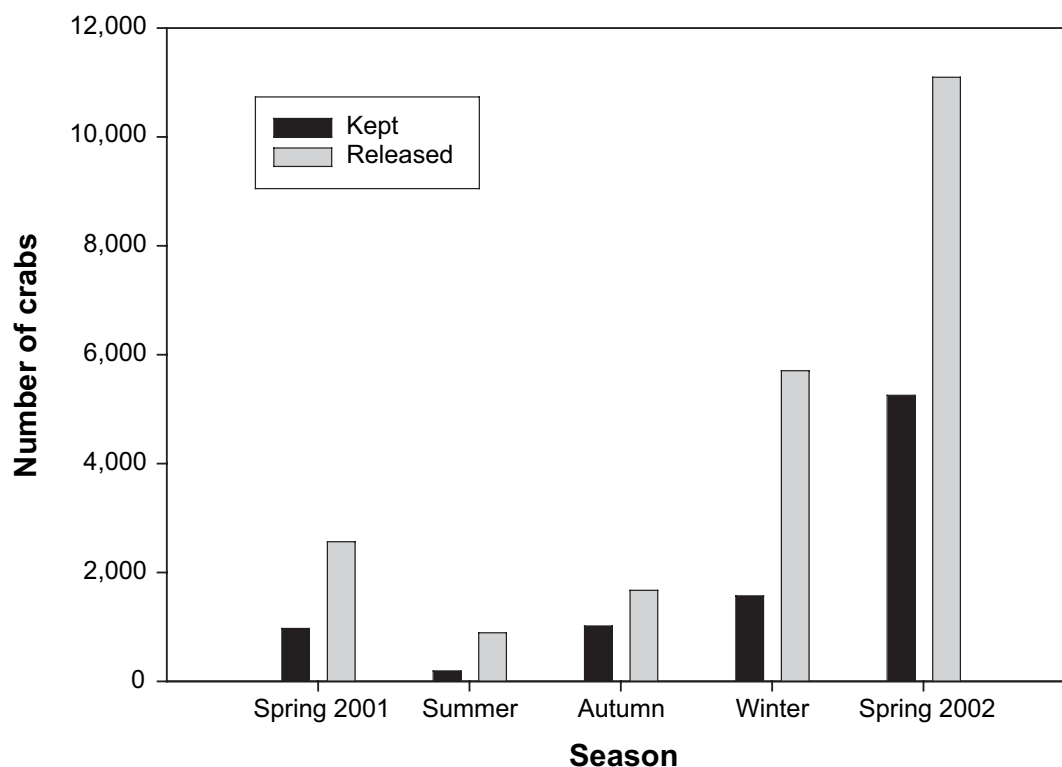


Figure 23. Estimated number of crabs kept and released per season by shore-based crabbers in Geographe Bay.

More crabs were kept by shore-based crabbers during spring 2002 than the other seasons surveyed (Figure 23). More crabs were released than kept throughout the year.

The total annual weight of crabs kept by recreational shore-based crabbers in Geographe Bay was estimated to be 1.58 tonnes (1.24 tonnes of females and 0.34 tonnes of males) (Table 9). This catch does not include spring 2001, which was part of the 2001 crabbing season.

Table 9. Estimated catch of blue swimmer crabs by recreational shore-based crabbers in Geographe Bay.

	Total	Standard Error
Number kept	8,100	1,800
Number released	19,400	4,200
Weight kept (tonnes)	1.58	0.35
Catch rate (crabs/party/trip)	6.9	1.0

Total Recreational Catch of Blue Swimmer Crabs

The total recreational harvest of blue swimmer crabs from Geographe Bay between December 2001 and November 2002 is estimated to have been 28.6 tonnes (139,600 crabs). It is also estimated that 238,600 crabs were released by recreational fishers over this same period (Table 10). This catch does not include spring 2001, which was part of the 2001 crabbing season.

Table 10. Estimated total recreational catch of blue swimmer crabs from Geographe Bay.

	Boat	Shore	Total	Standard Error
Number kept	131,500	8,100	139,600	13,700
Number released	219,200	19,400	238,600	23,500
Weight Kept (tonnes)	27.0	1.6	28.6	2.8

5.2.3 Size Frequency of Recreational and Commercial Catch

Size Frequency of Recreational Boat-based Catch

The size frequency for blue swimmer crabs displayed in Figure 24 shows the carapace width (CW) range for crabs kept by boat-based crabbers.

Half of the crabs kept by boat-based fishers have a CW between 127mm (minimum legal size) and 135mm. An estimated 219,200 crabs were released, predominantly because they were smaller than the legal minimum CW of 127mm. Only 5% of the weight (1.3 tonnes) of crabs kept by boat-based fishers have a CW of 127mm, which is less than the commercial minimum size of 128mm. Crabs as small as 110mm CW and as big as 172mm CW were kept by recreational boat-based crabbers. The distribution was similar for both male and female crabs (Figure 24), although the catch was predominantly females.

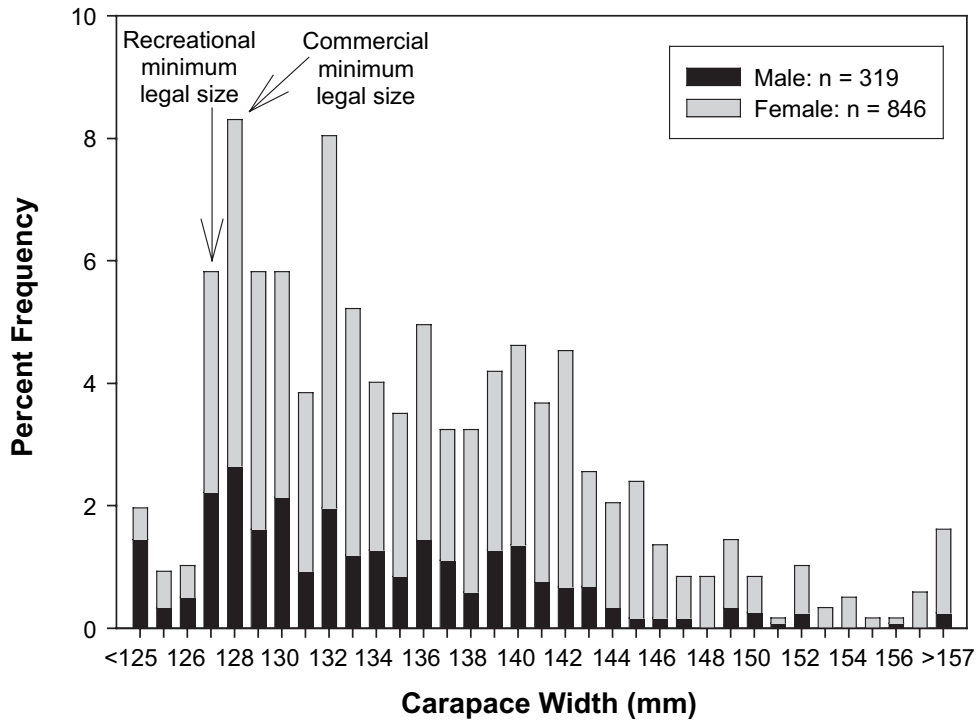


Figure 24. Size frequency for blue swimmer crabs kept by recreational boat-based fishers in Geographe Bay (2001/02).

Size Frequency of Recreational Shore-based Catch

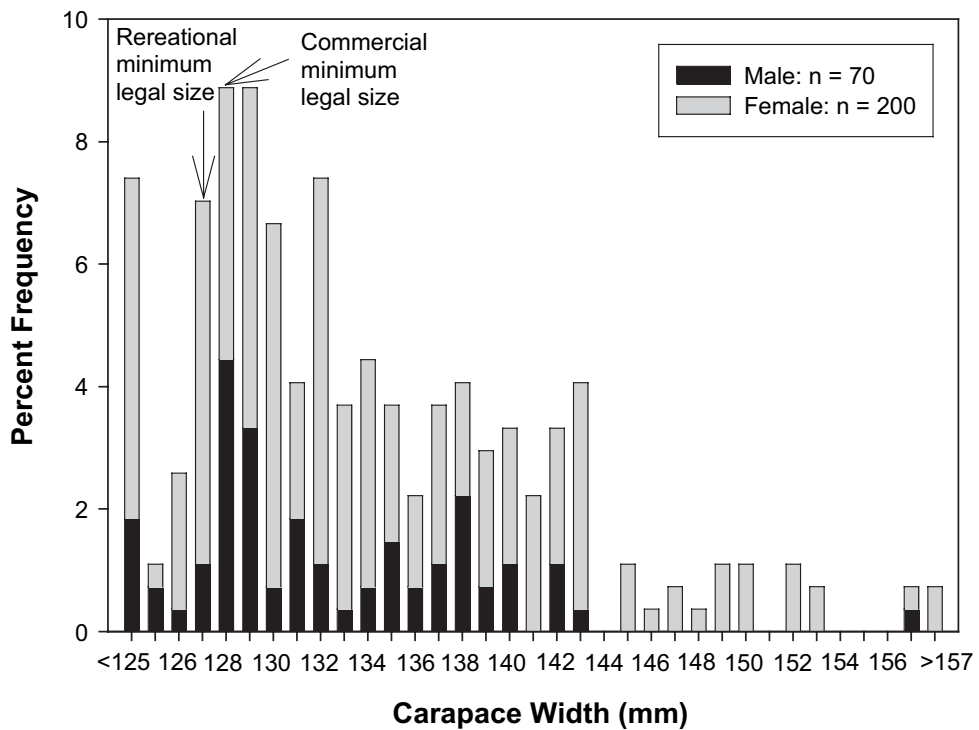


Figure 25. Size frequency for blue swimmer crabs kept by recreational shore-based fishers in Geographe Bay (2001/02).

Half of the crabs kept by shore-based fishers have a CW between 127mm (minimum legal size) and 134mm (Figure 25). Many crabs (19,400) were released, predominantly because they were smaller than the legal minimum CW of 127mm. Only 8% of legal size crabs kept by shore-based fishers have a CW of 127mm, which is less than the commercial minimum size of 128mm. Crabs as small as 111mm CW and as big as 164mm CW were kept by recreational shore-based crabbers, however, few crabs greater than 143mm were caught by shore-based fishers. The distribution was similar for both male and female crabs, although the catch was predominantly females.

Size Frequency of Commercial Catch

The size composition of the commercial catch (Figure 26) is similar to the recreational catch during 2001/02. Half of the crabs kept by commercial fishers in Geographe Bay during 2000 have a CW between 128mm (minimum legal size) and 134mm. The majority of crabs kept by both commercial and recreational boat-based fishers were female (85% and 81% respectively). This may be due to the fact that both the commercial and recreational fishers in Geographe Bay target crabs in shallow water close to the shore where female crabs tend to be more abundant.

Due to the larger minimum legal size, commercial crabbers only kept crabs of 128mm or bigger. Crabs of 127mm, which were released by commercial crabbers and made available to the recreational sector, comprised 7.45% of the potential commercial crab catch during 2000. The increased size limit of 128mm for commercial crabbers therefore made an extra 1.2 tonnes of crabs available to recreational crabbers in Geographe Bay in 2000.

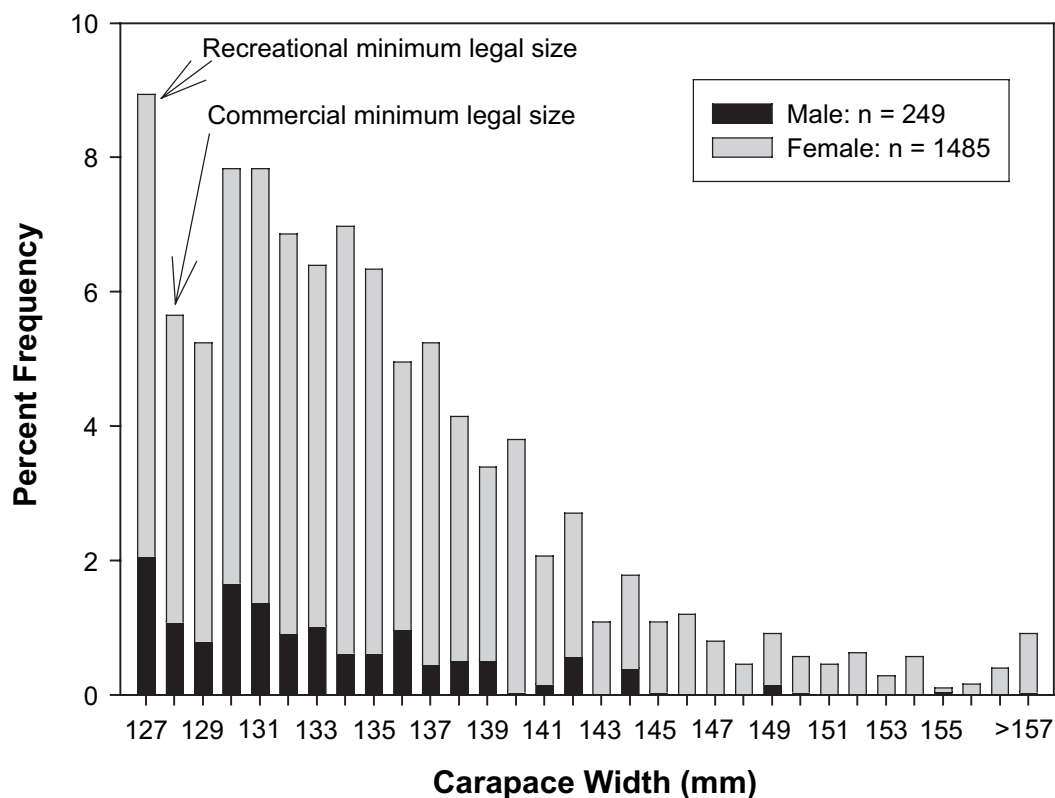


Figure 26. Size frequency for blue swimmer crabs ≥ 127 mm caught by commercial fishers from Geographe Bay (2000).

5.2.4 Comparison of Recreational and Commercial Catch and Effort

Over the past six years the commercial catch has fluctuated due to changing levels of recruitment into the fishery (Figure 27). For the two years the surveys were completed, the commercial catch was 16.5 tonnes in 1996/97 and 14.9 tonnes during 2002. The annual commercial crab catch peaked at 17.3 tonnes in 1997 and has fluctuated between 7.0 and 14.9 tonnes since. The overall commercial crabbing effort increased until 1997, after which it is difficult to compare effort between these years due to the change from using drop nets prior to 1999 to primarily traps in more recent years.

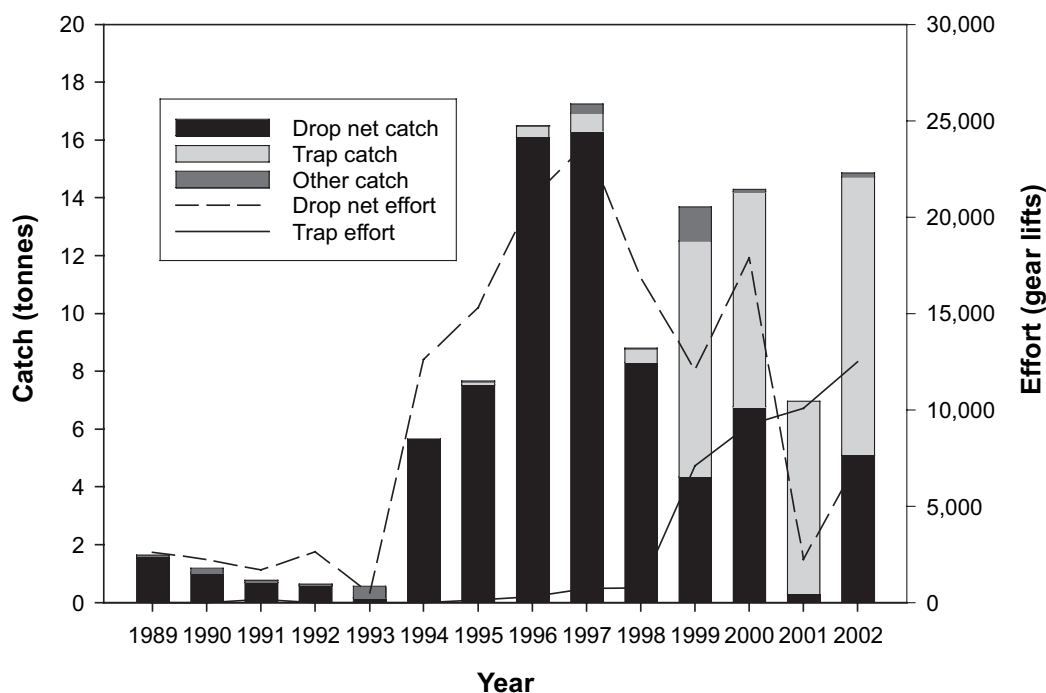


Figure 27. Annual commercial catch for blue swimmer crabs in Geographe Bay (1989 to 2002).

The proportion of the total catch taken by recreational fishers has increased from 51% (17.5 tonnes of 34.0 tonnes) in 1996/97 (Sumner *et al.*, 2000) to 66% (28.6 tonnes of 43.5 tonnes) during 2002. However, the 1996/97 survey only included the boat-based recreational catch. The increase in the recreational catch was primarily due to an increase in fishing effort.

It is difficult to compare commercial effort and catch rates between these years due to the change from using primarily drop nets in 1996/97 to primarily traps in 2002. The recreational boat-based effort increased from 10,900 fisher days in 1996/97 to 19,400 fisher days during 2002.

There was little change in the commercial and recreational catch rates from 1996/97 to 2002. The commercial catch per unit effort for drop nets was similar at 0.77 kg per net lift in 1996 and 0.70 kg per net lift in 2002. The catch rate for commercial traps cannot be compared for these years due to the low number of trap lifts in 1996. The recreational catch rates for these years were also similar at 18.2 crabs/boat in 1996/97 and 16.3 crabs/boat in 2002. The catch rates for 2002 were 91% and 90% of the 1996/97 values for the commercial and recreational sectors respectively. Both the commercial and recreational (September to November) catch and catch rates were lower in 2001 than 2002. This suggests that there is likely to be a positive

correlation between catch rates for the two sectors. This is not surprising since the catch rates for both sectors will be related to recruitment, however, several years of recreational catch data would be required to prove this statistically.

5.3 Evaluation of Management Measures

Management measures to allocate more of the catch to the recreational sector were put in place prior to the 2001/02 survey in Cockburn Sound and Geographe Bay. Estimates of the recreational catch were required to evaluate the effectiveness of these new management measures by comparing the catch shares with a survey conducted in 1996/97.

Cockburn Sound

The two sectors have agreed to resource sharing in Cockburn Sound with 5/8 (62.5%) of the catch allocated to commercial fishers and 3/8 (37.5%) to recreational fishers. This was to be achieved by applying a higher size limit of 130mm to commercial fishers from December 24, 1999. However, in the event that the recreational catch share was not achieved, the two sectors agreed to a commercial effort reduction (800 trap limit). The commercial fishery is also closed from 1st October to the 30th November to protect females during the breeding season.

The proportion of the total catch taken by recreational fishers from Cockburn Sound and Owen Anchorage has increased from 8% (28.4 tonnes of 357.1 tonnes) in 1996/97 (Sumner *et al.*, 2000) to 15% (around 1/8) (18.5 tonnes of 122.1 tonnes) during 2001/02. For both years, the recreational catch share was considerably smaller than the commercial catch and the proposed 3/8 allocation to the recreational sector was not achieved. There is considerable variation in the level of recruitment from year to year due to environmental effects. During 2002 a low level of recruitment limited both the recreational and commercial catches.

A further component of the management measures designed to provide the recreational sector with a 3/8 share was the higher minimum size limit adopted for commercial fishers. Based on the sampling, the 130mm minimum size limit for commercial fishers resulted in an estimated 16.6 tonnes of crabs between 127 and 130mm being returned to the sea over the year and available to recreational fishers. The creel survey results, however, indicate that only 2.2 tonnes of crabs kept by recreational fishers have a CW of greater than 127mm but less than the commercial minimum size of 130mm. This limited transfer of catch reflects the different spatial distribution of fishing effort between the two sectors. The recreational effort is concentrated in the shallow near shore areas at Palm Beach, East of Garden Island and North of Woodman Point (Figure 5) while the commercial effort is dispersed throughout Cockburn Sound. Secondly, many crabs with a CW between 127 and 130mm are discarded at times of the year when there is little or no recreational fishing effort i.e. Winter and Spring. These results indicate that the differential size limit is of limited benefit to the recreational sector.

The recreational sector would benefit more from a closure to commercial fishing in the three shallow near shore areas (Palm Beach, East of Garden Island and North of Woodman Point) frequented by recreational fishers. The closure to commercial fishing in these areas would need to be applied during the months of January, February and March.

Geographe Bay

Management measures to allocate more catch to the recreational sector were introduced in June 1999. These included spatial closures to exclude commercial fishers from areas frequented

by recreational fishers, temporal closures and a higher size limit of 128mm for commercial operators. The catch shares for Geographe Bay were not specified.

The proportion of the total catch taken by recreational fishers from Geographe Bay has increased from 51% (17.5 tonnes of 34.0 tonnes) in 1996/97 (Sumner *et al.*, 2000) to 66% (28.6 tonnes of 43.5 tonnes) during 2002. However, the 1996/97 survey only included the boat-based recreational catch. The increase in the recreational catch was primarily due to an increase in fishing effort. The recreational catch and catch rates for September and October 2002 were larger than the same months during 2001, which suggests that there is considerable variability in recruitment from year to year. This is supported by similar variation in the commercial catch results for these and other years.

Results show that 64% of recreational boats crabbing during 2002 were crabbing in the recreational only (commercial exclusion) zone within 400m of the shore between Dolphin Road and Port Geographe. Boats crabbing in this area took 72% of the boat-based catch. Most (79%) of the shore-based crabbing was from the Busselton Jetty, which is also in the recreational only zone.

The increased size limit of 128mm for commercial crabbers made 1.2 tonnes of crabs returned by commercial fishers available to the recreational sector in 2000. Results show that in 2002, 1.3 tonnes of crabs kept by recreational boat-based fishers had a carapace width of 127mm (less than the commercial minimum size of 128mm).

5.4 Compliance with Recreational Fishing Regulations

Cockburn Sound

There was a high level of compliance with the size limits amongst boat-based crabbers. Only eight (5%) of the 146 boat crews crabbing had kept undersize crabs. No boat-based crabbers exceeded the bag limit.

Geographe Bay

There was a fair level of compliance with the size limits amongst boat-based crabbers. Twenty four (12%) of the 206 boat crews crabbing had kept undersize crabs. No boat-based crabbers exceeded the bag limit.

Of the 24 boat crews which had kept undersize crabs, 16 (67%) were local Busselton or Dunsborough residents living within a 20 km radius of Geographe Bay and four (17%) were residents from the greater Perth metropolitan region living within a 50 km radius of the city centre. The remaining four were from other parts of the state.

Compliance rates were similar amongst shore-based crabbers with 12 (11%) of the 106 shore-based crabbing parties interviewed having kept undersize crabs. No shore-based crabbers exceeded the bag limit.

Of the 12 shore-based crabbing parties which kept undersize crabs, six (50%) were local Busselton and Dunsborough residents living within a 20 km radius of Geographe Bay and five (42%) were residents from the greater Perth metropolitan region living within a 50 km radius of the city centre. The remaining one was from interstate.

6.0 Benefits

The information provided by this study will be crucial for the consultation process involving the community, recreational fishers and commercial fishers in Cockburn Sound and Geographe Bay set up by the Department of Fisheries. Future management measures for these fisheries will be developed through the consultation process. Industry and recreational fishers will both benefit from the improved quality of management that will be possible with a clearer understanding of the recreational catch and effort in these areas.

In addition to the data collection role, the survey interviewers also performed a community awareness role. Recreational fishers benefited from having Department of Fisheries staff at the boat ramps to advise them of the fishing regulations and hand out brochures and fish rulers. Following the interview, recreational fishers were more aware of the management issues and the reasons for conducting the survey.

Fisheries managers in some other states will find the results of comparative value.

7.0 Further Development

Further creel surveys are required on a regular basis, about every five years, to monitor the recreational catch for both of these embayments and other areas throughout the south west of the state and to study long-term trends in catch and catch rates. This information is required to develop management strategies to facilitate the proper management of blue swimmer crab stocks in Cockburn Sound and Geographe Bay and ensure the sustainability of fishing activities and conservation of fish stocks and fish habitat.

This project has been succeeded by FRDC 2001/068 (Development of stock allocation and assessment techniques in WA blue swimmer crab fisheries). Now that the peak months when the recreational catch occurs is known, the later project will develop more cost effective survey methods during these months. The new project will further investigate the effect of minimum size and effort controls on resource shares in Cockburn Sound and Geographe Bay. The new project will also investigate whether juvenile abundance can be used to predict the strength of recruitment as well as providing an assessment for the Shark Bay blue swimmer crab fishery.

8.0 Planned Outcomes

The present study, funded by the Fisheries Research Development Corporation, which finished in June 2003 has estimated the total catch, catch rates, size composition and fishing effort for blue swimmer crabs in Cockburn Sound and Geographe Bay. The catch estimates from this survey have been compared with results from a similar creel survey conducted in 1996/97 before the management changes.

The results have already been utilised by the Department of Fisheries with the development of a management discussion paper (Borg and Campbell, 2003) about future management options for the commercial fishery for crabs in Geographe Bay. This study has highlighted the effectiveness of management measures, such as recreational only areas in Geographe Bay.

The results have also been utilised by the Department of Fisheries, Western Australian Fishing Industry Council and Recfishwest to resolve resource allocation issues between recreational and commercial fishers in Cockburn Sound. The decisions will now be based on current estimates of the catch and fishing effort.

The information collected will be used to develop strategies for the proper management of these blue swimmer crab fisheries to ensure the use of sustainable fishing practices and conservation of blue swimmer crab stocks and the marine habitat.

9.0 Conclusions

The study has provided information on the recreational catch and distribution of recreational crabbing effort in Cockburn Sound and Geographe Bay. The majority of the catch in these embayments was taken by boat-based crabbers, rather than shore-based crabbers.

The new management measures introduced in Cockburn Sound and Geographe Bay were intended to address resource allocation issues between the recreational and commercial sectors. It is difficult to determine the precise effects of the new management measures since this is confounded with changes in fishing effort, gear type and recruitment success (and hence abundance). However, the proportion of the recreational catch has increased for both areas.

Blue swimmer crabs are one of the key species for recreational boat-based fishers in Cockburn Sound with 18% of boats fishing in the embayment targeting crabs. The estimated recreational catch for 2001/02 of 18.5 tonnes comprised 15% of the total catch and has increased from 8% of the total catch during 1996/97. Although there has been a significant increase in recreational catch share, this appears to have been caused primarily by the reduction in commercial effort, rather than the change in the size limit to 130mm for commercial fishers. This did not appear to have caused the shift in catch shares expected, due to the limited temporal and spatial overlap in fishing activities the two sectors. For this reason, the recreational sector would benefit more from a closure to commercial fishing in the three shallow near-shore areas frequented by recreational fishers during January, February and March. The timing of the peak fishing effort for the two sectors was similar, i.e. over Summer, although the commercial sector continued fishing at a lower level through Autumn and Winter before the closure in October and November. The timing of peak fishing in Summer for both sectors was different to Geographe Bay, and reflects the catch being taken at about two years of age following the spring closure to commercial fishing.

In Geographe Bay, blue swimmer crabs are a key recreational focus with 25% of the boats surveyed targeting this species. The estimated recreational catch for 2002 of 28.6 tonnes comprised 66% of the total catch for the year and has increased from 51% recorded in 1996/97. The timing of both recreational and commercial peak catch periods was similar i.e. in Winter and Spring, with few legal size crabs remaining by the peak tourist seasons in Summer and Autumn. This timing of the peak catches is a function of the natural growth cycle of the species which spawns in Summer and reaches legal size about 18 months later in Winter and Spring of the following year. The fishing pressure during this period, predominantly by local resident recreational and commercial fishers, appears to result in few crabs of legal size surviving to their second year of life. This does not greatly impact on spawning capacity, noting that females spawn well below legal size and are therefore protected from fishing. The previously implemented management changes, including the spatial closure to commercial fishing in shallow inshore areas, has been successful in relocating some catch to the recreational sector. The slightly higher size limit for commercial fishers in Geographe Bay does appear to have contributed directly to the increased recreational catch in comparison to Cockburn Sound. This is likely to be the result of greater spatial and temporal overlaps in the effort of the two sectors in Geographe Bay. The timing of fishing in Geographe Bay and

the recreational catches being below the bag limits indicates that further resource reallocation to the recreational sector is unlikely to overcome the lack of legal sized crabs during the peak Summer tourist season. Additional crabs made available would primarily increase spring catch rates rather than allow increased survival into Summer.

The results show that measures to reduce the commercial catch, such as differential legal minimum sizes, closed seasons and effort restrictions will not necessarily achieve the desired management outcome in terms of increasing the recreational catch. The success of the management measures will depend on the ability of recreational fishers to take their allocated catch share and environmental factors that affect recruitment; both of which are beyond the control of fisheries managers.

Continued catches by the commercial sector, coupled with high recreational pressure, indicates that all stocks of blue swimmer crabs in the South West of Western Australia need continuing management. Resource allocation issues will provide challenges for the management of these and other similar recreational fisheries.

10.0 Acknowledgements

The authors acknowledge industry funding provided by Cockburn Cement Limited that enabled the study area in Cockburn Sound to be extended north to Fremantle to include Owen Anchorage, Success Bank and Parmelia Bank. Dr Lynda Bellchambers provided data on the length frequency of the commercial catch of blue swimmer crabs in Cockburn Sound and Geographe Bay.

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12.0 Appendices

Appendix 1: Intellectual Property

Based on the share of funding, the proportion of ownership of the project intellectual property is Department of Fisheries WA 50.5% and FRDC 49.5%.

Appendix 2: Staff

Principal Investigator	Neil Sumner
Project Coordinator	Ben Malseed
Database Administrator	Peta Williamson
Data Entry	Karen Santoro
Casual Survey Interviewers	Peter MacDonald
	Kim Clayton
	Aaron Turner
	Corey Wakefield
	Scott Evans

Appendix 3: Boat Ramp Trailer Count Form

BOAT RAMP FORM

Interviewer's Name: _____

Date: _____ Start Time(24hr): _____ Finish Time(24hr): _____

Boat Ramp Location: _____

ENVIRONMENTAL DATA

Wind:	Calm 1	Light 2	Mod 3	Strong 4	Gale 5	Direction
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Water:	Calm 1	Slight 2	Mod 3	Rough 4	V. Rough 5
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Cloud Cover:	Cloud %	Rainfall:	Nil 1	Light 2	Mod 3	Heavy 4
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Boat Launches				Boat Retrievals				Total Number of Trailers	
Time	Type	Time	Type	Time	Type	Time	Type	At Start	At Finish

Shore Fishers Sighted Between Last Ramp & This Ramp

Boat Types
 P: Power boat
 Y: Yacht
 O: Other

Appendix 4: Interview Questionnaire Form

Date: _____ Location: _____ Boat Reg. No. _____

Interview Time	Boat (Pwr/Yacht/Other)	Start Time	Fish/Dive/Snorkel/Other	Number in Boat	Number of Females in Boat	Age of Interviewee	Home Postcode of Interviewee	Length of Boat (ft/m)	Member Angling Club (Yes/No)	Time Spent Fishing (decimal hrs)	Block Number or Estuary	Number of Lines Used	Number and type of nets - Crab, Gill, Scoop, Pots	Number of Times Interviewed Before

FISHERS ONLY

Species	Number Kept	Number Released	Undersize Kept	Species Targeted _____ Measurements (mm)
Blue Swimmer Crab (Male)				
Blue Swimmer Crab (Female)				
Blue Swimmer Crab (Sex Unknown)				

Appendix 5: Catch and Effort Calculations for Boat-based Fishers

Estimation of Total Effort

The fishing effort for a day (boat hours) was estimated by the method of Jones and Robson (1991) as follows:

$$e = fT \sum_i \left[\left(\frac{1}{w_i} \right) \sum X_{ij} \right] \quad (1)$$

where T is the time taken to complete the bus route, w_i is the interviewer wait time at site i and X_{ij} is the time trailer j spends at site i . A correction factor $f \geq 1$ was used to adjust the effort for fishing that occurred before the morning shift commenced at time t .

$$f = \frac{\sum_j (r_j - \ell_j)}{\sum_j b_j} \quad (2)$$

where

$$b_j = \begin{cases} r_j - t, & \ell_j < t \\ r_j - \ell_j, & \ell_j \geq t \end{cases}$$

r_j is the retrieval time for boat j and ℓ_j is the launch time for boat j . The fishing effort was estimated for a random sample of days in each stratum (see Section 4.2). The estimated variance within stratum k is (Pollock *et al.*, 1994)

$$s_k^2 = \frac{1}{n_k - 1} \sum_{m=1}^{n_k} (e_{km} - \bar{e}_k)^2 \quad (3)$$

where n_k is the sample size (days) for stratum k , e_{km} the effort for stratum k on day m and \bar{e}_k the mean daily fishing effort for stratum k . The variance associated with the estimate of the mean, with finite population correction (Neter *et al.*, 1988), is calculated as

$$Var(\bar{e}_k) = \frac{s_k^2}{n_k} \left(\frac{N_k - n_k}{N_k} \right) \quad (4)$$

where N_k is the total number of days in stratum k . The total effort for stratum k is estimated as

$$\hat{E}_k = \frac{N_k}{n_k} \sum_{m=1}^{n_k} e_{km} \quad (5)$$

The variance associated with \hat{E}_k is estimated by

$$Var(\hat{E}_k) = N_k^2 Var(\bar{e}_k) \quad (6)$$

and the standard error is calculated by the usual method

$$SE(\hat{E}_k) = \sqrt{Var(\hat{E}_k)} \quad (7)$$

The total effort is estimated by summing the effort for the strata as follows

$$\hat{E} = \sum_{k=1}^n \hat{E}_k \quad (8)$$

where n is the number of strata. Similarly the variance of \hat{E} is estimated from the independent variances for the strata

$$Var(\hat{E}) = \sum_{k=1}^n Var(\hat{E}_k) \quad (9)$$

and the standard error of \hat{E} is calculated by the usual method

$$SE(\hat{E}) = \sqrt{Var(\hat{E})} \quad (10)$$

Estimation of Total Catch

The catch rate for each stratum k is estimated by (Crone and Malvestuto, 1991)

$$\hat{R}_k = \frac{\bar{c}_k}{\bar{L}_k} = \frac{\sum_{j=1}^{n_k} c_{kj} / n_k}{\sum_{j=1}^{n_k} L_{kj} / n_k} \quad (11)$$

where n_k is the number of boats where the catch was recorded, c_{kj} the catch for boat j and L_{kj} the effort, in boat hours, for boat j . The variances for \bar{c}_k and \bar{L}_k can be calculated by the usual method (see (3) and (4) without the finite population correction factor). The variance for \hat{R}_k can be estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{R}_k) \approx \hat{R}_k^2 \left(\frac{Var(\bar{c}_k)}{\bar{c}_k^2} + \frac{Var(\bar{L}_k)}{\bar{L}_k^2} - \frac{2Cov(\bar{c}_k, \bar{L}_k)}{\bar{c}_k \bar{L}_k} \right) \quad (12)$$

The total catch for stratum k is estimated as

$$\hat{C}_k = \hat{E}_k \hat{R}_k \quad (13)$$

and the variance was estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{C}_k) \approx \hat{C}_k^2 \left(\frac{Var(\hat{E}_k)}{\hat{E}_k^2} + \frac{Var(\hat{R}_k)}{\hat{R}_k^2} + \frac{2Cov(\hat{E}_k, \hat{R}_k)}{\hat{E}_k \hat{R}_k} \right) \quad (14)$$

where the covariance term was assumed to be zero. The total catch is estimated by summing the catch for each strata as follows

$$\hat{C} = \sum_{k=1}^n \hat{C}_k \quad (15)$$

and the variance of \hat{C} is estimated as

$$Var(\hat{C}) = \sum_{k=1}^n Var(\hat{C}_k) \quad (16)$$

and the standard error of \hat{C} is calculated by the usual method

$$SE(\hat{C}) = \sqrt{Var(\hat{C})} \quad (17)$$

Appendix 6: Catch and Effort Calculations for Shore-based Fishers

Estimation of Total Effort

The fishing effort for a half day shift (fisher hours) was estimated by the roving creel survey method (Pollock *et al.*, 1994) as follows:

$$e = IT \quad (1)$$

where I is the count of fishers and T is the length of the shift. The estimated variance within stratum k is (Pollock *et al.*, 1994)

$$s_k^2 = \frac{1}{n_k - 1} \sum_{m=1}^{n_k} (e_{km} - \bar{e}_k)^2 \quad (2)$$

where n_k is the sample size (days) for stratum k , e_{km} the effort for stratum k on day m and \bar{e}_k the mean daily fishing effort for stratum k . The variance associated with the estimate of the mean, with finite population correction (Neter *et al.*, 1988), is calculated as

$$Var(\bar{e}_k) = \frac{s_k^2}{n_k} \left(\frac{N_k - n_k}{N_k} \right) \quad (3)$$

where N_k is the total number of days in stratum k . The total effort for stratum k is estimated as

$$\hat{E}_k = \frac{N_k}{n_k} \sum_{m=1}^{n_k} e_{km} \quad (4)$$

The variance associated with \hat{E}_k is estimated by

$$Var(\hat{E}_k) = N_k^2 Var(\bar{e}_k) \quad (5)$$

and the standard error is calculated by the usual method

$$SE(\hat{E}_k) = \sqrt{Var(\hat{E}_k)} \quad (6)$$

The total effort is estimated by summing the effort for each strata as follows

$$\hat{E} = \sum_{k=1}^n \hat{E}_k \quad (7)$$

where n is the number of strata. Similarly the variance of \hat{E} is estimated as

$$Var(\hat{E}) = \sum_{k=1}^n Var(\hat{E}_k) \quad (8)$$

and the standard error of \hat{E} is calculated by the usual method

$$SE(\hat{E}) = \sqrt{Var(\hat{E})} \quad (9)$$

Estimation of Total Catch

The catch rate for each stratum k is estimated by (Pollock *et al.*, 1994)

$$\hat{R}_k = \frac{\sum_{j=1}^{n_k} \frac{w_{kj} c_{kj}}{L_{kj}}}{\sum_{j=1}^{n_k} w_{kj}} \quad (10)$$

where c_{kj} is the total catch and L_{kj} the total effort, in person hours, for party j with w_{kj} fishers, n_k is the number of shore-based parties where the catch was recorded. The variance for \hat{R}_k can be estimated using the formulae

$$Var(\hat{R}_k) \approx \frac{1}{\sum_{j=1}^{n_k} w_{kj} \left(\sum_{j=1}^{n_k} w_{kj} - 1 \right)} \sum_{j=1}^{n_k} w_{kj} \left(\frac{c_{kj}}{L_{kj}} - \hat{R}_k \right)^2 \quad (11)$$

The total catch for stratum k is estimated as

$$\hat{C}_k = \hat{E}_k \hat{R}_k \quad (12)$$

and the variance was estimated using the formulae described in Kendall and Stuart (1969)

$$Var(\hat{C}_k) \approx \hat{C}_k^2 \left(\frac{Var(\hat{E}_k)}{\hat{E}_k^2} + \frac{Var(\hat{R}_k)}{\hat{R}_k^2} + \frac{2Cov(\hat{E}_k, \hat{R}_k)}{\hat{E}_k \hat{R}_k} \right) \quad (13)$$

where the covariance term was assumed to be zero. The total catch is estimated by summing the catch for each strata as follows

$$\hat{C} = \sum_{k=1}^n \hat{C}_k \quad (14)$$

and the variance of \hat{C} is estimated as

$$Var(\hat{C}) = \sum_{k=1}^n Var(\hat{C}_k) \quad (15)$$

and the standard error of \hat{C} is calculated by the usual method

$$SE(\hat{C}) = \sqrt{Var(\hat{C})} \quad (16)$$

List of Fisheries Research Reports

Not all have been listed here, a complete list is available online at <http://www.fish.wa.gov.au/res>

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