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An assessment of the blue swimmer crab fishery in Geographe Bay

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Government of Western Australia

Fish for the future

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Fisheries Research in Western Australia

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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.

Contents

An assessment of the blue swimmer crab fishery in Geographe Bay

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Abstract

The study was undertaken to provide detailed information on blue swimmer crabs in Geographe Bay so that the recreational and commercial fishery issues could be addressed using more accurate data than was previously available. A ministerial decision that banned commercial fishing for blue swimmer crabs in Geographe Bay was made in January 2005 while this study was underway. The intention of this report was to provide a summary of information on crab stocks in the region, not to alter the current management arrangements. This report describes experimental sampling, commercial catch statistics, commercial catch monitoring and surveys of recreational fishers to describe blue swimmer crab stocks in Geographe Bay and their use by the commercial and recreational sectors.

Until January 2005, the Geographe Bay region was the southern most commercial blue swimmer crab fishery in the state. Commercial catches increased from < 2 tonnes annually during 1989 – 1993 to a peak of 17 tonnes in 1997 and remained between 7 – 15 tonnes annually between 1998 and 2002. In 2002, recreational fishers caught 10.24 tonnes of blue swimmer crabs in Geographe Bay and this figure decreased to 7.5 tonnes in 2003. Commercial – recreational catch sharing arrangements implemented in 1999 and again in 2002, including differential size limits for recreational versus commercial fishers, commercial effort restrictions and areas closed to commercial fishing, have been successful in increasing the share of catches taken by the recreational sector from 51% in 1996/97 to 64 – 66% in 2002/03. The fishery is unique in that it is predominantly a winter fishery and is also unusual because sex ratios favor females. It is likely that the fishery is driven by females migrating southward out of the Leschenault Estuary and Koombana Bay. Spawning in Geographe Bay appears to occur mainly in late spring.

1.0 Introduction

1.1 Background

The blue swimmer crab *Portunus pelagicus* Linnaeus is abundant in many coastal marine and estuarine waters throughout the Indo-West Pacific (Stephenson, 1962; Kailola *et al.,* 1993) and forms the basis for an expanding commercial and a key recreational fishery in Australia. In Western Australia (W.A.), blue swimmer crabs are found from Albany to the Northern Territory border. Blue swimmer crabs inhabit sandy, muddy, algal and seagrass habitats in estuaries, sheltered bays and offshore waters of up to 50 metres depth (Williams, 1982; Edgar, 1990; Borg and Campbell, 2003).

The total W.A. blue swimmer crab commercial catch expanded rapidly in the 1990's and peaked at 1003 tonnes in 2002/03. Recreational fishing for blue swimmer crabs in the south-west of W.A. dominates the inshore recreational catch in terms of the number caught for a single species, with 394 tonnes caught by recreational fishers in the south-west between August 1998 and July 1999 (Sumner *et al.,* 2000).

With the increasing popularity of recreational fishing and the potential for increasing interaction between commercial and recreational fishers, there are concerns that considerable pressure is being placed on the stocks of blue swimmer crabs in some areas around the state (Sumner *et al.,* 2000). While the numbers of commercial licences in many fisheries are being maintained at a constant level, catches are increasing in some areas of the state. Increasing catches are primarily due to advances in gear technology and fishing techniques in the commercial sector, developing commercial fisheries in Shark Bay and further north, coupled with the increasing popularity of recreational fishing particularly in the south-west. This has led to considerable debate and controversy between recreational and commercial fishers and growing concern that the resource sharing issue between the commercial and recreational sectors should be addressed.

Geographe Bay (33° 39'S, 115° 20'E) (Figure 1) the southern most commercial blue swimmer crab fishery on the west coast of W.A., is fished by both commercial and recreational fishers. Much of the debate between user groups is due to the perception that commercial fishers take the majority of the resource, leaving little for recreational fishers especially during holiday periods. However, the recreational catch between December 2001 and November 2002 (28.6 tonnes) was almost double the commercial catch (14.9 tonnes) (Sumner and Malseed, 2004). Despite this, the arrangements that were in place until recently have produced results unsatisfactory to some members of the recreational fishing sector and the commercial fishing sector. This conflict has resulted in commercial fishing for blue swimmer crabs being banned in Geographe Bay in January 2005. This report documents the fishing activities of the two sectors in Geographe Bay and provides a review of the blue swimmer crab stocks in the region.

Previous studies on the biology and life history traits of blue swimmer crabs in estuaries and a limited number of oceanic embayments in W.A. have revealed that aspects of the biology of blue swimmer crabs vary between locations. For example, a study of genetic stock structure of *P. pelagicus* throughout Australia revealed that populations from Geographe Bay and Peel-Harvey Estuary are genetically distinguishable from Cockburn Sound, Dongara and several other sites in the north-west (Chaplin *et al.,* 2001). Other studies of *P. pelagicus* in W.A. have revealed geographical variations in aspects of the biology of *P. pelagicus* such as the timing of spawning (Potter and de Lestang, 2000) and size at sexual maturity (de Lestang *et al.,* 2003).

However no research has been conducted specifically on blue swimmer crabs in Geographe Bay.

Historically resource sharing issues have been resolved by differential size limits and reducing commercial effort, usually by gear reductions (Shanks, 1999; Bellchambers *et al.,* 2005). The previous resource sharing agreement in Geographe Bay was based on temporal and spatial restrictions, with an inshore area (< 400m offshore) dedicated exclusively to recreational fishing. While the previous arrangements are based on catch and effort information from both the recreational and commercial sector, there has been no fishery independent survey on the distribution and abundance of blue swimmer crabs in this area. The lack of a baseline data to compare future catches/stocks has been identified as a gap in the knowledge of blue swimmer crab stocks in this region. The collection of this data and establishment of protocol for future surveys will ensure that future reviews of the management arrangements will have the best possible information to enable management decision on the crab resources.

Information is required incorporating aspects of blue swimmer crab biology, habitat requirements and fishery dynamics so that sustainable catch levels can be identified. The determination of crab densities and distribution over the various habitat types in Geographe Bay will assist to ensure that crab resources can be appropriately managed. The proposed survey will set the protocol for future surveys and provide information to allow a comparison of the results of management arrangements and a more proactive approach. It will also help ensure that management arrangements are sound, and that local communities who have a wider interest in the management of the Geographe Bay marine environment can be assured that adequate studies of their local resource have been undertaken.

1.2 The commercial fishery

The fishery in Geographe Bay commences when crabs move into the area in about late autumn (May) until about November and is unique in that it is most productive during winter months. The commercial fishery for *P. pelagicus* in Geographe Bay is one of six key commercial crab fisheries in waters between Port Hedland in the north-west and Albany in the south. Twelve commercial fishers operated in Geographe Bay, half of whom identified themselves as genuine crab fishers, however all licenced commercial fishers in W.A. were permitted to set drop nets in the waters of Geographe Bay (Borg and Campbell, 2003). Eight licence holders had exemptions to take crabs using traps (40 traps each), while there was no limit on the number of drop nets that could be used in Geographe Bay.

In 1999 a number of management arrangements were introduced, including a limit on the total number of traps that could be used in the fishery (320), temporal restrictions which limit commercial fishing to between an hour before sunset to an hour after sunrise and exclude weekends, public holidays and the months between November and April. Spatial restrictions were also introduced with an inshore area (< 400 m offshore) dedicated exclusively to recreational fishing. The legal commercial size limit for *P. pelagicus* is 128 mm carapace width (CW) compared to 127 mm for the recreational fishery (Borg and Campbell, 2003).

Commercial crab catches in Geographe Bay increased from < 2 tonnes per annum between 1989 and 1993 to a peak of 17 tonnes in 1997 and have fluctuated between 7 and 15 tonnes per annum between 1998 and 2002. Although debate between recreational and commercial fishing sectors is fuelled by the perception that commercial fishers take a large part of the catch, a Department of Fisheries (Western Australia) survey conducted in 2002 indicated that only

35% of the total crab catches from Geographe Bay were taken by commercial fishers (Borg and Campbell, 2003). The inshore nature of the fishery makes commercial fishing highly visible from the beach and this is likely to have contributed to the controversy surrounding commercial fishing for blue swimmer crabs in Geographe Bay. A ban was placed on commercial harvesting of blue swimmer crabs in January 2005.

1.3 The recreational fishery

Portunus pelagicus is one of the most important species targeted by recreational fishers in southwestern Australia (Laurenson *et al.,* 1993; Sumner *et al.,* 2000). Blue swimmer crabs in Geographe Bay are a significant natural feature that contribute to the tourist appeal of the south-west region. Most recreational fishers are residents, along with tourists in school holidays (Borg and Campbell, 2003). Busselton, with an estimated population of 23,337 (2001) and a growth rate of 5.1% p.a, receives over 300,000 tourists between January and June (South West Development Commission, 2003). The main group of tourists arrive in summer, *e.g.* Christmas school holidays, after the commercial fishing operations in winter.

A recent recreational survey estimated the recreational catch of *P. pelagicus* from Geographe Bay from December 2001 to November 2002 to be 28.6 tonnes, with 94% of this catch taken by boat-based as opposed to shore-based fishers (Sumner and Malseed, 2004). The majority of the recreational catches was taken < 200 m from shore (Sumner and Malseed, 2004). The survey showed 82% of the recreational catch of *P. pelagicus* in Geographe Bay was taken between July and September (Sumner and Malseed, 2004). There is no recreational licence for blue swimmer crabs in Western Australia. However, a bag limit of 20 crabs per person or 40 per boat and a minimum legal size limit of 127 mm CW applies. The fishery is closed to all fishers in October to protect spawning females. Most recreational fishing occurs between the Port Geographe Marina and the Busselton Jetty.

1.4 Objectives of the present study

The objectives of the present study were to undertake an experimental sampling regime in order to determine the spatial and temporal distribution and abundance by size and sex of blue swimmer crabs in Geographe Bay. Commerical catch and effort statistics have been reviewed and the results of commercial length monitoring trips that were undertaken in Geographe Bay are discussed. The results of recreational fishing surveys, undertaken in 1996/97, 2001/02 and 2003 are also reported.

2.0 Materials and Methods

2.1 Inshore sampling regime

2.1.1 Location of sampling

Geographe Bay (Figure 1) is the southern most protected marine embayment in south-west Australia. It is north facing and therefore the prevailing south-westerly swell is refracted around into the bay (Walker *et al.,* 1987). Geographe Bay covers an area of about 290 square nautical miles between the north-west point of Cape Naturaliste (33° 32’ S, 115°00’E) and the lighthouse on the Bunbury breakwater (33° 18'S, 115° 39' E). The maximum water depth in the bay is 30 m. Geographe Bay is largely untrawlable with expansive (~ 70%) and continuous monospecific seagrass meadows *(Amphibolis griffithii and Amphibolis antarctica)* in water depths from 2 to ~14 m (Heald 1976; Walker *et al.,* 1987), limited areas of sand habitat and a considerable area of rough rocky bottom (Laurenson *et al.,* 1993).

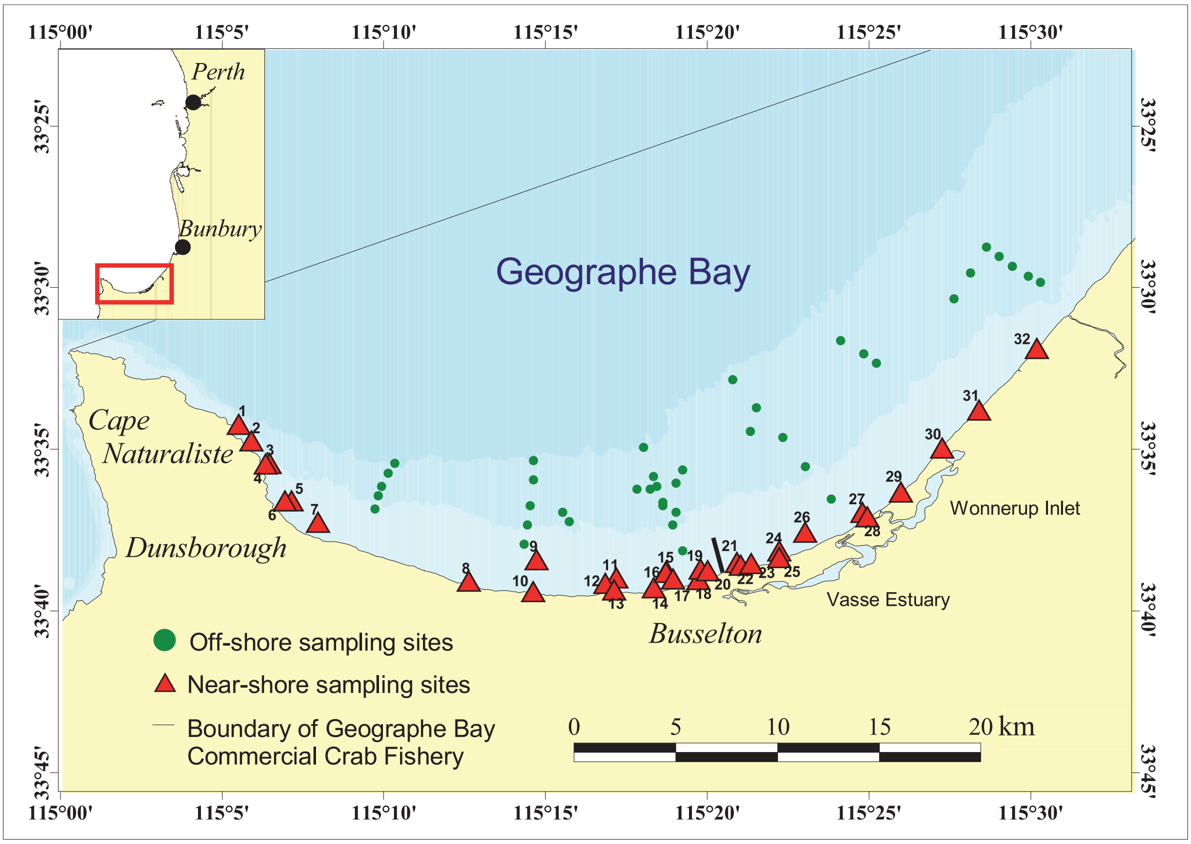

Figure 1 Map of Geographe Bay showing locations of the inshore and offshore sampling sites.

The inshore sampling locations were over sand habitat to enable trawling. Thirty-two sites were sampled seasonally, where possible, between April 2004 and February 2005 with an otter trawl (Figure 1; Table 1 of Appendix). In autumn, the trawl net was affected by large amounts of detached seaweed. Therefore, traps were used during summer, winter and spring in addition to trawling.

Data for the present study were collected from dedicated experimental fishing surveys using both traps and trawls in inshore waters in every season, using traps in deeper waters of the bay in one season and from Department of Fisheries Western Australia, Catch and Effort Statistics (CAES).

2.1.2 Otter trawl

The otter trawl net had a headrope length of 4.5 m, was 0.7 m high at the opening and approximately 5 m long from opening to codend. The net consisted of 51 mm mesh in the wings and panels, with 13mm mesh in the cod end. The bridle length was 13 m, while the warp was 60 m long and calculated at a ratio of 3.5 times the depth. At each site, the net was trawled at a speed of 2.5 knots for a distance of 750 m.

2.1.3 Traps

The commercial blue swimmer crab traps used in the present study were hourglass shaped, 630 mm high and 1000 mm in diameter. The two halves are covered in mesh (2 or 3.5 inch) and connected with cable ties to complete the trap, leaving elongated gaps around the middle for the entry of crabs. Traps were baited and set 150 m apart. Traps were pulled after a 24-hour soak.

2.2 Offshore sampling regime

A fishery independent trap survey was conducted from the *R.V. Naturaliste* between February 10 – 13, 2004. Eight transects perpendicular to the shoreline and extending from the 20 m contour to within one nautical mile of the coast were sampled from Cape Naturaliste to the Bunbury lighthouse (Figure 1). Each transect was fished using five lines of traps comprising of 10 traps separated by 50 m. Traps were baited and left to soak for 24 hours. Two transects were fished per day, commencing on February 10 at the southern end of the bay. Initial sampling revealed that crab catches from over seagrass were either nil or very low. In order to catch more crabs, on subsequent sampling occasions lines were set over bottom consisting of patches of seagrass and sand.

2.3 Commercial Catch and effort statistics

Catch and Effort Statistics were extracted from CAES. The monthly submission of an accurate monthly catch and effort return to the Department of Fisheries is a compulsory requirement of commercial licence holders and/or masters. Information provided for each block (with Geographe Bay defined as a block) was catch, number of days fished and average number of traps used per day.

2.4 Commercial catch monitoring

Commercial catch monitoring in Geographe Bay was undertaken during July and October in 1999 and during August, September and October in 2000. Commercial fishers in Geographe Bay use the same traps described above. Traps are set in lines of 25 - 40 and each trap is separated by a distance of ~50 m. Traps were baited and left to soak for 24 hours. The carapace width (mm), sex and breeding condition of each crab caught was recorded, along with various environmental factors such as salinity, water temperature and the prevailing weather conditions.

2.5 Recreational fishing surveys

We report data collected by Sumner *et al.* (2000) during recreational fishing surveys that were conducted in Geographe Bay between September 1996 and August 1997 and September 2001 to November 2002, and also surveys that were undertaken as part of the current investigation between July and October of 2003 when the majority of catches are taken. In order to make direct comparisons between the consecutive years of 2002 and 2003, recreational survey data from July – October 2002 were selected from the broader data set. Two creel survey methods were used to estimate the recreational catch, effort and size composition of blue swimmer crabs for both boat-based and shore-based fishers over 12 months in 1996/97 and 2001/02. The bus route method (Robson and Jones, 1989; Jones *et al.,* 1990), where a survey interviewer visits all boat ramps in a district on 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.

These surveys demonstrated that the vast majority of effort comes from boat-based crabbers fishing the area adjacent to Port Geographe, between Wonnerup and the Busselton Jetty. More than 90% of crabbers fishing this area launched their vessels from the boat ramp at Port Geographe. Consequently, it was concluded that an additional and useful set of data could be collected to produce an accurate estimate of catch and effort in Geographe Bay by surveying boat-based crabbers that launch from this boat ramp. This protocol also proved the most cost effective. Thus, the bus route survey method was used to estimate recreational catches of blue swimmer crabs captured by trailered boats launched from Port Geographe. Interviews were conducted on four week and four weekend days (including public holidays) during each month between September 2001 and November 2002 and on eight week and eight weekend days per month between July and October 2003.

The surveys were stratified by time of day (morning or afternoon) and weekdays or weekends (including public holidays). Separate total catch estimates were made for each of these 4 strata (two for mornings and afternoons × two for weekends and weekdays). The surveys were also stratified to ensure that corrections could be made to account for boats either crabbing or angling within Geographe Bay, fishing outside Geographe Bay, or not fishing at all. These estimates were then combined to obtain the total recreational catch and effort during the survey period. Between July and October 2002, Department of Fisheries personnel conducted 59 interviews with recreational fishers launching from the Port Geographe marina boat ramp. In comparison, 357 interviews were recorded during July – October 2003.

2.5.1 Recreational data

On arrival at a boat ramp, the number of recreational trailers in the car park was recorded along with the prevailing environmental conditions. All recreational boat launches and retrievals during the time period prescribed for that boat ramp were then noted. A second form was used to record catch and effort, biological and demographic information from boat-based fishers who were interviewed when they returned to the boat ramp.

Survey personnel were asked to measure all blue swimmer crabs that were caught by interviewed fishers. However when several boats returned to a ramp at the same time and it was not possible to measure all the crabs in a catch. On these occasions, a random sample was measured as it was considered more important to collect as much basic catch information from as many fishers as possible. A random sample was also measured when fishers were in a hurry to leave the ramp. The number of recreational trailers was again noted when departing a boat ramp, to validate the number of launch and retrievals recorded during the surveyed period.

2.5.2 Statistical analyses

Estimates of catch and effort for boat-based recreational fishers in Geographe Bay during the surveyed periods were determined using the methodology described by Sumner and Malseed (2004).

2.5.3 Measurements

On each occasion that experimental surveys and commercial catch monitoring was undertaken, the following criteria were recorded for each crab caught per line of traps or per trawl shot: sex, carapace width (*i.e.* the distance between the two lateral spines of the carapace) recorded to the nearest millimetre, shell state (hard or soft), and for females, ovigerous condition (non-berried or berried stage 1, 2 or 3). For experimental surveys using traps, crabs caught in 2-inch meshed traps versus crabs caught in 3.5-inch meshed trap were recorded separately. Water temperature, salinity and the weather and sea conditions for each trawl night were recorded.

2.5.4 Data analyses

Catch rates were log(catch rate+1) transformed to normalise the data due to the skewness of the distribution of catch rates. The transformed catch rates for each sex, site, season and sampling unit were subjected to ANOVA, with each factor being fixed. The same set of factors was considered in the ANOVA of carapace length, the values of which were not transformed.

3.0 Results

3.1 Inshore sampling regime

3.1.1 Catch rate

All crabs

The catch rate of crabs caught in trawls varied significantly between seasons ($P < 0.01$) but not sites ($P = 0.08$, Table 2, Appendix). The catch rate of crabs in traps also varied significantly between seasons, and also between sites and traps with different mesh sizes ($P < 0.01$). Season recorded the largest mean square value followed by trap mesh size (Table 3, Appendix).

The comparative catch rates of crabs caught in traps versus trawls produced conflicting results with respect to seasonal trends in catch rates (Figure 2). This is mainly because detached seagrass caused heavy fouling of the trawl net during autumn and winter and is likely to have reduced the catch rate of crabs in the trawl net. Trawl catches peaked at 23.3 crabs/trawl during spring, declined markedly in summer to 9.9 crabs/trawl, to reach their lowest levels in autumn, 7.4 crabs/trawl before increasing to 9.6 crabs trawl in winter (Figure 2). During spring and summer when the net was probably working more efficiently than in the other seasons when there was a lot of detatched seagrass, the catch rate of crabs in trawls was higher. The high catch rate in traps during winter indicates that the catch rate per trawl may have been highest overall in winter had the net not been so heavily fouled.

Although the effect of site on the catch rate of crabs in traps was significant there does not seem to be a clearly defined relationship between catch rate and location within the bay. Catch rates of crabs in traps were highest at sites 22, 24, 26, 27 and 28 which are all situated seaward of the Vasse Estuary and west of the opening to the Wannerup Inlet (Figure 1). The lowest catch rates were recorded from the eastern and western extremities of the bay.

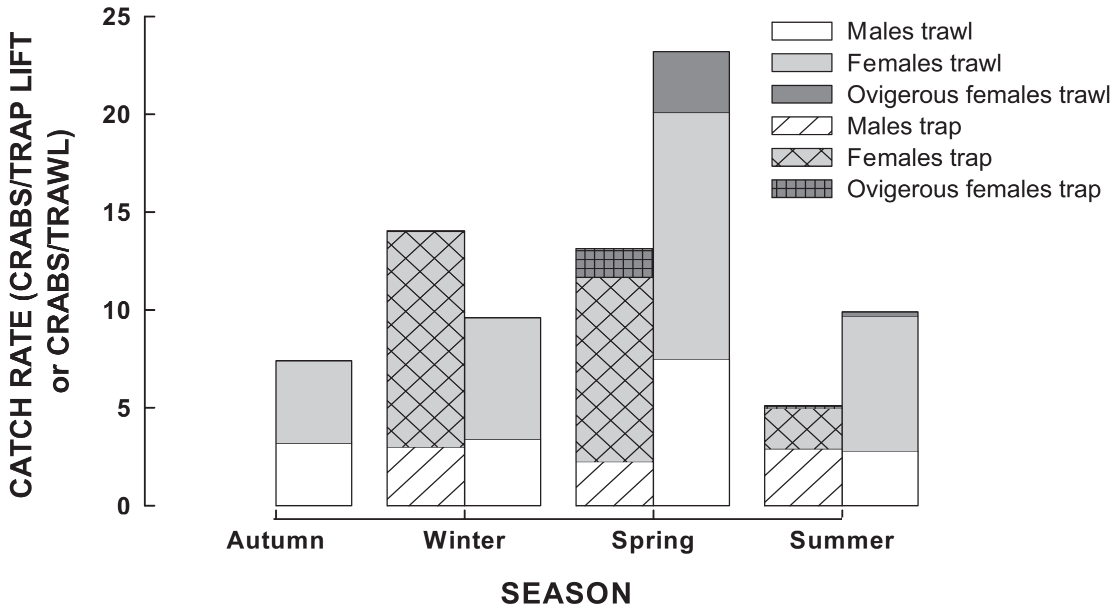

Figure 2 Catch rate of crabs caught using traps and trawls during the inshore sampling regime conducted in Geographe Bay.

The 3.5-inch mesh traps caught more crabs than the 2-inch mesh ($P < 0.01$). On average, the 3.5-inch mesh trap caught 3.81 more crabs than the 2-inch mesh trap. Neither the effect of season or site, on this difference, was significant ($P > 0.05$).

Male crabs

Both season ($P < 0.01$) and site ($P < 0.05$) had significant effects on the catch rate of males in trawls (Table 4, Appendix). However the effect of season on the catch rate of male crabs in traps was not significant ($P > 0.1$), but the effects of site and size of trap mesh were significant ($P < 0.01$, Table 5, Appendix).

The catch rates of males in trawls and traps in each season reflected those of the overall population. Autumn, spring, summer and winter had respective catch rates of 3.2, 7.5, 2.8 and 3.4 male crabs per trawl (Figure 2). Catch rates for male crabs caught in traps were highest in winter (14.0 crabs/trap) and spring (13.2 crabs/trap) and lowest in summer (5.1 crabs/trap). The proportion of males caught in trawls remained relatively constant between seasons, ranging between 34% in summer to 43% in autumn. Males as a proportion of trap catches fluctuated greatly between seasons, i.e. 22% in spring - 56.5% in summer. In comparison, sex ratios of trawl catches were more consistent between seasons and always favoured females.

Site had a significant effect on the catch rate of male crabs in both traps and trawls. The catch rate of males caught using both trawls and traps was higher at sites 21 – 30 that are adjacent to both the Wonnerup Inlet and the Vasse Estuary, compared with sites 1 – 20, 31 and 32 (all $P < 0.01$). The catch rate of male crabs using trawls at sites 21-30 versus the other sites was 4.33 (95% CLs 2.58 – 6.94) versus 2.20 (95% CLs 1.62 – 2.92) crabs/trawl respectively. The catch rate of males using traps at sites 21-30 versus the other sites was 3.47 (95% CLs 2.48 – 4.74) versus 1.85 (95% CLs 1.57 – 2.16) crabs/trap lift respectively. The lowest catch rates were at sites 1 and 32, situated at the eastern and western extremities of the inshore region of the bay. The data did not allow for examining the interaction between site and season. A comparison of the catch rates across sites showed that although catch rates were highest in winter, the catch rates at sites 26-28 that are adjacent to the entrance to the inlet were no higher than surrounding sites during winter. There was a significant difference in the catch rates of the two trap types with 3.5-inch mesh traps catching 1.6 more crabs than the 2-inch mesh traps. The effect of season on this difference was not significant ($P > 0.05$) while that of site was significant ($P < 0.01$).

Non-ovigerous female crabs

The effect of season on the catch rate of non-ovigerous females in trawls was significant ($P < 0.05$) but that of site was not ($P > 0.05$, Table 6, Appendix). The size of trap mesh did not have a significant effect on the catch rate of non-ovigerous female crabs ($P > 0.05$), but the effects of both season and site were significant ($P < 0.01$, Table 7, Appendix).

Autumn, spring, summer and winter had respective catch rates of 4.2, 12.6, 6.9 and 6.2 non-ovigerous female crabs per trawl (Figure 2). The catch of non-ovigerous females relative to total catch in trawls varied between 51% during spring to 64% during winter. The catch rate of non-ovigerous females in traps was highest in winter and spring and lowest in summer. Seasonal trends in catch rates of non-ovigerous females caught in traps showed that the lowest proportion of non-ovigerous females of total catches (40.4%) was recorded in summer while the highest was winter (68%).

Despite the fact that the effect of site on the catch rate of non-ovigerous females in traps was significant, there is no clear geographical trend other than catches tending to be lower at sites located at the eastern and western boundaries of the sampling region.

The 3.5-inch mesh traps caught on average 2.16 more non-ovigerous female crabs than the 2-inch mesh ($P < 0.01$) and neither the effect of season nor site on this difference was significant ($P > 0.05$).

Ovigerous female crabs

The effect of season on the catch rate of ovigerous female crabs in trawls was significant ($P < 0.01$) but that of site was not ($P = 0.66$, Table 8, Appendix). The effect of trap mesh on the catch rate of ovigerous crabs was not significant ($P = 0.94$), but the effects of site and season were significant ($P < 0.01$, Table 9, Appendix). Spring recorded the highest catch rate of ovigerous females per trawl at 3.1 crabs/trawl, with minor quantities of 0.2 crabs/trawl in summer and 0.02 crabs/trawl in winter (Figure 2). Ovigerous females were also most abundant in trap catches during spring and were absent in autumn and winter. Ovigerous females as a proportion of the totals of both trawl and trap catches (all males and females) comprised 15% in spring and 3% in summer.

The catch rate of ovigerous females in traps was relatively consistant across the bay except that catch rates were elevated at between 1.11 and 5.25 crabs/trap lift at sites 1-3 on the western end of the sampling area, compared with a mean across all sites of 0.59 crabs/trap lift.

3.1.2 Trends in carapace width

In each season, trawling resulted in a much broader size range of crabs than trapping and this difference in size range was most pronounced during winter when small crabs (<90 mm) were most abundant in trawl samples (Figures 1 - 7, Appendix).

Male crabs

For trawl caught samples, only the effect of season and the interaction between season and site were significant on the mean carapace width of male crabs (P < 0.01 and P < 0.05, respectively; Table 10, Appendix). For trap caught samples, the effects mesh size, season, site and the interaction between season and site were each significant on mean carapace width of male crabs (P < 0.01, Table 11, Appendix). The two-way interaction between season and site for traps was also significant (P < 0.01). The Least Square Mean carapace widths of males were highest in summer and autumn in trawl samples and in summer in trap samples and lowest in winter in both trap and trawl samples when new recruits entered the area (Table 1).

Table 1 LSM carapace width (mm) of male crabs caught in trawls in each season, independent of site. 95% confidence limits are also presented.

	Trawling			Traps		
Season	Estimate	Lower	Upper	Estimate	Lower	Upper
Spring	103.06	98.73	107.40	119.56	118.17	120.94
Summer	112.16	106.18	118.14	125.25	123.95	126.55
Autumn	112.35	105.97	118.73			
Winter	88.66	81.16	96.16	119.45	117.52	121.38

For trap caught samples, the mean square was highest for trap mesh size (Table 11, Appendix), the LSM carapace width (and 95% C.I.s) for 2” and 3.5” mesh traps were 118.2 (117.3 – 119.2 mm) and 124.6 (123.4 – 125.8 mm) respectively.

Despite the fact that the effect of site on LSM carapace width was significant using both methods of sampling, there was no discernable geographical trend amongst the LSM carapace widths of males caught by either trapping or trawling across Geographe Bay. The two largest mean carapace widths for males were recorded from the adjacent sites 19 (126.7 mm) and 20 (131.5 mm) that are situated closest to Busselton jetty. The smallest LSM carapace width for males, 108.6 mm, was recorded at the eastern most sites within the bay, site 32. It is unclear why the interaction between season and site was significant for both trawl and trap caught males. There appears to be greater dissimilarity in the mean carapace widths between seasons at sites 1 – 19, compared to the mean carapace widths at sites 20 – 30 between seasons.

Non-ovigerous female crabs

For trawl caught samples, the effect of site and the interaction between site and season were significant on the mean carapace width of non-ovigerous female crabs (P < 0.01 and P < 0.05 respectively, Table 12 Appendix). The effects, mesh size, season, site and the interaction between season and site were also significant on mean carapace width of non-ovigerous female crabs caught in traps (Table 13, Appendix). The LSM carapace widths of non-ovigerous females by season are presented in Table 2. They followed the same general trends as males except for traps in winter that recorded the highest overall LSM carapace width. The LSM carapace width of non-ovigerous females was consistently larger than males in each season and was less variable between seasons compared to males (Table 2). The modal size class of females caught in traps was higher than that for trawls in every season.

Table 2 LSM carapace width of non-ovigerous female crabs for each season, standardised for site and trap mesh size. 95% confidence limits are also presented.

	Trawls			Traps		
Season	Estimate	Lower	Upper	Estimate	Lower	Upper
Spring	113.83	109.63	118.03	129.84	128.64	131.04
Summer	118.61	113.18	124.04	128.44	126.58	130.29
Autumn	123.05	117.07	129.02			
Winter	107.84	102.15	113.54	131.55	130.05	133.06

The LSM carapace width of non-ovigerous females caught in 2-inch mesh was 127.7 mm compared with 132.2 mm for 3.5-inch mesh.

For trawl and trap caught samples, although the pattern is not very consistent, sites with the largest LSM carapace widths such as sites 1, 2, 9, 15 and 16, tended to be situated in the western side of the bay. The association between season and site is unclear, however similar to males, there is a greater dissimilarity in the mean carapace widths in different seasons at sites 1 – 5 compared to the remaining sites.

Ovigerous female crabs

Neither of the effects season ($P = 0.7$) or site ($P = 0.14$) were significant on mean carapace width of ovigerous female crabs caught in trawls (Table 14, Appendix) and only site was significant for samples caught with traps ($P < 0.01$, Table 15, Appendix). There was no obvious trend between mean carapace width and of ovigerous females and geographic location for crabs caught in traps.

3.2 Offshore sampling regime

3.2.1 Catch rate

Catches in the offshore regions of the bay, > 1 nautical mile from the coast, where the water depth ranged from approximately 5 to 20 m, were very low compared with the inshore areas in the same season and in the other seasons. The vast majority of the traps were empty; of the 40 trap lines set over the four days only half contained crabs, resulting in a total catch of 158 crabs. The mean catch/trap lift was therefore 0.4 crabs per trap lift (S.E. = 0.13). The ratio of females: males was 4.3:1 and the highest ratio of females for the entire study. Females were caught more frequently than males at all sites except site 10. The higher ratio of females caught in the offshore trapping study in summer is contrary the inshore trapping study in the same season that recorded a slightly higher ratio of males than females.

3.2.2 Trends in carapace width

The mean carapace width of males (136.3 mm) was similar to that of females (135.8 mm, Figure 8, Appendix). For offshore samples, the modal carapace width of both males and females (135 – 139 mm) was larger than the modal carapace width for both sexes 12 months later from inshore areas, caught in both traps and trawls. The modal carapace width and maximum carapace length classes were also similar for each sex. Small crabs were uncommon, and only 4% of females or 3.2% of all crabs were ovigerous.

3.3 Commercial Catch and effort statistics

3.3.1 Annual trends in commercial catches

Annual catches of blue swimmer crabs in Geographe Bay peaked in 1997 at 17.3 tonnes, fluctuated between 8.8 and 14.5 tonnes per annum in 1998 – 2000, decreased to 7.0 tonnes in 2001, increased to 14.5 tonnes in 2002 and declined steadily to 8.1 tonnes in 2004 (Figure 3). Commercial catches were taken mainly using drop nets and traps with minor quantities in haul and gill nets. Inter-annual trends in effort over this period, as measured by numbers of drop net and trap lifts, followed the same patterns as annual catch, fluctuating between 15,417 and 25,208 trap lifts in 1994 – 1999, peaking at 27,110 trap lifts in 2000, and progressively declining from 19,085 in 2002 to 5,590 in 2004 (Figure 3). Inter-annual trends in CPUE throughout this period show that CPUE increased rapidly from 0.22 kg/trap lift in 1994 to 0.78 kg/trap lift in 1996 as traps were being used for the first time in the fishery. CPUE was steady between 1997 and 2002 at between 0.50 kg/trap lift – 0.78 kg/trap lift before increasing dramatically in to 1.34 kg/trap lift in 2003 and 1.44 kg/trap lift in 2004 as traps, that are more efficient, became used more than drop nets.

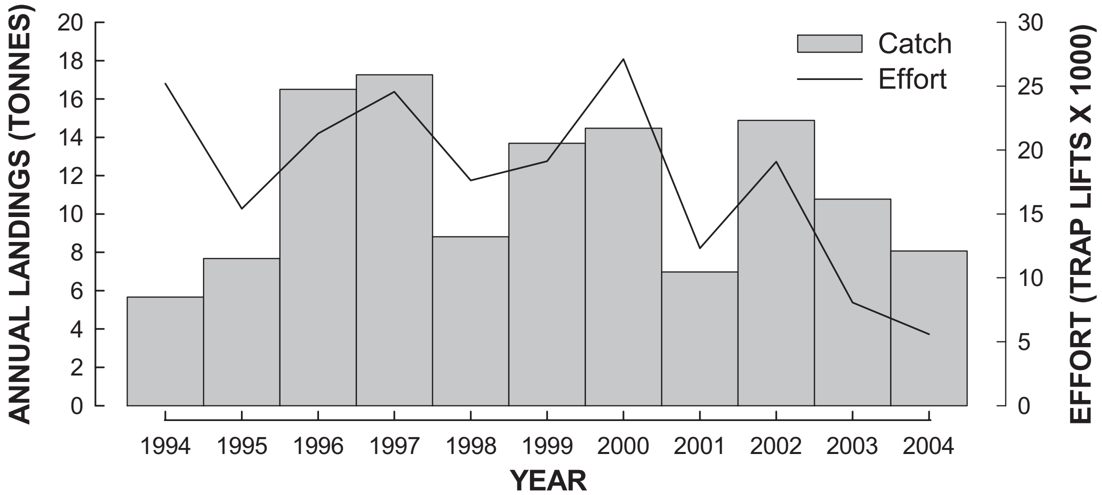

Figure 3 Annual commercial catch and effort for the Geographe Bay fishery, 1994 – 2004.

3.3.2 Fishing methods

The vast majority of catches were caught using drop nets between 1994 and 1998 with only a minor component (< 6%) of catches landed by alternative methods. Traps accounted for the majority of catches between 1999 and 2003, however catches from drop nets remained high throughout this period (Figure 4). The conversion from mainly using drop nets in 1998 to mainly traps in 1999 did not alter CPUE immediately, but CPUE did increase in the ensuing years, probably after fishers became efficient with the new gear. Fishing methods other than drop nets or traps accounted for a minor component of the catches (Figure 4).

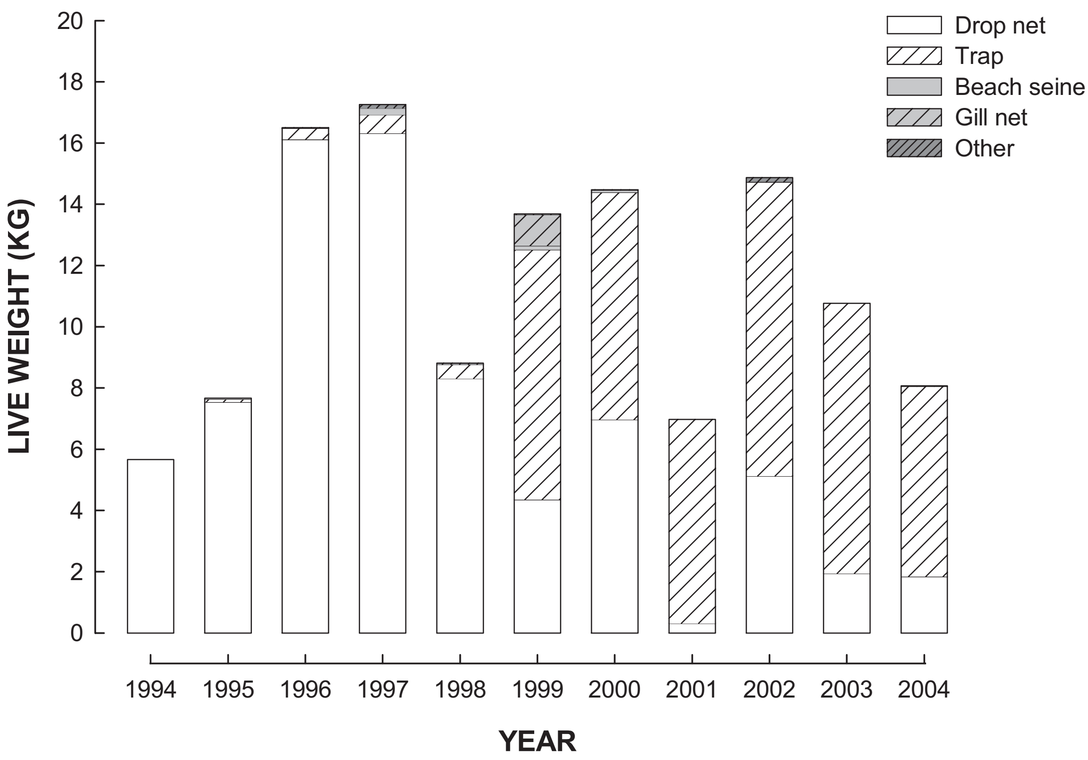

Figure 4 Commercial catches of blue swimmer crabs in Geographe Bay by various fishing methods.

3.3.3 Monthly patterns in commercial catches

The mean monthly commercial catches of *P. pelagicus* in Geographe Bay, presented for 2002 and 2003, show a pronounced seasonal trend (Figure 5). In 2003 annual landings reflected the same monthly trends as in 2002, however catches peaked in August at 3,591 kg and did not reach values as high as those recorded in 2002. CPUE recorded in 2003 reflected general patterns in monthly catch, and were higher than in 2002. CPUE increased steeply from 0.39 kg/trap lift in April, to between 1.15 – 1.68 kg/trap lift between June and November (Figure 5).

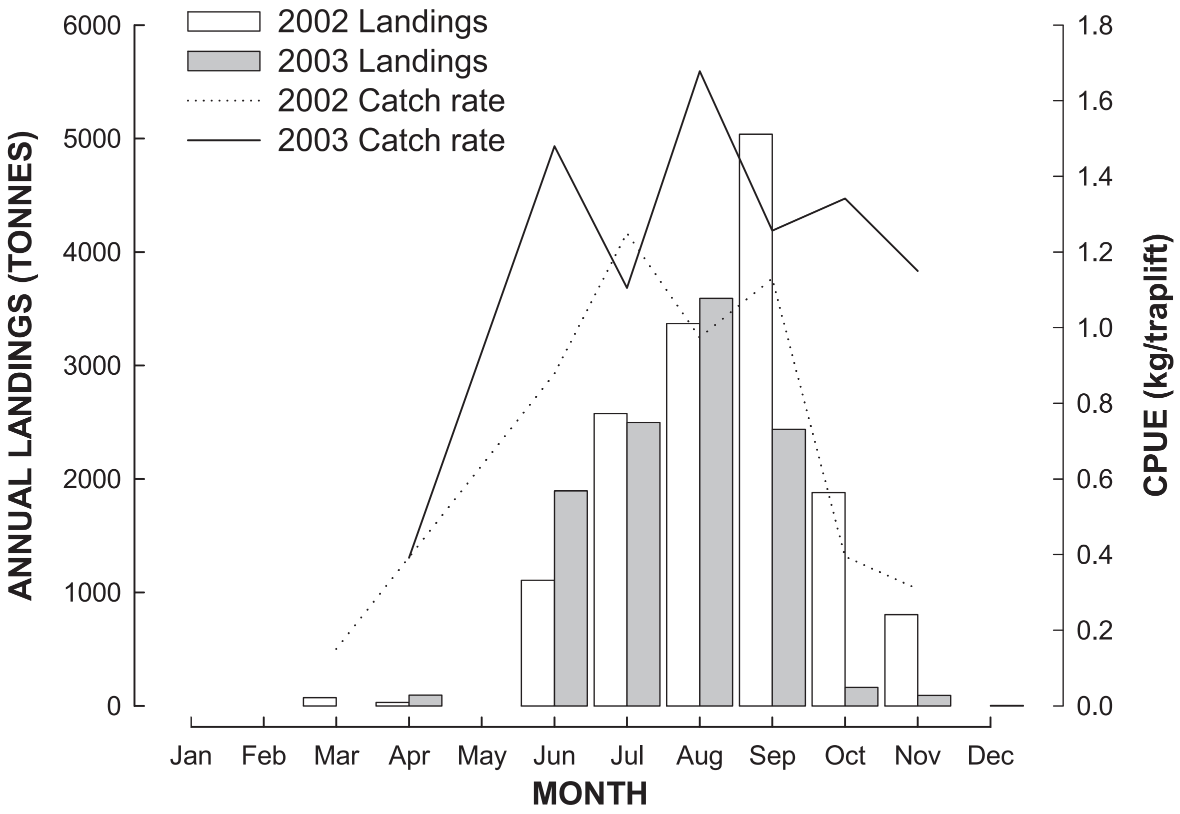

Figure 5 Mean blue swimmer crab commercial catches and CPUE per month in Geographe Bay for 2003 and 2004.

3.4 Commercial catch monitoring

A total of 6,556 blue swimmer crabs were measured during commercial catch monitoring surveys in Geographe Bay between 1999 and 2000. The mean carapace width of females recorded ranged from 123.3 – 128.6 mm and was consistently larger than the mean carapace length of males (116.1 – 127.4 mm) (Figures 9 – 13, Appendix). Furthermore, the maximum size of females was larger (154 – 171 mm) than that of males on each sampling occasion (145 – 158 mm). The numbers of ovigerous females as a percentage of all females was low (< 2%) on all occasions except October 2000 when 12% were berried. In October of the previous year only 1.1% were ovigerous (Figure 10, Appendix). Females consistently comprised a larger proportion of catches than males at a ratio of between 1.4:1 and 3.4:1 (Figures 9 – 13, Appendix). It is interesting to note that there was no modal progression in consecutive months for females however and for males the modal size class increased by one 5 mm carapace width interval between July and October 1999 (Figures 9 and 10, Appendix).

3.5 Recreational fishing surveys

Between July and October 2002, Department of Fisheries personnel conducted 59 interviews with recreational fishers launching from the Port Geographe marina boat ramp. In comparison, 357 interviews were recorded during July – October 2003.

3.5.1 *Recreational boating activity*

More recreational boats launched at Port Geographe went crabbing than angling in Geographe Bay between July and October 2002 (Figure 5). Of the fishers surveyed in 2002, 24 (40.7%) were fishing for blue swimmer crabs, only 14 (23.7%) were angling for finfish, while 15 (25.4%) fished for both (Figure 6). The remaining six (10.2%) participated in activities other than fishing (Figure 6).

Although a similar proportion of boaters fished for blue swimmer crabs (38.7%) during 2003, only 15.7% fished for both finfish and crabs and the number of anglers targeting only finfish increased to 38.9% (Figure 6). Boating parties undertaking activities other than fishing comprised 6.7% of those surveyed, a similar proportion to the previous year (Figure 6).

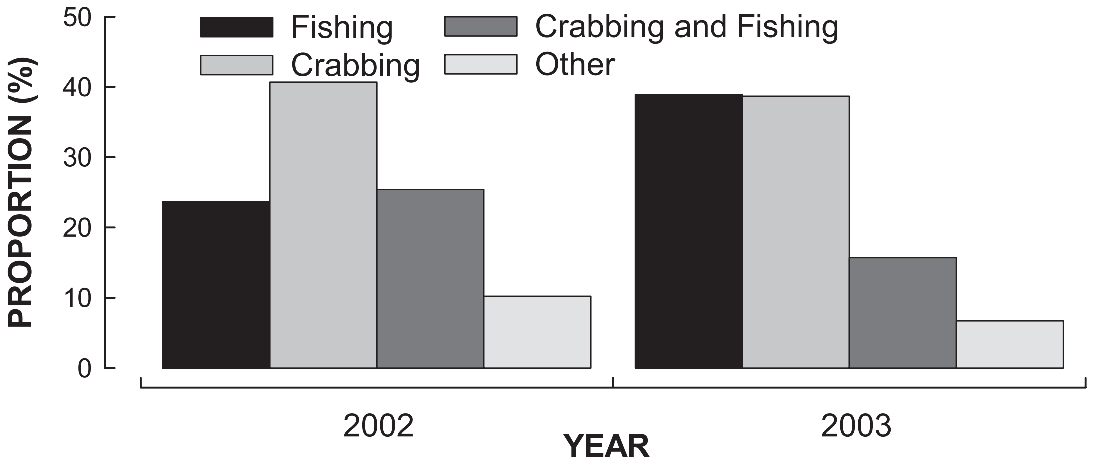

Figure 6 Activity of boating occupants interviewed at boat ramps around Geographe Bay between July and October 2002 and 2003.

3.5.2 *Recreational crabbing effort*

Surveys conducted between September 2001 and November 2002 showed that Spring 2002 (September – November) was the most popular season for recreational boat-based crabbing (Sumner and Malseed, 2004). Between two and three times the fishing effort occurs in spring compared within either of the other three seasons of the year. Recreational fishers spent 5,515 hours targeting blue swimmer crabs in Geographe Bay between July and October 2002. This effort was spread over a combined 4,092 crabbing days. The mean effort during each crabbing trip was 3.28 fisher hours and involved 2.44 crabbers (Table 3). Extrapolation of these estimates to the whole year provides for a recreational crabbing effort of 19,424 days for the 2002 calendar year.

The recreational crabbing effort in 2003 decreased slightly between July and October compared with that period in 2002. Recreational crabbers fished for an estimated 4,315 fisher hours over 3,566 crabbing days, with the average crabbing trip lasting 2.90 fisher hours. The average number of crabbers per boat trip, however, was 2.39 crabbers per trip, similar to 2002. The estimated fishing effort, for the whole of 2003 was 16,926 crabbing days, down 13% on the previous year (Table 3).

Table 3 Estimated recreational crabbing effort for blue swimmer crabs in Geographe Bay for 2002 and 2003. (Numbers in brackets denote standard error).

	2002*		2003	
Average number in party (fishers)	2.44		2.39	
Ave. effort of crabbing trip (fisher hours)	3.28		2.90	
Number of fisher hours July – October	5,515	(1,271)	4,315	(557)
Number of crabbing days July – October	4092	(943)	3566	(460)
Number of crabbing days whole year	19 424		16 926	

**Results derived from Sumner and Malseed (2004).*

3.5.3 Recreational crabbing catch

Females dominate catches of blue swimmer crabs in Geographe Bay. Of the 2,600 blue swimmer crabs caught by recreational fishers within this period, 88.1% of the retained catch and 78.2% of the released catch were female (Table 4). The estimated total number of blue swimmer crabs caught in Geographe Bay for 2002 is 49,934 (10.24 tonnes) (Table 5). The catch rate of crabs between July and October 2002 in Geographe Bay (28.31 crabs kept/boat/trip) (Table 4) was nearly three times that recorded for Cockburn Sound, *i.e.* 11.11 kept/boat/trip.

A total of 477 males and 4,567 females were retained by fishers between July and October 2003. The proportions of males and females that were kept versus the proportions of each sex that were released remained constant from the previous year. The estimated total number of blue swimmer crabs caught by recreational fishers in Geographe Bay in 2003 was 37,958 (7.5 tonnes), less than the previous year (Table 5). The catch rate of crabs in 2003 (26.0 crabs kept/boat/trip) was slightly lower than 2002 (28.31 crabs/boat/trip), however total catches including those both kept and released were much higher (Table 4).

Table 4 Numbers of blue swimmer crabs recorded from surveys of recreational boat-based fishers at five boat ramps in Geographe Bay between July and October 2002 and 2003.

		2002*		2003	
		NUMBER	%	NUMBER	%
Retained	Male	131	11.9	477	9.5
	Female	973	88.1	4,567	90.5
	TOTAL	1,104		5,044	
Released	Male	326	21.8	1,956	22.8
	Female	1,170	78.2	6,617	77.2
	TOTAL	1,496		8,573	
% released		57.5		63.0	
Catch rate (crabs kept/boat/trip)		28.31		26.00	

**Results derived from boat ramp surveys conducted by Sumner and Malseed (2004).*

Table 5 Estimated recreational blue swimmer catch in Geographe Bay for 2002 and 2003. (Numbers in brackets denote standard error).

			2002*		2003*	
			NUMBER	WEIGHT (t)	NUMBER	WEIGHT (t)
July – Oct	Retained	Male	5,925	1.29	3,590	0.76
		Female	44,009	8.95	34,368	6.77
		TOTAL	**49,934** (18,211)	**10.24**	**37,958** (7,584)	**7.53**
	Released	Male	18,138		19,309	
		Female	65,097		65,321	
		TOTAL	**83,235** (31,116)		**84,630** (17,891)	
Annual	Retained	Male	15,604	3.39	9,453	1.99
		Female	115,896	23.56	90,510	17.83
		TOTAL	**131,500**	**26.95**	**99,963**	**19.82**
	Released	Male	47,767		50,851	
		Female	171,433		172,023	
		TOTAL	**219,200**		**222,874**	

**Results derived from boat ramp surveys conducted by Sumner and Malseed (2004).*

3.5.4 Size distribution of recreational vs commercial catch

Between July and October 2001 – 2003, a total of 3,395 crabs were measured from the catches of recreational fishers. Catches throughout this period were primarily females, which comprised between 54% and 67% of the catch in any of these years (Table 6). The mean carapace widths of blue swimmer crabs retained by recreational fishers were well above the legal size limit of 127 mm. Variations between respective years in the mean carapace widths of males (133.9 – 135.8 mm) and females (134.8 – 136.2 mm) were small, as were the differences between the mean carapace width of males and females in each year (0.4 – 1.1 mm).

A total of 6,556 blue swimmer crabs were measured aboard commercial vessels during catch monitoring surveys in Geographe Bay between 1999 and 2000. In both years the sex ratio favored females at ~ 3: 1. The mean size of males was smaller than that of females in both 1999 and 2000. The proportions of the catch which were ovigerous were very low, *i.e.* 1.0 – 2.0% (Table 7).

Table 6 Composition of blue swimmer crabs retained by recreational fishers interviewed at boat ramps in Geographe Bay between September and October of 2001 – 2003.

	MALE			FEMALE			
	NUMBER	%	CW (mm)	NUMBER	%	CW (mm)	TOTAL
***2001**	144	32.8	133.9	295	67.2	135.9	439
***2002**	674	46.5	135.8	775	53.5	136.2	1449
2003	563	37.3	135.6	944	62.6	134.8	1507
TOTAL	**1381**	**40.7**		**2014**	**59.3**		**3395**

**Results derived from boat ramp surveys conducted by Sumner and Malseed (2004).*

Table 7 Composition of blue swimmer crabs caught (retained and released) by commercial vessels during on board catch monitoring surveys in Geographe Bay between July and October of 1999 and 2000.

	MALE			NON-BERRIED FEMALES			BERRIED FEMALES			
	No.	%	CW	No.	%	CW	No.	%	CW	TOTAL
1999	389	24.6	121.4	1179	74.4	126.7	16	1.0	132.4	**1584**
2000	1426	32.8	117.2	3463	69.6	124.5	83	2.0	122.9	**4972**
TOTAL	**1815**	**27.7**		**4642**	**70.8**		**99**	**1.5**		**6556**

Table 8 Composition of blue swimmer crabs retained by commercial vessels during on board catch monitoring surveys in Geographe Bay between July and October of 1999 and 2000.

	MALE			FEMALE			
	NUMBER	%	CW	NUMBER	%	CW	TOTAL
1999	105	17.0	134.7	511	83.0	135.7	616
2000	213	13.7	134.1	1337	86.3	136.0	1550
TOTAL	**318**	**14.7**		**1848**	**85.3**		**2166**

The percentage of females retained in the commercial catch (83 – 86%) was higher than that in the recreational catch (54 – 67%) but the mean size of retained males and females was similar in the recreational and comemrcial catches (134 – 136 mm) (Tables 6 – 8). The size class of blue swimmer crabs which are smaller than the commercial legal size and larger than the recreational legal size (i.e. 127 – 128 mm CW), in Geographe Bay represents 3.4% of the total number caught by commercial fishers (Figure 7).

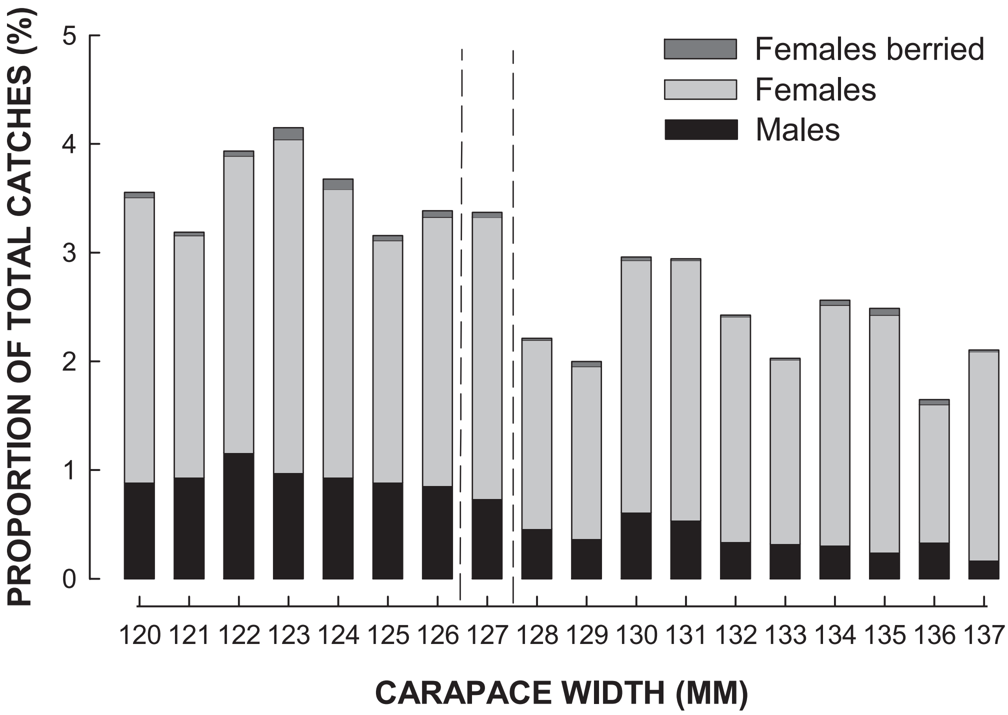

Figure 7 Proportions of male, non-berried and berried female blue swimmer crabs greater than the recreational minimum size limit (127mm CW) but less than the commercial size limit (128mm CW), caught by commercial fishers operating in Geographe Bay between August 1999 and October 2003

4.0 Discussion

The inshore nature of the Geographe Bay blue swimmer crab fishery was demonstrated by the fact that traps set in water depths less than ca five metres displayed catch rates of six to 14 crabs/trap lift compared with 0.4 crabs/trap lift in traps set in water depths greater than five metres which is greater than one nautical mile from shore. This has contributed to the perception that commercial fishers take the majority of the resource, leaving little for recreational fishers. However, recreational fishing surveys conducted in 1996/97, 2001/02 and 2003 illustrate that recreational crabbers have always taken the majority of the crab catch in Geographe Bay and management agreements implemented in December 2002 appear to have been successful at increasing the recreational catch share.

The majority of blue swimmer crab catches in Geographe Bay are taken in winter-spring between July and October, before the peak tourism period in summer. Spawning and maximum growth rates occur in summer, causing most crabs to reach legal size in winter and spring at about 18 months of age (Sumner and Malseed, 2004). The natural peak in abundance of legal size crabs in winter and spring results in exploitation primarily by local recreational fishers and by commercial fishers. This reduces the catches taken during the peak summer tourism period amplifying conflict between recreational and commercial sectors.

Sumner and Malseed (2004) suggested that mature crabs, particularly females, possibly move offshore into deeper waters during summer months, thereby reducing the numbers of legal size crabs that are available in summer and autumn. However while our offshore sampling regime conducted in summer, caught higher numbers of females than males, the overall number of crabs caught was low.

A net movement of males from Geographe Bay into deeper water would account for the fact that the fishery is characterised by disproportionally large ratios of females to males. Sumner and Malseed (2004) reported that the high proportions of females in both commercial (85%) and recreational (81%) trap catches in 2001/02 were possibly because females crabs tend to be more abundant in the shallow waters targeted by these fishers. However, our offshore sampling regime yielded higher proportions of females in deeper waters.

During the present study non-berried females dominated all of the commercial catches as well as all of the catches collected Department of Fisheries W.A. staff, except for trap catches in summer. Amongst populations where sex ratios are balanced, behavioural differences between the sexes make male *P. pelagicus* more vulnerable to capture in traps than females (Potter and de Lestang, 2000). Therefore, trawl catches are more indicative of actual sex ratios. Potter and de Lestang (2000) also recorded a higher ratio of females amongst the blue swimmer crab population in Koombana Bay, 40 km north of Geographe Bay. This is due to large (1+ age class) females remaining in the bay during spring and early summer to spawn as soon as the environmental conditions are favourable, while other crabs migrate to the Leschenault Estuary (Potter and de Lestang, 2000). Once females reach sexual maturity they have a greater tendency to move out of the Leschenault Estuary to Koombana Bay than do males of comparable size as females spawn in Koombana Bay (Potter and de Lestang, 2000). The prevalence of mature females in Geographe Bay particularly in winter suggests that these crabs originate from Koombana Bay and the Leschenault Estuary.

Higher numbers of female than male blue swimmer crabs in Geographe Bay suggest that females are more likely to emigrate into Geographe Bay or that males migrate from Geographe Bay. The bay is adjacent to the nine kilometre long Vasse Estuary and five kilometre long Wonnerup

Inlet (White, 1999). Although the waters inside the Vasse Estuary and Wonnerup Inlets were not sampled during the present study, the possibility that crabs migrate in and out of these systems is very unlikely. The mouth of the Wonnerup Inlet is shallow and often closed by the formation of a sand bar and floodgates installed on the exit channels of the two estuaries are only occasionally opened to allow the estuary and inlet to become inundated with saline to hypersaline water in summer (White, 1999). Furthermore, no-one fishes for crabs in the inlet or estuary. Catch rates at sites adjacent to the estuary mouth were no higher than adjacent sites in winter when crabs might be expected to migrate out of Wonnerup Inlet to avoid low salinity levels caused by higher freshwater input as is the case in Koombana Bay (Potter and de Lestang, 2000). However it is difficult to compare seasonal effects as sampling was conducted over only one year.

The highest number of ovigerous females in traps and trawls was recorded in spring. It would therefore appear that crabs may utilise the warmer water temperatures of late spring – summer to maximise rates of egg development and larval growth (de Lestang *et al.,* 2003). Water temperature has been shown to influence ovulation and egg development in *P. pelagicus* and other decapods (Rahaman, 1980; Campbell, 1984; Pollock, 1995; de Lestang *et al.,* 2003). This is consistent with commercial catch monitoring undertaken in 1999 and 2000, which detected higher proportions of ovigerous females in October compared with the other months sampled.

The annual commercial crab catch in Geographe Bay increased from 1.6 tonnes in 1989 to 14.9 tonnes in 2002 with a peak catch of 17.3 tonnes in 1997. Catch rates are much higher in Geographe Bay than in Cockburn Sound. In contrast to Cockburn Sound, recreational catches in Geographe Bay declined by seven tonnes between 2002 and 2003. This has been primarily due to a decline in effort within the recreational sector from 19,424 crabbing days in 2002 to 16,926 crabbing days in 2003. There was also a pronounced decline in the commercial fishing effort over this period, from 19,085 trap lifts in 2002 to 8,060 trap lifts in 2003. This can be attributed mainly to the reductions in the number of commercial traps allowed in the fishery from numbers that were unrestricted previously. Both the commercial and recreational catch rates have remained relatively constant between 2002 and 2003, despite the reductions in effort.

The recreational share of total catches has increased from 51% (of a total of 34.0 tonnes) in 1996/97 to between 64% and 66% (of a total of 30.6 – 43.5 tonnes) between 2002 and 2003. In Geographe Bay recreational crabbing was more popular than angling in 2002 and equally as popular as angling in 2003 for boats launched at Port Geographe between July and October. Geographe Bay is renown for crabbing and is a popular past-time amongst holiday makers who, lacking local knowledge, may be less familiar with the techniques required to catch fish in the region. Further estimates of recreational catch share in light of reduced commercial effort in 2004 are not available due to the absence of a concurrent estimate in recreational effort.

Crabs protected from the commercial fishery but available to the recreational fishery, *i.e.* crabs that were 127mm, represented 3.4% of the entire number of crabs measured during commercial length monitoring, and 10% of all crabs > 127 mm. Therefore, this component of their catches, which they are obliged to return to the sea, represents what would otherwise be a significant portion of their catch. Crabs that were 127 mm comprised 5.8% of the retained catches of recreational fishers.

The recreational fishing surveys conducted during the present study were designed specifically to quantify recreational catch and effort for blue swimmer crabs in Geographe Bay, within the period when peak catches are recorded. By conducting the surveys within a restricted period, the cost and effort involved in implementing year-round surveys has been drastically reduced. The results are consistent with the results from the year-round survey conducted in 1996/97 by

Sumner and Malseed (1994), and also reflect more recent trends within the fishery, particularly those associated with the implementation of catch share arrangements. In 1996 the Minister for Fisheries responded to local concerns about crab catch shares between the commercial and recreational sectors by instigating a review of crab fishing in Western Australia, which resulted in a management agreement in December 2002.[1] The management arrangement restricted the maximum number of traps allowed in the commercial fishery to 320, and implemented a number of temporal closures to commercial fishing i.e. school holidays and long weekends. Spatial restrictions were also introduced prohibiting commercial fishing in waters < 400 m offshore between "old Dunsborough" boat ramp and the Quindalup boat ramp; in waters < 400 m offshore between Dolphin Road (Busselton) and the Port Geographe Marina; in waters within 800 m of the Busselton jetty and in the Port Geographe marina between the two groynes. Prior to the closure of the commercial fishery in January 2005, a large component of this fishery was caught by the recreational sector. Recreational fishing surveys should therefore be conducted on an on-going basis so as to reflect temporal shifts in fishing activities, and are suitable for adaptation and implementation within other blue swimmer crab fisheries throughout the State.

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[1] *This fishery was officially closed on January 21, 2005 due to escalating conflicts between the fishery's recreational and commercial sectors*

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Appendix

Table 1 Locations of sampling sites, occasions sampled and methods used

Site No.	Start Lat	Start long	Autumn 1-4/4 2004 Trawl/trap	Winter 13/8 – 9/9 2004 Trawl/trap	Spring 30/10 – 1/11 2004 Trawl/trap	Summer Trawl/trap
1	33°34.176’	115°05.382’	Y	Y/Y	Y/Y	Y/Y
2	33°34.692’	115°05.764’	Y	Y/Y	Y/Y	Y/Y
3	33°35.379’	115°06.321’	Y	Y/Y	Y/Y	Y/Y
4	33°35.401’	115°06.215’	Y	Y/Y	Y/Y	Y/Y
5	33°36.536’	115°07.008’	Y/N	Y/Y	Y/Y	Y/Y
6	33°36.542’	115°06.797’	Y/N	Y/Y	Y/Y	Y/Y
7	33°37.209’	115°07.816’	Y/N	Y/Y	Y/Y	Y/Y
8	33°39.035’	115°12.491’	Y/N	Y/Y	Y/Y	Y/Y
9	33°38.359’	115°14.584’	Y/N	Y/Y	Y/Y	Y/Y
10	33°39.351’	115°14.484’	Y/N	Y/Y	Y/Y	Y/Y
11	33°38.930’	115°17.043’	Y/N	Y/Y	Y/Y	Y/Y
12	33°39.091’	115°16.709’	Y/N	Y/Y	Y/Y	Y/Y
13	33°39.292’	115°16.973’	N/N	Y/Y	Y/Y	Y/Y
14	33°39.239’	115°18.209’	N/N	Y/Y	Y/Y	Y/Y
15	33°38.701’	115°18.595’	N/N	Y/Y	Y/Y	Y/Y
16	33°38.748’	115°18.573’	Y/N	Y/Y	Y/Y	Y/Y
17	33°38.967’	115°18.805’	Y/N	Y/Y	Y/Y	Y/Y
18	33°38.982’	115°19.582’	N/N	Y/Y	Y/Y	Y/Y
19	33°38.643’	115°19.646’	Y/N	Y/Y	Y/Y	Y/Y
20	33°38.711’	115°19.875’	Y/N	Y/Y	Y/Y	Y/Y
21	33°38.448’	115°20.769’	Y/N	Y/Y	Y/Y	Y/Y
22	33°38.528’	115°20.883’	Y/N	Y/Y	Y/Y	Y/Y
23	33°38.488’	115°21.212’	Y/N	Y/Y	Y/Y	Y/Y
24	33°38.092’	115°22.088’	N/N	Y/Y	Y/Y	Y/Y
25	33°38.303’	115°22.085’	N/N	Y/Y	Y/Y	Y/Y
26	33°37.518’	115°22.875’	Y/N	Y/Y	Y/Y	Y/Y
27	33°36.895’	115°24.657’	Y/N	Y/Y	Y/Y	Y/Y
28	33°37.044’	115°24.807’	N/N	Y/Y	Y/Y	Y/Y
29	33°36.271’	115°25.841’	Y/N	Y/Y	Y/Y	Y/Y
30	33°34.912’	115°27.113’	N/N	Y/Y	Y/Y	Y/Y
31	33°33.735’	115°28.252’	N/N	Y/Y	Y/Y	Y/Y
32	33°31.828’	115°30.047’	N/N	Y/Y	Y/Y	Y/Y

Table 2 ANOVA for the log(catch rate +1) of all crabs in trawls during inshore sampling (R^2 = 0.55).

Factor	df	SS	MS	F	*P*
Season	3	15.0	5.0	7.1	< 0.01
Site	31	34.2	1.1	1.6	0.08
Residuals	57	40.5	0.7		

Table 3 ANOVA for the log(catch rate + 1) of crabs for traps during inshore sampling (R^2 = 0.59).

Factor	df	SS	MS	F	*P*
Season	2	58.2	29.1	25.4	< 0.01
Site	30	158.8	5.3	4.6	< 0.01
Trap mesh	1	8.4	8.4	7.4	< 0.01
Residuals	138	158.1	1.1		

Table 4 ANOVA for the log(catch rate +1) of male crabs in trawls during inshore sampling (R^2 = 0.61).

Factor	df	SS	MS	F	*P*
Season	3	9.2	3.1	6.5	< 0.01
Site	31	31.7	1.0	2.2	0.01
Residuals	57	26.7	0.5		

Table 5 ANOVA for the log(catch rate + 1) of male crabs for traps during inshore sampling (R^2 = 0.59).

Factor	df	SS	MS	F	*P*
Season	2	2.3	1.2	2.0	0.13
Site	30	88.6	3.0	5.2	< 0.01
Trap mesh	1	20.2	20.2	35.8	< 0.01
Residuals	138	77.9	0.6		

Table 6 ANOVA for the log(catch rate+1) of non-ovigerous female crabs caught in trawls during inshore sampling (R^2 = 0.46).

Factor	df	SS	MS	F	*P*
Season	3	9.6	3.2	3.8	0.02
Site	31	31.8	1.0	1.2	0.26
Residuals	57	48.3	0.8	NA	NA

Table 7 ANOVA for the log(catch rate + 1) of non-ovigerous female crabs for traps during inshore sampling (R^2 = 0.63).

Factor	df	SS	MS	F	*P*
Season	2	155.1	77.6	57.6	< 0.01
Site	30	163.0	5.4	4.0	< 0.01
Trap mesh	1	4.2	4.2	3.1	0.08
Residuals	138	185.9	1.3		

Table 8 ANOVA for the log(catch rate+1) of ovigerous female crabs for trawls during inshore sampling (R^2 = 0.63).

Factor	df	SS	MS	F	*P*
Season	3	19.7	6.6	23.9	< 0.01
Site	31	7.4	0.2	0.9	0.66
Residuals	57	15.7	0.3		

Table 9 ANOVA for the log(catch rate + 1) of ovigerous crabs for traps during inshore sampling (R^2 = 0.76).

Factor	df	SS	MS	F	*P*
Season	2	61.6	30.8	153.6	< 0.01
Site	30	27.7	0.9	4.6	< 0.01
Trap mesh	1	0.0	0.0	0.0	0.94
Residuals	138	27.7	0.2		

Table 10 ANOVA for the carapace width of male crabs caught in trawls, in terms of season and site, for the inshore sampling. Type III sum of squares have been presented (R^2 = 0.30).

Factor	df	SS	MS	F	*P*
Season	3	7833.9	2611.3	10.06	< 0.01
Site	31	9400.1	303.2	1.17	0.25
Season:Site	43	18757.59	436.2	1.68	< 0.01
Residuals	328	85141.0	259.6		

Table 11 ANOVA for the carapace width of male crabs caught in traps, in terms of mesh size, season and site, for inshore sampling. Type III sum of squares have been presented (R^2 = 0.25).

Factor	df	SS	MS	F	*P*
Mesh size	1	10532.0	10532.0	122.0	<0.01
Season	2	4639.9	2320.0	26.9	<0.01
Site	30	10474.7	349.2	4.0	<0.01
Season:Site	47	9227.0	196.3	2.3	<0.01
Residuals	1205	103935.9	86.2		

Table 12 ANOVA for the carapace width of non-ovigerous female crabs caught in trawls in terms of season and site, for inshore sampling. Type III sum of squares have been presented (R^2 = 0.18).

Factor	df	SS	MS	F	*P*
Season	3	2205.4	2205.4	2.52	0.06
Site	31	18134.9	18134.9	2.01	< 0.01
Season:Site	47	21324.0	21324.0	1.56	0.01
Residuals	633	184548.2	291.5		

Table 13 ANOVA for the carapace width of non-ovigerous female crabs in traps, in terms of mesh size, season and site, for inshore sampling. Type III sum of squares have been presented (R^2 = 0.11).

Factor	df	SS	MS	F	*P*
Mesh size	1	14761.6	14761.6	152.1	<0.01
Season	2	1271.8	635.9	6.6	<0.01
Site	30	11452.7	381.8	3.9	<0.01
Season:Site	46	8815.5	191.6	2.0	<0.01
Residuals	3139	304577.4	97.0		

Table 14 ANOVA for the carapace width of trawl caught ovigerous female crabs in trawl, in terms of mesh size, season and site, for inshore sampling. Type III sum of squares have been presented (R^2 = 0.28).

Factor	df	SS	MS	F	*P*
Season	1	24.1	24.1	0.15	0.70
Site	18	4164.9	231.4	1.45	0.14
Residuals	69	10979.9	159.1		

Table 15 ANOVA for the carapace width of ovigerous female crabs in traps, in terms of mesh size, season and site, for inshore sampling. Type III sum of squares have been presented (R^2 = 0.21).

Factor	df	SS	MS	F	*P*
Mesh size	1	32.3	32.3	0.31	0.58
Season	2	388.7	194.4	1.84	0.16
Site	27	5779.4	214.1	2.02	<0.01
Season:Site	6	764.0	127.3	1.21	0.30
Residuals	253	26697.4	105.5		

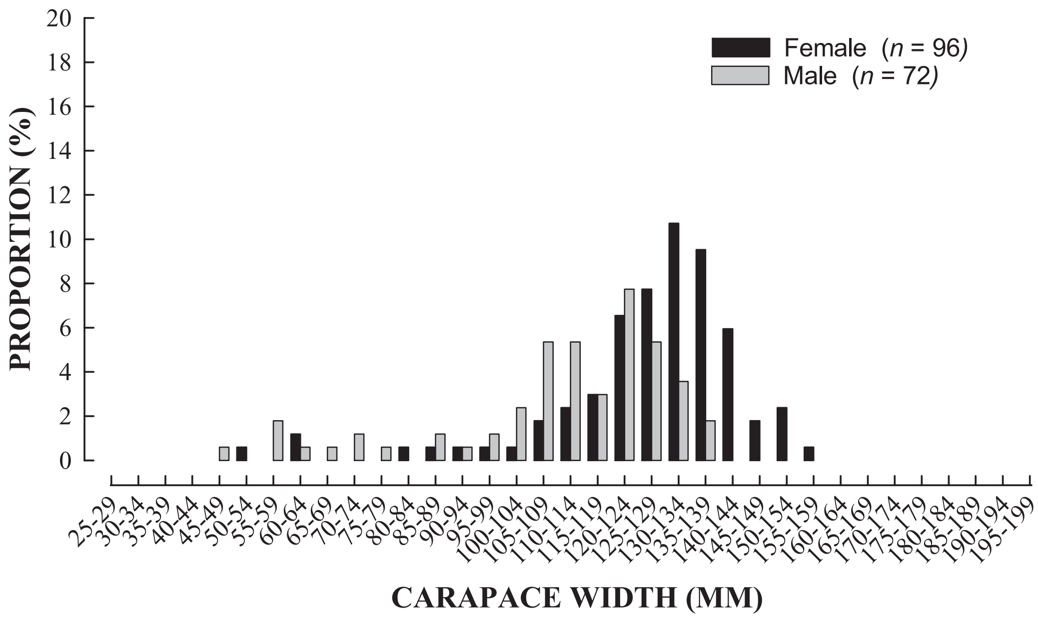

Figure 1 Size frequency composition of crabs caught using the trawl net in autumn during the inshore sampling regime.

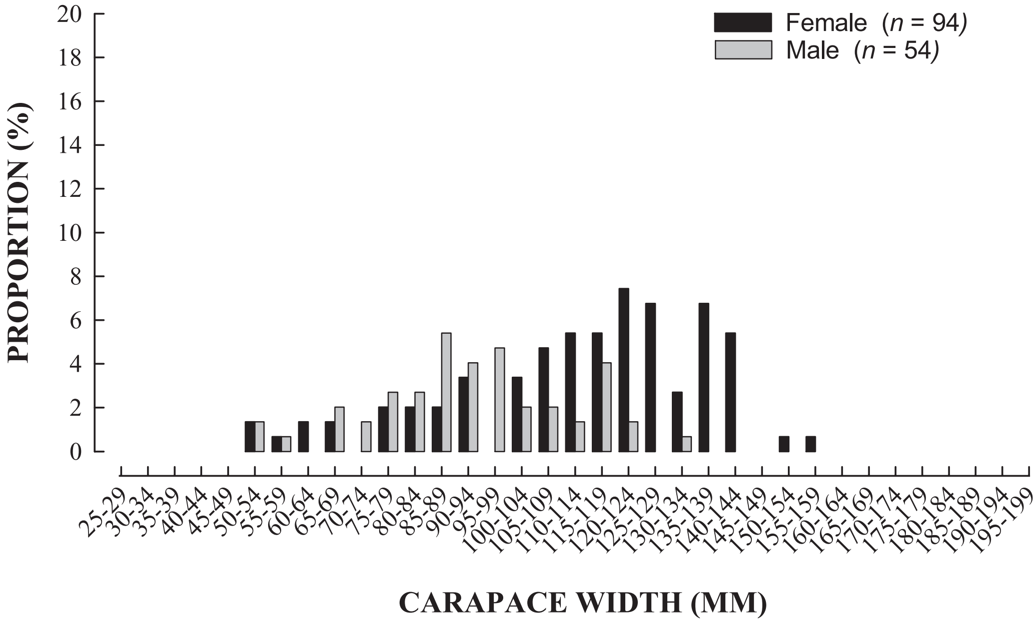

Figure 2 Size frequency composition of crabs caught using the trawl net in winter during the inshore sampling regime.

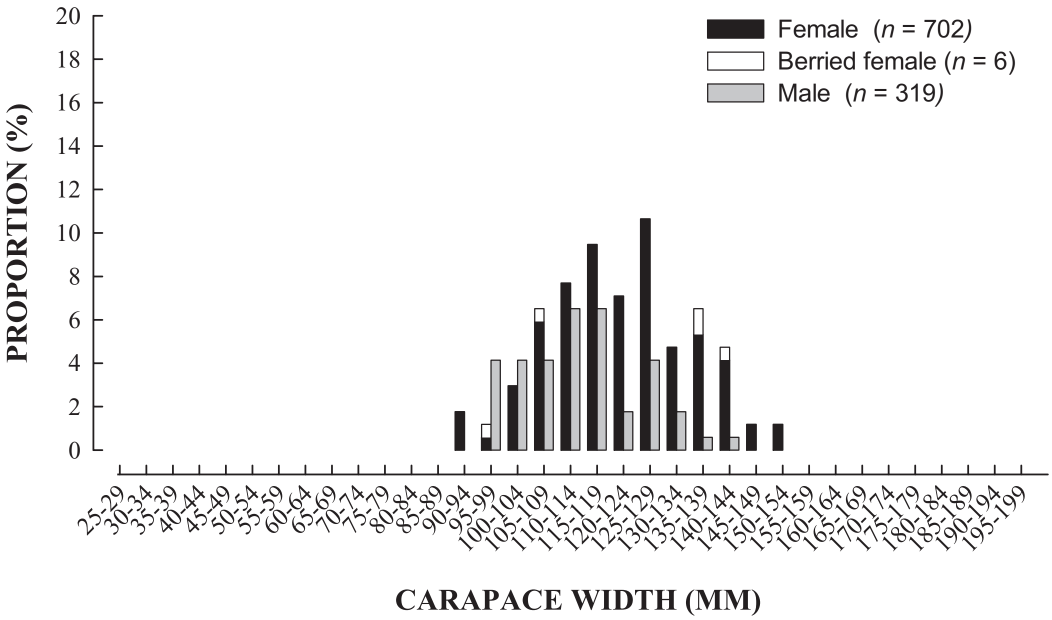

Figure 3 Size frequency composition of crabs caught using the traps in winter during the inshore sampling regime.

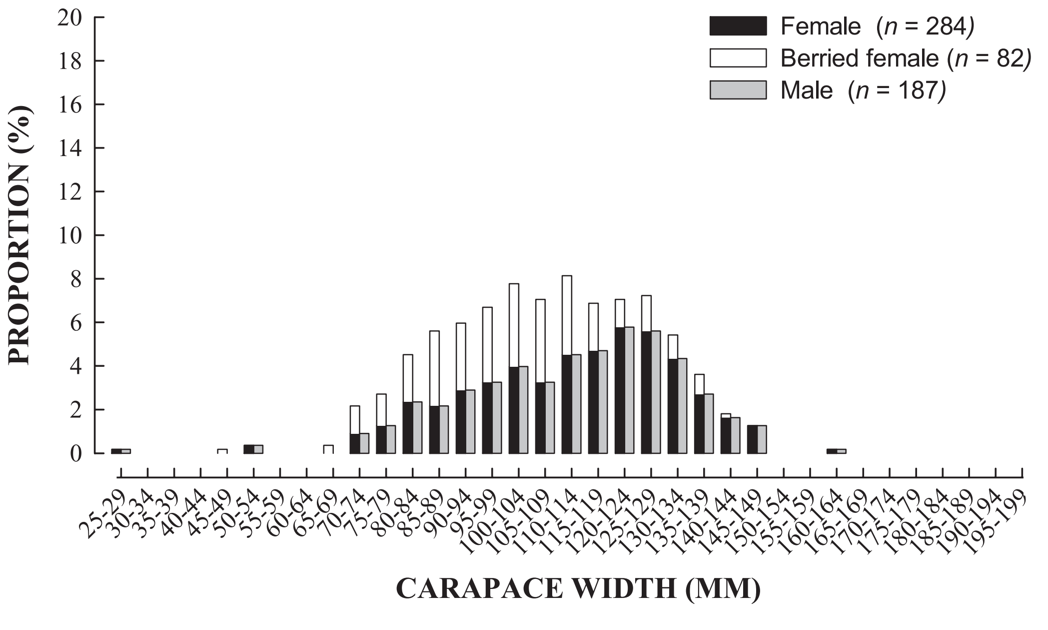

Figure 4 Size frequency composition of crabs caught using the trawl net in spring during the inshore sampling regime.

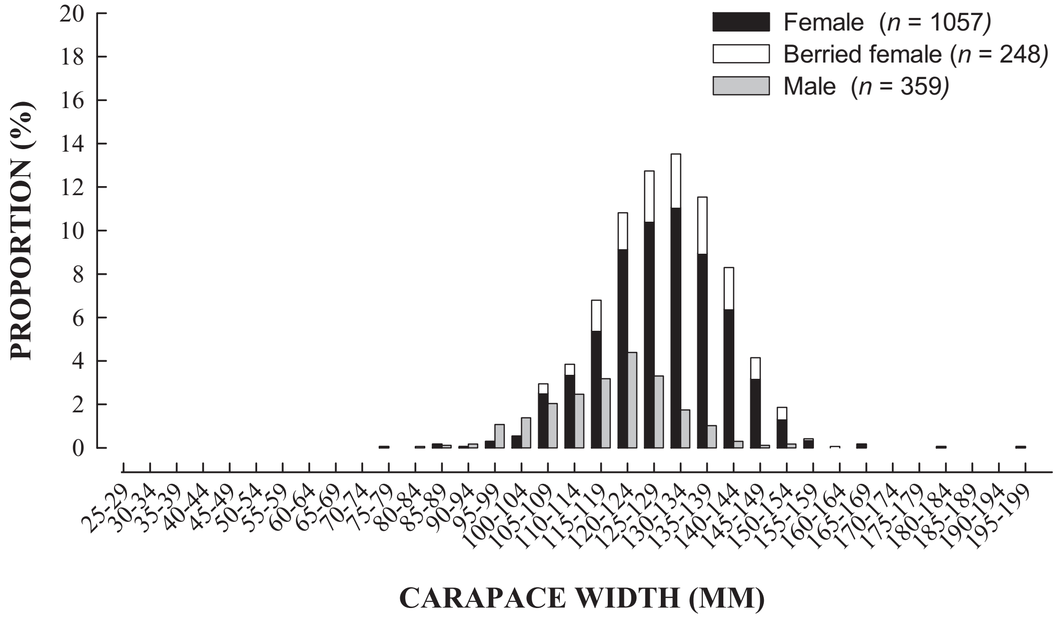

Figure 5 Size frequency composition of crabs caught using the traps in spring during the inshore sampling regime.

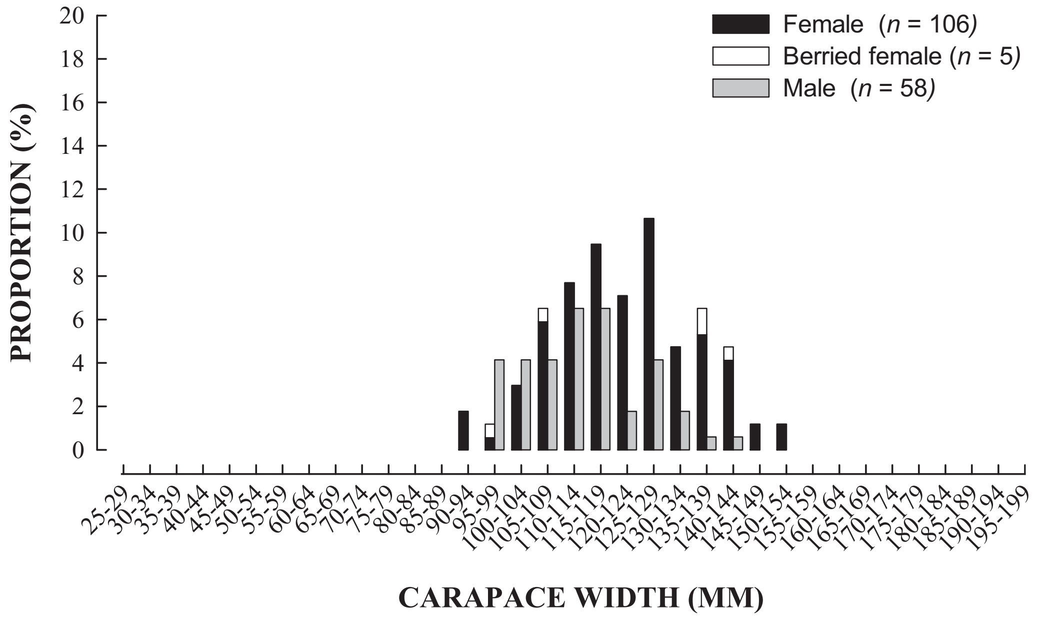

Figure 6 Size frequency composition of crabs caught using the trawl net in summer during the inshore sampling regime.

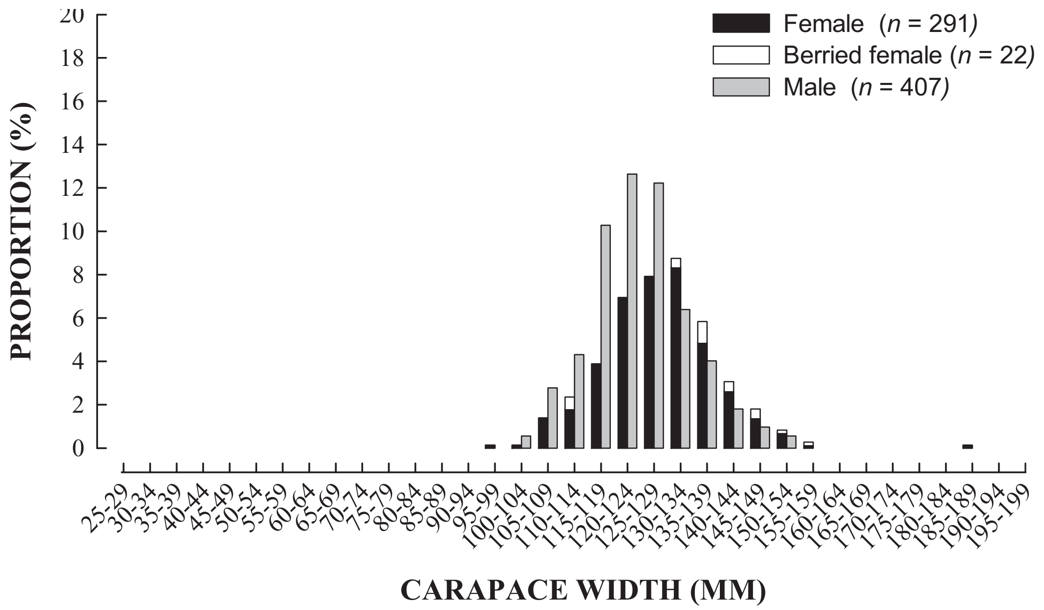

Figure 7 Size frequency composition of crabs caught using traps in summer during the inshore sampling regime.

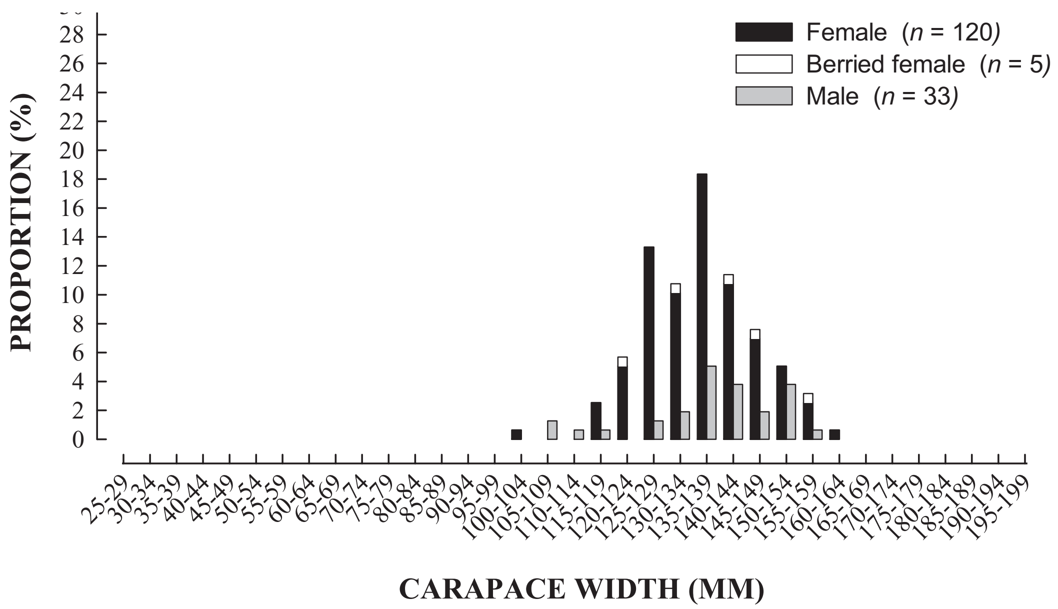

Figure 8 Size frequency composition of crabs caught using traps aboard the *R.V. Naturaliste* during summer during the offshore sampling regime.

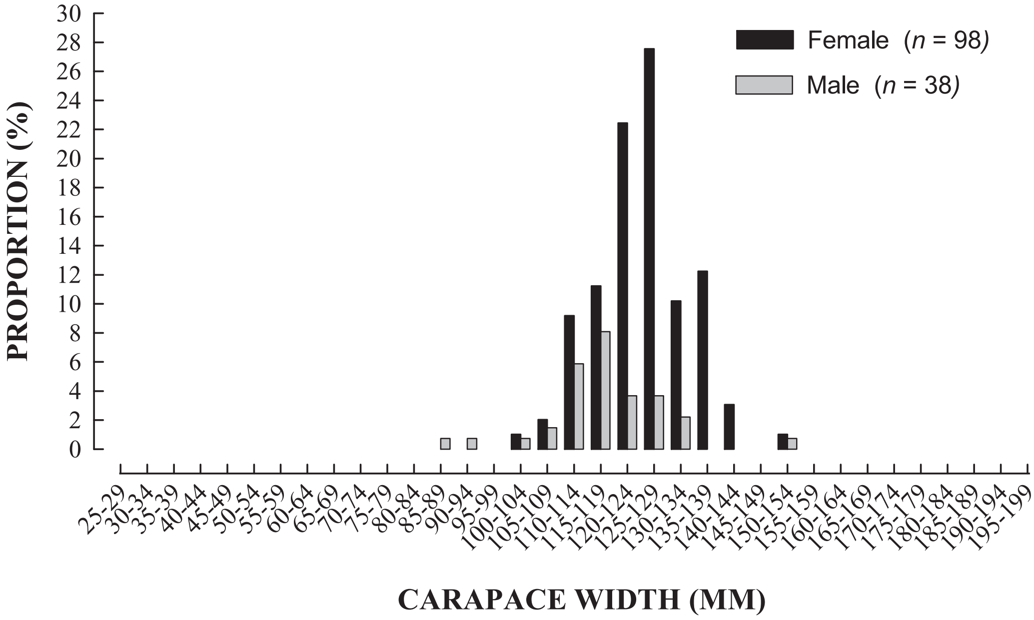

Figure 9 Size frequency composition of crabs caught during commercial catch monitoring during July 1999.

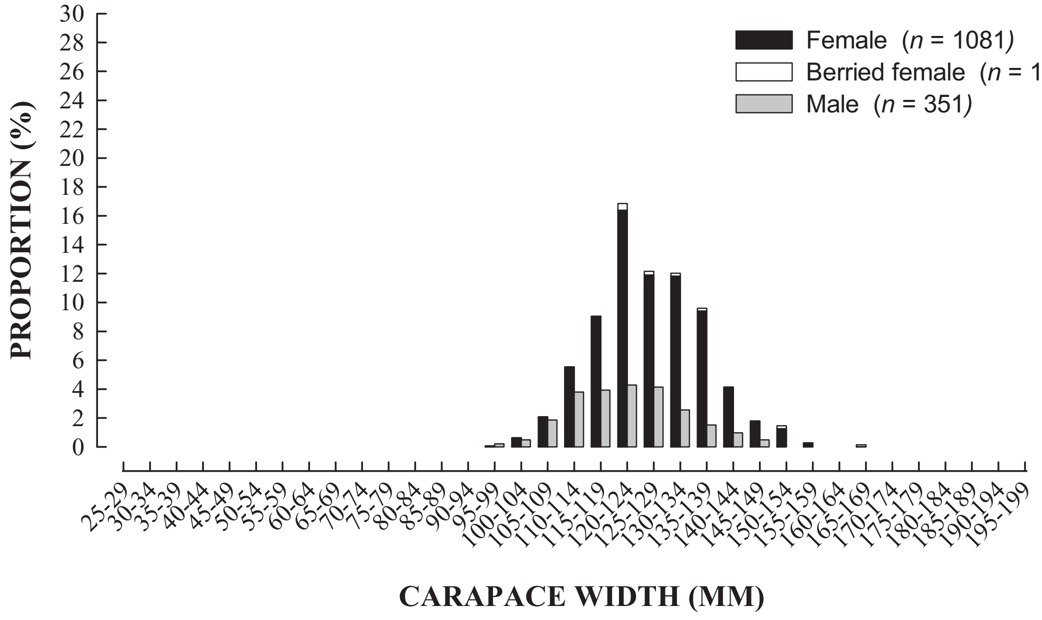

Figure 10 Size frequency composition of crabs caught during commercial catch monitoring during October 1999.

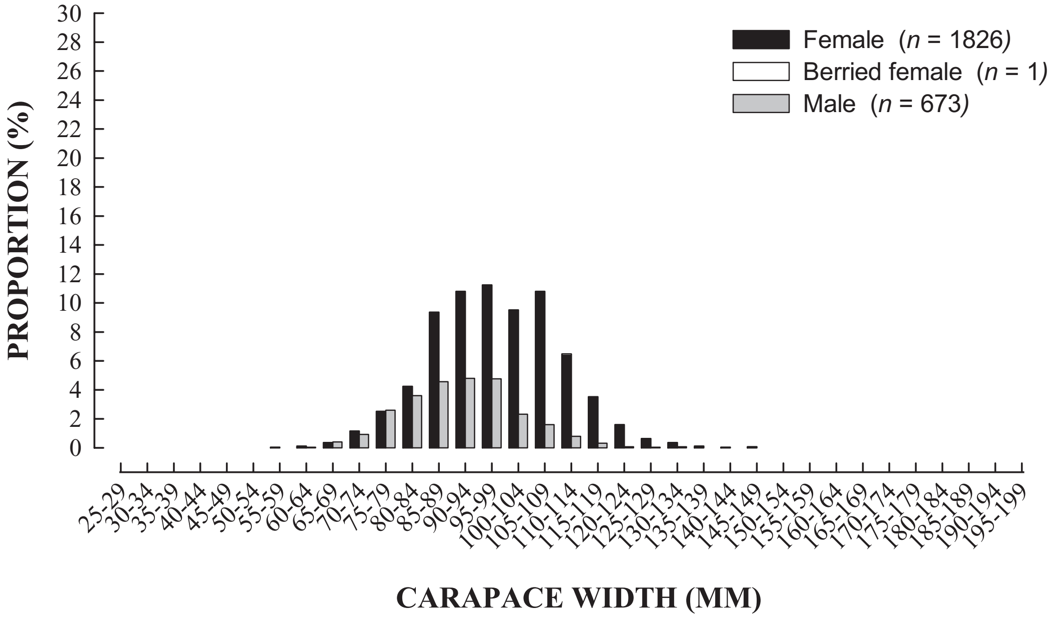

Figure 11 Size frequency composition of crabs caught during commercial catch monitoring during August 2000.

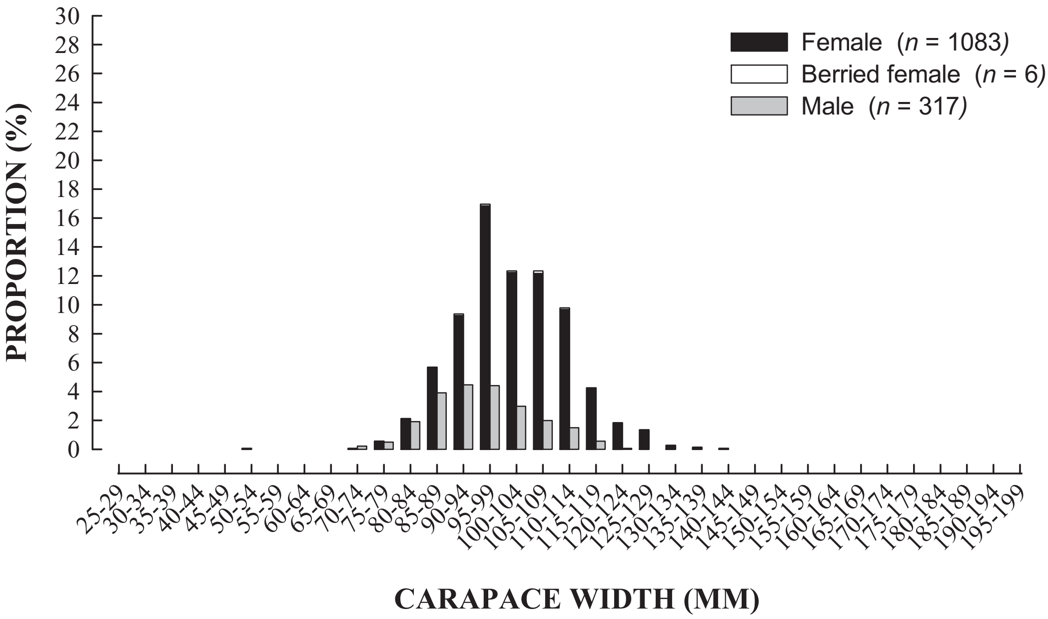

Figure 12 Size frequency composition of crabs caught during commercial catch monitoring during September 2000.

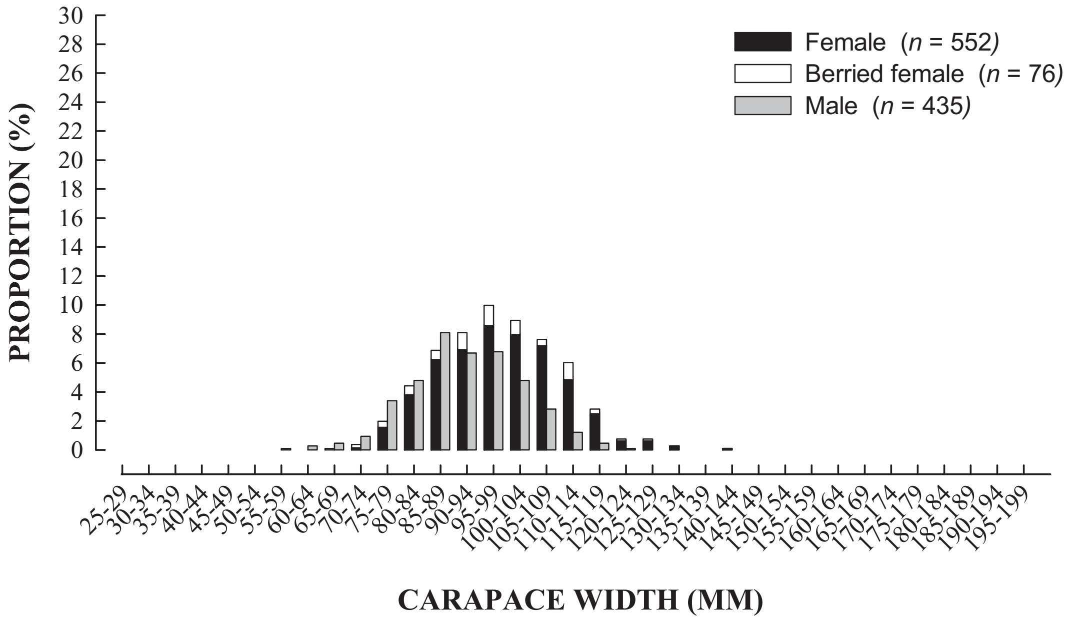

Figure 13 Size frequency composition of crabs caught during commercial catch monitoring during October 2000.

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

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