Development of stock allocation and assessment techniques in Western Australian blue swimmer crab fisheries

FRDC Project No. 2001/068

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Government of Western Australia Department of Fisheries

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Objectives:

1. To determine if the abundance of juveniles can be used to predict the relative strength of the subsequent recruitment of the adults of this species into the fishery.
2. To develop low cost annual recreational catch monitoring methods for resource allocation adjustments.
3. To assess the relative impacts of minimum size and fishing effort controls on the resource shares in Cockburn Sound and Geographe Bay.
4. To work with industry to collect baseline data on unfished stocks of blue swimmer crabs by developmental fishing, which is necessary to set initial catch limits, in selected areas along the coast of Western Australia.
5. To provide an assessment for the Experimental Carnarvon Crab Trap Fishery, based on commercial fishing and tagging data, as a means of developing methods for rapid assessment of new areas.
6. To investigate the model for blue swimmer crabs, which is currently being developed in South Australia (FRDC 98/116) and to determine its suitability for application to selected Western Australian blue swimmer crab fisheries.

1.0 NON-TECHNICAL SUMMARY

OUTCOMES ACHIEVED TO DATE

This project has resulted in the collection of biological data that will improve the stock assessment methods for blue swimmer crab fisheries throughout the state. The catch prediction devised during the current study is a direct method of forecasting future commercial catches within the Cockburn Sound fishery and provides and indication of the recreational catch. For fisheries managers, fishers and marketers of blue swimmer crabs the catch prediction will remove uncertainty. Recreational surveys are essential to quantify total catches of blue swimmer crabs within the Cockburn Sound and Geographe Bay fisheries and provide a basis for resource sharing. The surveys have shown that restrictions on commercial fishing effort in Cockburn Sound have been successful in increasing the share of the recreational sector but that this share falls short of the 3/8ths allocated mainly due to a lack of fishing effort on behalf of the recreational sector. In contrast, catches of blue swimmer crabs in Geographe Bay are mainly taken by the recreational sector. A comparison of recreational and commercial catches has enabled the efficiency of the current management to be assessed. Over time these surveys will help to explain temporal shifts in recreational catch and effort, enabling managers to implement new policies or modify existing strategies to ensure the sustainability of these fisheries. An assessment of developing blue swimmer crab fisheries within the Pilbara region showed that these fisheries have been productive and catch rates are steady, however the results are preliminary and highlight the need for ongoing research and management. The stock assessment of the Experimental Carnarvon Crab Trap Fishery shows that the fishery is productive, catches are resilient and stocks appear to be underexploited. However due to the short period for which the fishery has been operating a pre-cautionary and planned approach for the management of the expansion of this fishery is required. Large gaps in the knowledge of the fishery remain due to the size of Shark Bay and ongoing research and monitoring are crucial.

With the increasing popularity of recreational fishing, advances in gear technology and fishing techniques in the commercial sector 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.

Commercial catches of *Portunus pelagicus* in Cockburn Sound, the second largest blue swimmer crab fishery in Western Australia, vary markedly between years from 92 tonnes to 362 tonnes ($0.4 million to $1.6 million) between 1989/90 and 2002/03. The stock also supports an important recreational fishery as it is close to the metropolitan area. The prediction of each season's catch would remove uncertainty and aid management and marketing of this valuable species. This study has produced a robust and cost-effective catch-prediction index based on juvenile abundance. The densities of seven age/sex categories of *Portunus pelagicus* in three regions of Cockburn Sound, derived by research otter trawling between 1999 and 2005, were examined to determine which related best with the commercial catches in the following fishing season. The majority of age/sex categories correlated well with subsequent commercial catches, with the "all 0+ females and males" category producing the best prediction index. This category was then split into individual regions and month combinations and re-analysed to determine the minimal level of effort required to produce a reliable catch-prediction. The resulting index, which uses "all 0+ females and males" sampled in only the northern and middle regions of Cockburn Sound between May and July accurately predicts the subsequent commercial catch ($r = 0.70$, $n = 7$) in the following year and has predicted a catch of 101 t for the 2005/06 fishing season.

Recreational fishing surveys were conducted in Cockburn Sound and Geographe Bay during peak catch periods identified by Sumner and Malseed (2004) to determine a cost-effective method of assessing recreational catches. They have shown that catch share agreements, mainly restrictions on commercial fishing effort, were initially successful in increasing recreational catches in Cockburn Sound, but subsequently the recreational share has declined because recreational fishing effort has remained the same and commercial fishing effort has increased. Despite public perception, in Geographe Bay, recreational fishers have always taken the majority of the catch (51-66%). The commercial fishery in Cockburn Sound operates throughout the year except in October and November when the season is closed to protect spawning females. Peak commercial catches in this fishery occur between January and March, corresponding with the period of peak recreational crabbing activity. In contrast, the Geographe Bay fishery is a winter fishery.

Commercial catch monitoring within developing blue swimmer crab fisheries in the Pilbara has demonstrated that these stocks have so far proven resilient to exploratory fishing and that harvest levels (*ca* 50 tonnes) are commercially sustainable. The size at maturity (92.0 mm carapace width) is well below the minimum legal size (135 mm CW), ensuring that a sufficient proportion of the brood stock is protected. It is likely that future catches will increase as fishers refine their methods and become more familiar with the distribution of the stock. Because these fisheries are in such early stages of exploitation, continued monitoring is required before sustainable levels of fishing effort can be determined. Existing effort levels and licenses should be maintained to

ensure adequate assessment and to prevent later effort restrictions such as those set in place in Cockburn Sound.

The Experimental Carnarvon Crab Trap Fishery has become the most productive blue swimmer crab fishery in Western Australia with total annual catch of 525 tonnes (2003). With extensive areas of Shark Bay remaining unfished or only lightly fished, the potential for increased exploitation of blue swimmer crabs in Shark Bay is significant. Conflicts between user groups such as those that occur between the recreational and commercial sectors in Cockburn Sound do not occur in the Shark Bay Fishery since recreational catches, as indicated by recreational fishing surveys, are small. Commercial fishers have voluntarily raised the legal size from 127mm to 135mm CW, ensuring that a large component of the stock is available to other sectors. Due to the short time period the fishery has been operating, the tendency for blue swimmer crab populations to aggregate on the basis of size and sex, the small spatial area covered, and the fact that the data were collected from aboard commercial vessels, caution should be used when interpreting the data as it may not be representative of the total stock. Intra annual trends in catch rate and inter-annual relationships between catch and effort indicate that the fishery is not yet fully exploited. However, it could be some time before dramatic changes in the catch rate and stock structure become evident. It is essential that research continues to ensure that future decisions are based upon a sound knowledge of the stocks and research needs to be undertaken preferably by fishery independent methods to ensure accurate and meaningful results.

KEYWORDS: portunid, crab, catch, prediction, recreational, commercial, fishery, stock, assessment

2.0 ACKNOWLEDGEMENTS

We acknowledge the assistance of commercial blue swimmer crab fishers around the state who provided advice and allowed us to conduct research from their vessels. We would also like to thank the numerous recreational fishers who took time out of their fishing trips to answer recreational surveys and the numerous colleagues who helped collect crabs. We acknowledge the assistance of David Harris for his contribution both in the field and in the preparation of this report. We are grateful to the FRDC for providing the funding for this project.

3.0 BACKGROUND

The blue swimmer crab *Portunus pelagicus* Linnaeus, is abundant in many coastal marine and estuarine waters throughout the Indo-West Pacific (Stephenson, 1962) and forms the basis for an expanding commercial and a key recreational fishery in Western Australia (WA). Recreational fishing for blue swimmer crabs in the SW of WA dominates the inshore recreational catch in terms of the number caught for a single species, with approximately 298 tonnes caught (Sumner and Williamson, 1999). Recent surveys of marine recreational fishers showed that blue swimmer crabs were one of the most important species, in terms of numbers caught, for boat based fishing (Sumner and Williamson, 1999) and the second most important for shore based fishing (Ayvazian *et al*., 1997).

The total WA blue swimmer crab commercial catch expanded rapidly in the 1990s peaking at 740 tonnes in 1997/98, and has subsequently been reduced through resource sharing initiatives implemented in 1999/2000 to reallocate catches back to the recreational sector. In addition to these established fisheries in the waters south of Perth, a developmental commercial blue swimmer crab fishery in Carnarvon (Northern Shark Bay) has highlighted the potential for further expansion of the commercial fishery in the Gascoyne region and offshore waters of the west coast, areas that have been previously unfished commercially. A number of areas, in oceanic and embayment waters in the SW of the state and northward from Shark Bay, have been highlighted as having potential for future expansion of the commercial blue swimmer crab fishery. Developmental fisheries applications have been issued for a number of these areas. Recreational and commercial catches in these areas are low, therefore it is expected that these areas may provide an opportunity for the transfer of commercial effort as the demands in prime recreational areas expand. These developing fisheries provide a unique opportunity for the collection of baseline data on virgin unfished stocks of blue swimmer crabs to allow comparisons between ongoing developmental fisheries (i.e. Experimental Carnarvon Crab Trap Fishery) and established fisheries (i.e. Cockburn Sound Managed fishery). Thus providing an opportunity to collect data on the fishery from commencement to examine any initial changes in size frequency and monitor changes caused by fishing pressure, which has not been previously achieved.

Information to support management of all these stocks has been provided by a variety of studies. Basic biological data has been provided for blue swimmer crabs in Peel Harvey estuary (FRDC 95/042), Cockburn Sound and southern Shark Bay (FRDC 97/137), while genetic stock structure information (FRDC 98/118) has also been provided for WA and other states. Fisheries assessment research (FRDC 98/121) is providing data for management restructuring of the major commercial fishery in Cockburn Sound and smaller fisheries in the Swan-Canning River and Peel estuary. This project together with recreational catch survey data (FRDC 98/119) has enabled rationalisation of major commercial trap fishing in Cockburn Sound and allowed the establishment of a resource sharing agreement between commercial and recreational fishers for this area and Geographe Bay in 2000.

While the number of holders of commercial licenses in the blue swimmer crab fishery is being maintained at a constant level, the combined recreational and commercial catches of blue swimmer crabs is thought to be placing considerable pressure on stocks of the species in some areas of the state (Sumner *et al*., 2000). The rapid growth in commercial catches of blue swimmer crabs, through the use of traps rather than gill-nets, 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.

A major obstacle in the resolution of the fishery management and resource sharing issues has been the lack of current data on crab stocks and fishing effort. Future management of the expanding blue swimmer crab commercial fishery and ongoing management of the commercial and recreational catch allocations requires the further development of annual monitoring methods and tried stock assessment methods to estimate stock size for these areas. For the ongoing management of the commercial and recreational resource sharing there is also a need to further develop low cost methods to provide data on the annual variation in recreational catches and size composition. This information, collected on a year-to-year basis over a number of key periods, will provide a low cost complement to the more intensive survey work conducted previously, enabling further development and validation of the annual Cockburn Sound allocation model, as a method for other coastal crab fisheries.

4.0 NEED

Specifically the ongoing management and development of WA commercial and recreational crab fishing requires:

1. A fishery independent method to assess annual variation in pre-fishery recruitment strengths to enable variations in catch data due to effort or technology changes to be distinguished from environmental variations in recruit survival. This will also enable the strength of the recruitment to be predicted in advance, which may allow for a pro-active management approach to be adopted.
2. Improved methodologies for estimating stock abundance and size from newly surveyed areas using developmental fishing (e.g. Experimental Carnarvon Crab Trap Fishery), to enable more rapid assessment and allocation of fishing areas.
3. The validation of the allocation model adopted in Cockburn Sound and Geographe Bay, based on differential size limits and commercial effort control, and the associated development of low cost recreational catch monitoring systems to assess ongoing variations to catch shares. These data complement the more detailed data collected from creel surveys as they focus on the key recruitment periods. An allocation model that allocates the catch between the commercial and recreational sectors, 5/8:3/8 respectively, is currently in place for Cockburn Sound. Therefore it is important that a cost effective annual monitoring program is available to confirm its success.
4. To collect baseline data on currently unfished stocks of blue swimmer crabs to allow comparisons between ongoing developmental fisheries and established fisheries. This provides an opportunity to collect data on the fishery from commencement and to examine any changes caused by fishing pressure.

5. An assessment of the applicability of the SA model for blue swimmer crabs to WA commercial catch data from longstanding fishing such as is available for Cockburn Sound is required, to enable the ongoing stock assessment of the WA blue swimmer crab fisheries for annual ESD reporting.
6. The development of a dedicated blue swimmer crab database to record ongoing commercial catches and data from exploratory fishing permitted during the life of the project.

5.0 OBJECTIVES

1. To determine if the abundance of juveniles can be used to predict the relative strength of the subsequent recruitment of the adults of this species into the fishery.
2. To develop low cost annual recreational catch monitoring methods for resource allocation adjustments.
3. To assess the relative impacts of minimum size and fishing effort controls on the resource shares in Cockburn Sound and Geographe Bay.
4. To work with industry to collect baseline data on unfished stocks of blue swimmer crabs by developmental fishing, which is necessary to set initial catch limits, in selected areas along the coast of Western Australia.
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6. To investigate the model for blue swimmer crabs, which is currently being developed in South Australia (FRDC 98/116) and to determine its suitability for application to selected Western Australian blue swimmer crab fisheries.

6.0 CATCH PREDICTION FOR THE BLUE SWIMMER CRAB (*PORTUNUS PELAGICUS* LINNAEUS) IN COCKBURN SOUND WESTERN AUSTRALIA by Bellchambers, de Lestang, Smith and Thomson

6.1 INTRODUCTION

The landings of decapods around the world vary markedly from year to year. This has been noted in the United States' fisheries for the portunid blue crab (*Callinectes sapidus*) in Chesapeake Bay (Lipcius and Van Engel, 1990) and the York River (Metcalf *et al.,* 1995), the nephropid American lobster *Homarus americanus* in the northeast Atlantic Ocean (Wahle *et al.* 2004) and snow (*Chionoecetes opilio*) and tanner crabs (*Chionoecetes bairdii*) (Lithodidae) in the Bering Sea (Zheng *et al.,* 1998; Zheng and Kruse, 1999, 2000). For example, the Alaskan *C. bairdii* fishery has shown a 20-fold difference in abundance of male crabs from the mid 1970s to the mid 1990s (Zheng *et al.,* 1998). Large fluctuations in landed catch can have complex ecological, economic and sociological consequences (Metcalf *et al.,* 1995) and are a major source of uncertainty in fisheries management (Mense and Wenner, 1989).

Changes in total catches, which most probably reflect changes in population abundance, are caused mainly by variations in recruitment (Beverton and Holt, 1957; Ricker, 1957; Sharov *et al.,* 2003), which in turn are affected by physical and biotic factors both before and after settlement (Wahle, 2003). The environmental factors include water temperature, salinity (Hurt *et al.,* 1979), predation, availability of food (de Lestang *et al.,* 2003a) and habitat availability (Pile *et al.*, 1996). The stock–recruitment relationships include the size of the reproductive biomass (Zheng and Kruse, 1999), the rate of density-dependent mortality (Lipcius and Van Engel, 1990) and the rate of emigration (Pile *et al.,* 1996). For example, annual production in the western rock lobster

(*Panulirus cygnus*) fishery in Australia can be estimated 3-4 years in advance from the densities of post-larval lobsters (puerulus) (Caputi *et al.,* 1995).

The Western Australian commercial blue swimmer crab fishery is the largest blue swimmer crab fishery in Australia, with a total commercial catch of 902 t with a value of $ 4.1 million in 2003/04 (Bellchambers *et al.,* 2005). The number of commercial licenses in the blue swimmer crab fishery is constant (there are curently 48 linces in WA) and while the recreational fishery is managed by bag limits, the numbers of participants is continuing to grow. As a result, the combined recreational and commercial catches are placing considerable pressure on *P. pelagicus* stocks in some areas of the state (Sumner *et al.,* 2000).

A large component of this fishery is in Cockburn Sound close to the Perth metropolitan area (Fig. 6.1), and hence has a large recreational fishery (Bellchambers *et al.,* 2005). The total commercial catch of *P. pelagicus* in Cockburn Sound (all gear types) increased from 153 t in 1989/90 to peak at 362 t in 1996/97, before declining to 110 t in 2003/04 with slight increases in 1999/00 and 2002/03. Fishing effort, as measured by the number of trap lifts, peaked in 1996/97 at 322,000 trap lifts and declined to less than 150,000 trap lifts in 2003/04. Traps were first introduced in 1993 and have now completely replaced gillnets.

For the ongoing management of the Cockburn Sound blue swimmer crab fishery, and particularly commercial and recreational resource sharing, there is a need for a predictive strategy to provide data on annual variations in blue swimmer crab abundance. Predictive indices can be used to implement effort limits and thereby help prevent population collapse through over-fishing of the spawning biomass, which is a risk in species with only one or two major year-classes (Lipcius and Van Engel, 1990). Successful management of the commercial blue swimmer crab fishery and of the commercial and recreational catch allocations will rely on accurate estimates of stock sizes. Methods of monitoring and assessing the stock each year are needed. The objective of the present study was to develop a cost-effective method of measuring the annual recruitment of *P. pelagicus* into the Cockburn Sound fishery to predict the subsequent commercial catch.

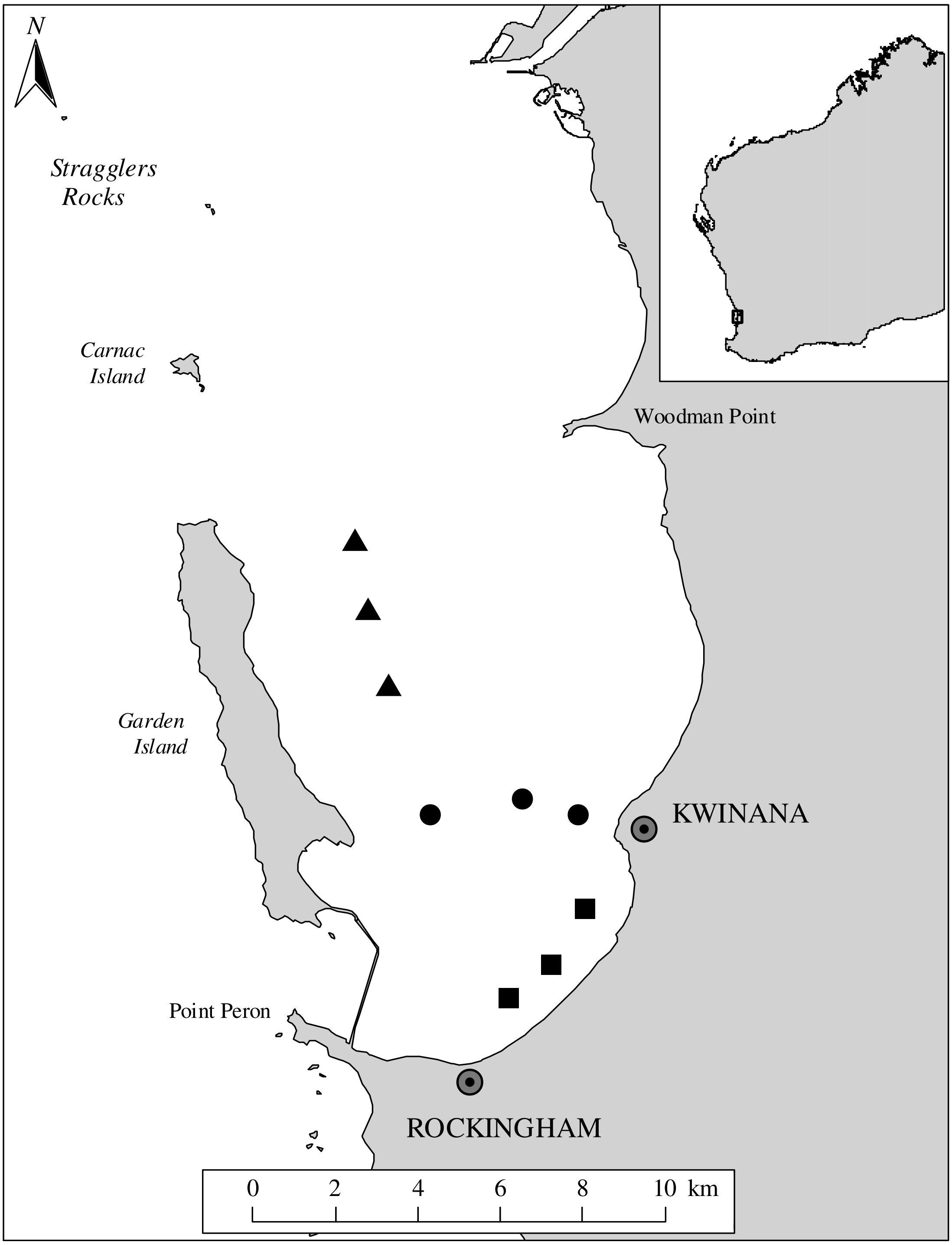

Figure 6.1 Map of Cockburn Sound displaying the individual sites and regions (groups of sites) sampled. ▲ Northern Deep, ● Middle Deep and ■ Southern Deep.

6.2 *MATERIALS AND METHODS*

6.2.1 Life cycle of the blue swimmer crab.

The reproductive cycle of blue swimmer crabs varies with water temperature. Reproduction of blue swimmer crabs in Cockburn Sound, Western Australia, is restricted to warmer months with mating occurring in late summer (January to March) when females are soft-shelled (Kangas, 2000). In Cockburn Sound and the other temperate regions of the fishery, ovigerous females are caught between November and January (Penn, 1977; Smith, 1982). Incubation takes 10 – 18 days, depending upon water temperature, with each female releasing up to one million eggs (Kangas, 2000). The larval phase consists of five stages, which spend up to six weeks in coastal waters, drifting as far as 60 km out to sea before settling in inshore waters (Kangas, 2000). Rapid growth occurs over summer during the juvenile phase. The size at which maturity occurs can vary with latitude or location and between individuals at any location. Most (85%) are mature in less than 12 months between 86 –96 mm carapace width (CW). Blue swimmer crabs in estuaries and embayments in southwestern Australia typically start to attain minimum legal size (127 mm) in late summer, when they are approximately one year old. Most have died either through natural or fishing mortality by the time they are 20 months old (Potter *et al.,* 2001).

6.2.2 Study site

Cockburn Sound (32°10'S, 115°43'E), located 20 km southwest of Perth, is an embayment 15 km long, 10 km wide and about 100 km^2 in extent (Fig. 6.1). The benthic habitat types and water depths in the Sound range from shallow, sheltered inshore waters < 2 m deep with sandy bottoms, to expansive seagrass flats 2–6 m deep and a central basin with waters 17–24 m deep. Cockburn

Sound receives no freshwater discharge from rivers or streams; salinity remains ~35 ppt all year (Hutchinson and Moore, 1979).

6.2.3 Sampling gear

A research otter trawl net (small try-net), 5 m wide, 0.5 m high and 5 m long was fitted with 51 mm mesh in the wings and 25 mm mesh in the bunt. The bridle was 13 m long, while the warp length was varied to 3.5 times the water depth, each tow of the net covered 750 m at 3.5 km h^{-1}. The effective spread of the net on the seabed was estimated as 0.6 × net headrope length in metres. The area trawled at each of the nine sites was then calculated by multiplying the distance covered by the effective net spread (de Lestang *et al*., 2003b).

Each crab was sexed and its carapace width (CW i.e. the distance between the tips of the two lateral spines of the carapace) was recorded to the nearest millimeter. Catch rates are expressed as a density, i.e. number of crabs/100 m^{-2}.

6.2.4 Sampling regime

Sites were chosen randomly from the entire area of deep water within the sound. These sites were then grouped based upon geographical proximity to one another, resulting in three sites at each of the three regions (Fig. 1). Initially the sites were analysed individually, but after grouping into three categories greater statistical power was generated by the larger number of samples within each category that gave greater confidence in the model.

The sites were each 1000 m × 250 m and oriented southwest–northeast to accommodate local weather and sea conditions. Sampling consisted of trawling for 750 m somewhere inside ths grid. The substrate at each of the locations consisted of sparsely vegetated sand and silt, in depths ranging from 17–24 m.

Between April 1998 and March 2000, samples were collected once a month during daylight. This sampling was undertaken by staff from Murdoch University and sampling was undertaken during the day due to logistics. The Department of Fisheries WA collected samples fortnightly during November and December 2001. Between 2002 and 2005 sampling was undertaken by staff from the Department of Fisheries Western Australia. Throughout that period each site was trawled every two weeks between January and May during both the day and night. Night sampling commenced as crabs are most active during the night (Sumpton and Smith, 1990) and are therefore more likely to be caught in the trawl net. The effect of sampling during the day versus at night was removed by incorporating a day-night factor into the model.

6.2.5 Data analysis

Mid–points between the estimated mean length-at-age of female and male crabs in corresponding months of consecutive year classes (e.g. 0+ and 1+), derived from a seasonal von Bertalanffy growth curve (de Lestang *et al.*, 2003c), were used to determine a carapace width (*CW*) to separate 0+ from 1+ crabs (Table 6.1). The crabs were also assigned a maturity state (immature or mature) based on a previously recorded size at first maturity (87 mm CW for both sexes) for blue swimmer crabs in this embayment (de Lestang *et al.*, 2003b).

The crabs were then allocated to one of seven categories according to their age and sex: 0+ female crabs (f0+); 0+ male crabs (m0+); all 0+ crabs (all 0+); 1+ female crabs (f1+); 1+ male crabs (m1+); all 1+ crabs (all1+) and all mature female crabs (all mf).

Table 6.1 Monthly carapace widths that separate 0+ and 1+ *Portunus pelagicus* in Cockburn Sound derived from a seasonal von Bertalanffy growth curve (de Lestang *et al*., 2003c).

Month	Carapace width (mm)
January	68.5
February	77.5
March	91.8
April	104.1
May	108.7
June	118.5
July	127.0
August	134.2
September	140.3
October	145.6
November	150.1
December	153.9

Annual catch and effort (number of trap lifts) for the Cockburn Sound commercial crab fishery are recorded by the Department of Fisheries. The commercial crab season in the sound runs from December to the following September with the bulk of the commercial catch landed between January and March.

Indices to predict catch

The abundances (crabs per 100 m^{-2}) of the various age/sex categories from January to November in the previous year were each analysed to determine which index best described the large seasonal fluctuations in total crab landings recorded in Cockburn Sound.

The mean abundance of each "age/sex" category of crabs was transformed ln (*abundance*+0.1), to remove the skewness from the catch rate data. To produce an annual index for each "age/sex" category that could be compared to the seasonal commercial landings, the within-season and between-sampling variations in the recruitment indices were analyzed by ANOVA, using year, month, sampling time and sites as fixed factors. The ANOVA was unbalanced as not all months and sites were sampled each year.

The subsequent back-transformed least-squared means (*LSM*), by year, were used as mean annual indices to predict catch. The correlation coefficients between these indices and the subsequent seasonal commercial crab landing were used to determine the best catch predictor.

As a key objective of the present study was to determine a cost-effective method of predicting catch in the forthcoming season, the minimum number of regions and months needed for a good prediction without compromising the accuracy of the model was determined in the following way. Once the most appropriate *LSM* annual index of recruitment was chosen, the data from this category were divided into three data sets on the basis of where the samples were collected (Cockburn-north, Cockburn-middle and Cockburn-south). These data sets and their various combinations were then treated in the same manner as the seven "age/sex" categories to determine the appropriateness of each as a catch predictor. This was assessed by a direct comparison of R^2. If two combinations had equal or similar R^2 values they were then assessed using AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion). AIC and BIC provide measures for determining whether a model is improved by dropping various terms. Once the most appropriate region or combination of regions was selected the data sets were divided into sampling months and combinations of months for the reduced locations to determine the minimum time period required for sampling that still produced an accurate predictive recruitment index.

6.3 RESULTS

6.3.1 Indices to predict catch

The highest correlation coefficient resulting from the regression between the various *LSM* annual indices of catch rate derived from each "age/sex" category and the total seasonal crab landings was 0.74 ($P < 0.05$) produced by the "female 0+" category followed by 0.70 produced by the "all 0+" category (Fig. 6.2, Table 6.2). Since the index derived by the "all 0+" category was based on more crabs per sample (*i.e.* females + males vs only females) and the use of this index does not require the sexing of small crabs (which is sometimes difficult and time consuming), this category was considered to produce the most robust index. The "all 0+" category was also preferred over other age cohorts as it provides the longest lag period between the catch prediction and the start of the commercial fishing season, providing the model with maximum predictive capacity.

The data for the "all 0+" category was then divided into the three regions to assess whether fewer sampling regions would still produce a good index. The inter-annual abundance of "all 0+"

varies markedly with the abundance of “all 0+” in the north being the most closely linked to catch in the following year (Fig. 6.3A). The correlation coefficients produced between the *LSM* annual index of catch of “all 0+” crabs caught in the southern, middle and northern regions of Cockburn Sound and combinations of these regions were lower than that displayed by the combined “all 0+” category, except for the combination of the middle and northern regions and the northern region alone (Table 6.3). The *LSM* annual indices of catch based on the northern region and on the combination of the northern and middle regions both produced the highest correlation coefficients with seasonal catch of 0.78 and 0.77 respectively ($P < 0.05$). The combination of all three regions (S+ M + N) was marginally less strongly correlated ($R^2 = 0.70$) than that produced by the northern region or combined northern and middle regions. As the northern region was also not continuously sampled, the northern and middle index was considered to be the most appropriate as it produced a recruitment index over a broader area.

Patterns in the monthly abundance of “all 0+” illustrates that recruitment of the “all 0+” class commences in June (Fig. 6.3B). The highest correlation coefficient for the *LSM* annual indices of catch using the “all 0+/middle–northern” category and combinations of months was 0.96, produced by both May-September and May-October (Table 6.4). The correlation co-efficient for the May-July sample was 0.95. Based on the fact that sampling for only three months as opposed to five or six months represents a significant reduction in sampling effort and based on the correlation value and an assessment of the AIC and BIC criteria, the May-July sample was selected as the most appropriate combination of months (Fig. 6.3B). The predicted catch using this index for the 2005/06 season was 101 t (Fig. 6.4).

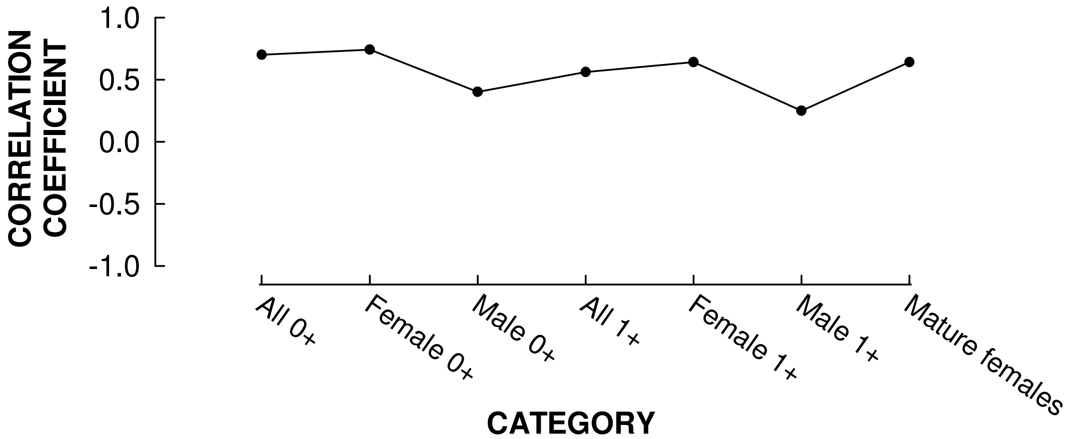

Figure 6.2 Correlation coefficients between of commercial crab landings in Cockburn Sound and annual indices of abundance of 'all 0+' category based on data derived from individual sites and regions.

Table 6.2 Correlation coefficients and AIC and BIC criteria values produced between the abundance of seven age/sex categories and catch in the following year. * Indicates the most appropriate data set.

Category	Sample size	Correlation	AIC	BIC
All 0+ *	7	0.70	83.33	83.16
Female 0+	7	0.74	82.63	82.46
Male 0+	7	0.40	86.86	86.70
All 1+	7	0.56	85.42	85.26
Female 1+	7	0.64	84.46	84.30
Male 1+	7	0.25	87.67	87.50
Mature females	7	0.64	84.41	84.24

Table 6.3 Correlation coefficients and AIC and BIC criteria values produced between LSM annual index of catch of "all 0+" crabs caught in the southern, middle and northern regions and combinations of these regions. * Indicates the most appropriate data set.

Region(s)	Sample size	Correlation	AIC	BIC
Southern deep (S)	7	0.37	87.07	86.91
Middle deep (M)	7	0.14	87.96	87.80
Northern deep (N)	7	0.78	59.49	58.32
S + M	7	0.26	87.60	87.44
S + N	7	0.65	84.32	84.16
N + M*	7	0.77	81.90	81.74
S + M + N	7	0.70	83.33	83.16

Table 6.4 Correlation coefficients and AIC and BIC criteria values produced between LSM annual index of catch of "all 0+" crabs, where data has been restricted to North and Middle deep and combinations of months. * Indicates the most appropriate data set.

Month	Sample size	Correlation	AIC	BIC
January	5	0.34	64.68	63.51
February	5	-0.43	64.25	63.08
March	4	-0.28	53.96	52.12
April	4	0.32	53.85	52.01
May	4	0.94	45.40	43.56
November	3	0.67	40.44	37.74
Jan-May	5	0.70	61.95	60.77
May-June	5	0.90	57.15	55.97
May-July	5	0.95	53.96	52.79
May-August*	5	0.95	53.74	52.57
May-September	5	0.96	53.08	51.91
May-October	5	0.96	53.12	51.95
May-November	6	0.90	67.18	66.56

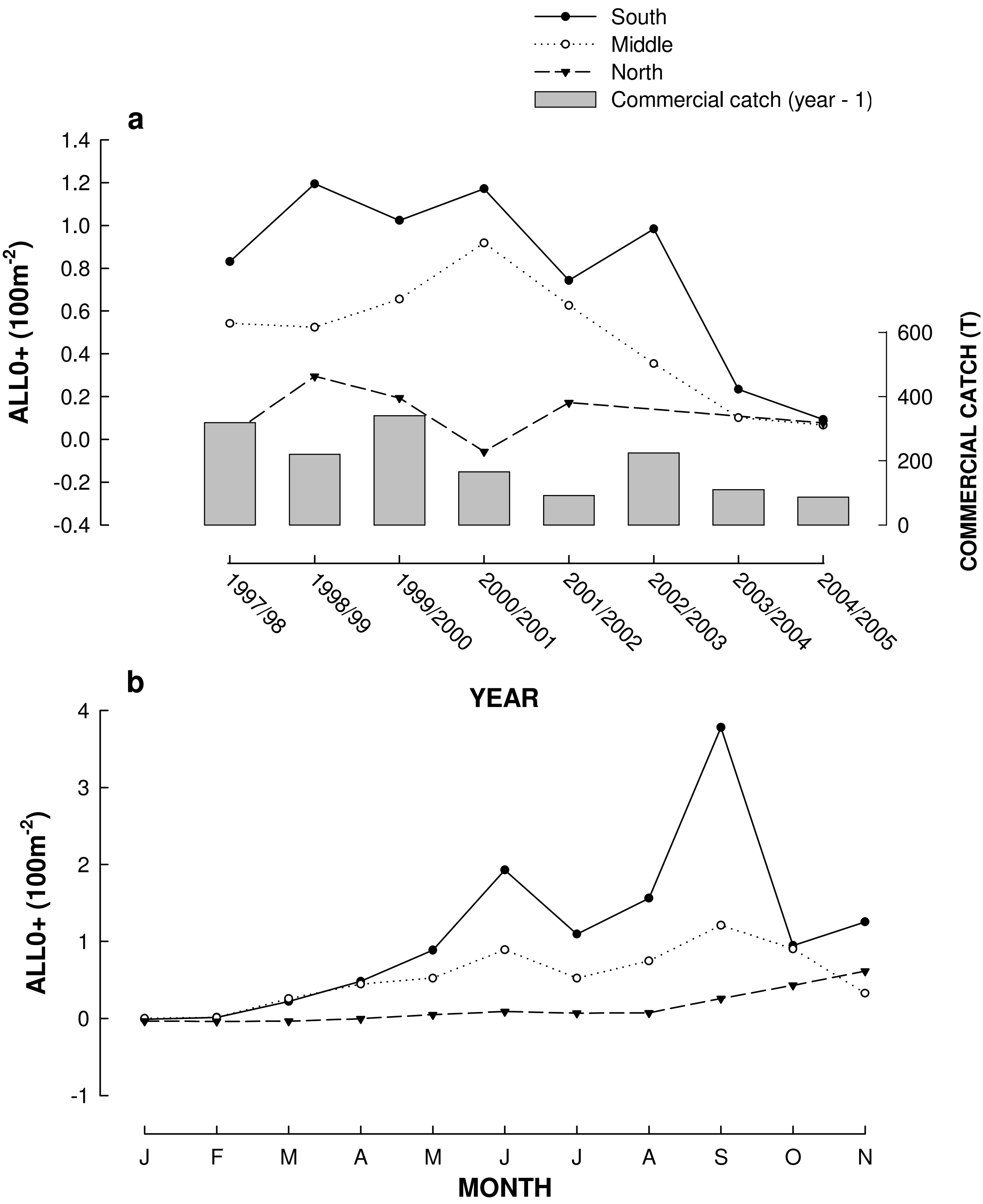

Figure 6.3 Annual 'All 0+' indices derived from data collected in the north, middle and southern regions of Cockburn Sound compared to the following seasons commercial crab landings (a) and monthly 'All 0+' indices based on data collected in the northern, middle and southern regions of Cockburn Sound (b).

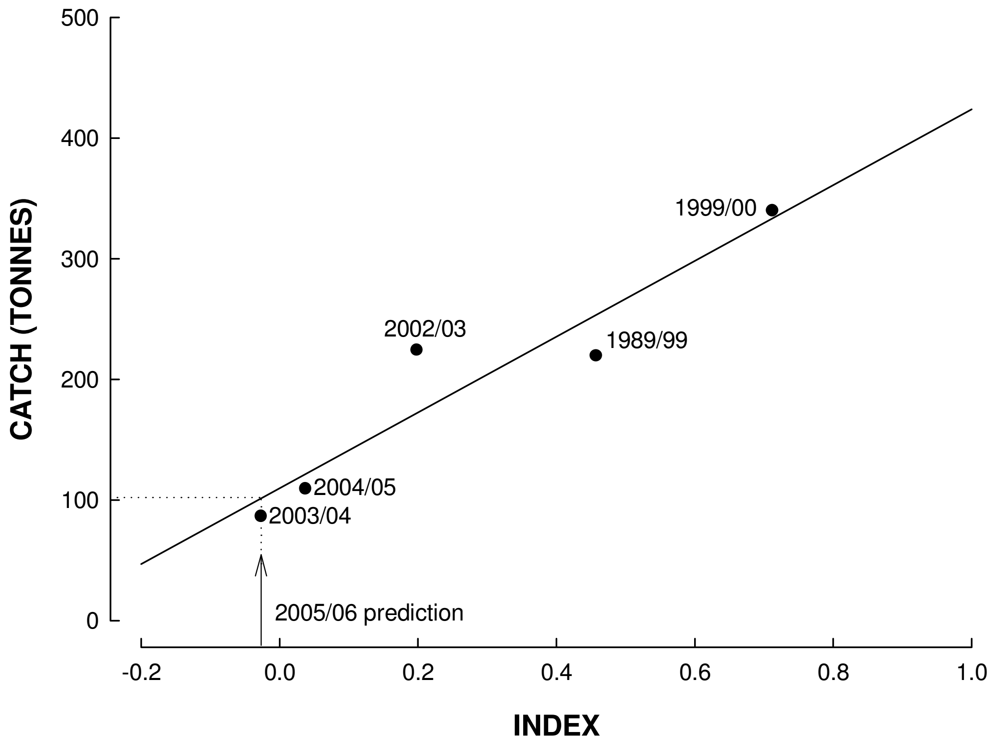

Figure 6.4 The relationship between commercial crab landings and the 'all 0+' index based on data collected between May-July in the Northern and Middle regions of Cockburn Sound.

6.4 DISCUSSION

Historically, commercial blue swimmer crab catches in Cockburn Sound have shown large annual fluctuations in landed catch, ranging from 92 t in 2001/02 to 362 t in 1996/97. These fluctuations are attributable to changes in commercial fishing practices and changes in recruitment. Since 1993/94 commercial fishers have shifted from set-nets to crab traps. This shift coincided with a marked increase in total crab landings by mid-1990s. This is not a reflection of greater catching efficiency of pots but due to an overestimate of the net to trap conversion factor (100 traps: 1200 m set net): fishers were allocated too many traps. Melville-Smith et al. (1999) re-calculated the conversion factor and produced a ratio (67 traps: 1200 m of net) that was 33% less than that used in the fishery since 1994. In an attempt to restabilize catches and reallocate catches back to the recreational sector, the total number of commercial traps was reduced from 1600 to 1280 in 1999/00 and to 960 in 2001/02. As a result, the catch has returned to historical levels and the CPUE has remained relatively stable.

Although a change in commercial fishing practices resulted in increases in total crab landings, this change does not explain the marked fluctuations in the years between 1997/98 and 2003/04; for example, they varied from 318 t to 220 t to 340t in three consecutive years. Much of this variation is attributable to variations in recruitment and natural mortality, a situation that has been recorded in other commercial decapod fisheries worldwide (Perry *et al.,* 1995; Zheng and Kruse, 1999). For example, over the last 20 years, sporadic recruitment levels, coupled with high natural and fishing mortality, resulted in a 20-fold difference between peak and low abundances of legal-sized male tanner crab, *Chionoecetes bairdii* in Alaska (Zheng *et al.,* 1998).

Since the exploitation of legal-sized blue swimmer crabs in Cockburn Sound is relatively high, each season's catch consists primarily of 12- and 18-month-old crabs recruiting into the fishery (de Lestang *et al.,* 2003a). Therefore, it is not surprising that an annual measure of juvenile abundance in Cockburn Sound correlates well with the subsequent year's commercial catch. Blue swimmer crabs recruiting into the fishery early in their second year of life and contributing significantly to the catch has also been recorded in other commercial crab fisheries in southern Australia (Smith, 1982; Potter *et al.,* 1983).

This study showed that a measure of 0+ abundance derived from sampling both sexes in the middle and northern regions of Cockburn Sound produced a good index to predict the following season's commercial catch based on correlation, time to process samples and predictive capacity that this age category provides the model. Potter *et al.* (2001) recorded that, in the sound, juvenile crabs were first found in southern nearshore areas. At a carapace width of ~50 mm, these juveniles moved into the deeper southern offshore waters and, as numbers accumulated in this habitat they flowed over into the middle and northern regions of this embayment. Therefore it is likely that, if the habitat in the southern region becomes 'saturated' with 0+ crabs, a measure of their abundance in this region may not vary much with changes in the overall abundance of 0+ crabs in the whole system. In contrast, since the middle and northern regions of this embayment possibly act as 'flow over' regions, 0+ abundance in these regions would vary markedly with changes in overall 0+ population size. This explains why the juveniles from the middle and northern regions correlate better with annual catch than juveniles from the south.

Larval, postlarval, or juvenile settlement indices have proved useful in forecasting adult abundance in decapods e.g. western rock lobster, *Panulirus cygnus* (Caputi *et al.,* 1995) and the blue crab, *Callinectes sapidus* (Lipcius and Stockhausen, 2002). Attempts to correlate the abundance of different life stages of decapod crustaceans and fishery catches, have not generally been successful in forecasting future catches. In the Western Australian rock lobster (*Panulirus cygnus*) fishery, catches are accurately predicted 3-4 years in advance, based on the densities of post-larval lobsters (puerulus) (Caputi *et al.,* 1995). The abundance of juvenile crabs (*Callinectes sapidus*) has been used successfully to measure recruitment in Delaware Bay, Chesapeake Bay (Kahn *et al.,* 1998) and the eastern Bering Sea (Zheng *et al.,* 1998); however, these models have not been used to predict subsequent catch.

Quantifying the earliest life-history stage that will result in accurate predictions can yield the greatest lead-time for forecasting year-class strength (Metcalf et al., 1995). Similarly, in a dredge survey of Chesapeake Bay, Sharov et al. (2003) found a strong relationship between blue crab abundance and catch. Although not attempted, they suggest that winter estimates of blue crab abundance can be used successfully to forecast summer catch. In the current study the best correlation between an "age/sex" category and the total seasonal crab landings was displayed by both the "all 0+" and the "f 0+" categories. The "all 0+" category produced the best catch-predicting index, presumably because "1+" crabs constitute most of the catch in the year they are sampled, while the "0+" category constitute the following season's commercial catch. The assessment undertaken in this study was based on only 4-5 years of data and needs to be confirmed with additional years of sampling.

We estimate the total commercial catch for the upcoming 2005/2006 blue swimmer crab fishing season in Cockburn Sound at approximately 101 t, based on the catch rate of the "all 0+" category between May-July. Indices such as those developed here can provide a measure of annual recruitment successes, and be used to separate natural changes in abundance from the effects of fishing. The predictive model reduces the uncertainty of future total commercial catches in the fishery, helping both fisheries management and the marketing of this resource. For example, predicting catches of western rock lobster enables exporters to establish their markets in advance. The model is currently based on a small number of data points and will be updated and improved as additional years of data become available. The catch prediction generated by this model is not absolute but will improve over time. The model is not intended for use in allocating catch shares between commercial and recreational sectors within the fishery but as a tool to remove some uncertainty from the fishery.

7.0 RECREATIONAL AND COMMERCIAL CATCH AND EFFORT OF BLUE SWIMMER CRABS IN COCKBURN SOUND AND GEOGRAPHE BAY, WESTERN AUSTRALIA BY BELLCHAMBERS, SMITH, HARRIS AND SUMNER.

7.1 INTRODUCTION

The blue swimmer crab (*Portunus pelagicus* Linnaeus) is abundant in many coastal marine and estuarine waters throughout the Indo-West Pacific (Stephenson, 1962). It supports an important commercial and recreational fishery in Western Australia, concentrated in the embayments and estuaries between Geographe Bay in the south and Port Hedland in the north (Kangas, 2000).

Commercial blue swimmer crab catches in WA have risen steadily since the early 1990s, from 216 tonnes in 1991/92 to 890 tonnes in 2002/03. There has been a parallel increase in the level of recreational fishing, with blue swimmer crabs now dominating the inshore recreational catch in the southwest of WA in terms of numbers caught for a single species (Sumner and Williamson, 1999). Consequently, concerns were raised that blue swimmer crab stocks in some areas of the state were under considerable pressure (Sumner *et al*., 2000).

Continued conflict between recreational and commercial blue swimmer crab fishers, along with the implementation of an Integrated Fisheries Management model, required that the resource-sharing issue between the two sectors be addressed. The major obstacle to the resolution of these issues was the lack of information on the recreational blue swimmer crab catch and effort in WA (Sumner and Malseed, 2004). Several studies were subsequently carried out to quantify the recreational catch and effort in several popular fisheries (Sumner and Williamson, 1999; Malseed and Sumner, 2001; Sumner and Malseed, 2004).

Through the State Government's Resource Sharing process, various management initiatives were then introduced to reallocate shares of crab stocks between recreational and commercial sectors (Sumner and Malseed, 2004). Both Cockburn Sound and Geographe Bay were identified as fisheries that would benefit from the implementation of resource-sharing arrangements, and management measures were introduced into both fisheries in 1999. The effectiveness of these new initiatives was evaluated in a study by the Department of Fisheries (FRDC Project No. 2001/067). A 12-month creel survey provided estimates of recreational catch, fishing effort and size composition for both areas during 2001/02 (Sumner and Malseed, 2004). These results were then compared to a similar survey conducted in 1996/97, prior to the introduction of the catch-sharing initiatives.

An ongoing evaluation of the catch and effort of recreational and commercial blue swimmer crab fishers was required to further assess the catch-sharing initiatives introduced in Cockburn Sound and Geographe Bay, and to provide information to refine management packages to maintain the agreed resource shares (Sumner and Malseed, 2004). The current study reports on a cost-effective annual monitoring program that focused on the peak periods of recreational activity in each fishery, that were identified by Sumner and Malseed (2004), to estimate the annual recreational catch and effort for 2003 and 2004 in Cockburn Sound and for 2003 in Geographe Bay. Data from these months collected during the 2001/02 surveys by Sumner and Malseed (2004) are also included.

7.1.1 Cockburn Sound

The Cockburn Sound Crab Managed Fishery encompasses the inner waters of Cockburn Sound, a protected marine embayment 20km to the south of Perth. The commercial fishery is managed using a combination of input and output controls which regulate fishing methods and gear specifications, seasonal and daily time restrictions, retainable species and associated minimum size limits, and the numbers of licensees that can operate in the fishery.

Crab fishing in Cockburn Sound started in the 1970s and traditionally used gill nets to supply the domestic market. Few restrictions were placed on commercial fishing activities other than the return of berried females and a minimum size limit. As fishing pressure increased, the need for a comprehensive management plan became apparent, and the *Cockburn Sound Crab Management Plan* was introduced in 1995. Industry rapidly converted to purpose-designed crab traps, greatly improving efficiency. Commercial fishers operate from December to September, with a closed spawning season in October and November. Currently, 11 license holders have access to the Cockburn Sound Managed Fishery, sharing a total allocation of 800 crab traps. During the 2004 season, however, just five vessels fished the full allocation of traps. The commercial catch in Cockburn Sound gradually increased during the 1990s, from 98 tonnes in 1991/92 to a peak of 347 tonnes in 1996/97 as fishers moved from using gill nets to more efficient hour-glass crab traps (Fig. 7.2). Large fluctuations in annual catch are common, however, as the strength of recruitment is primarily dependent on favorable environmental conditions between spawning and recruitment of juvenile crabs to the fishery.

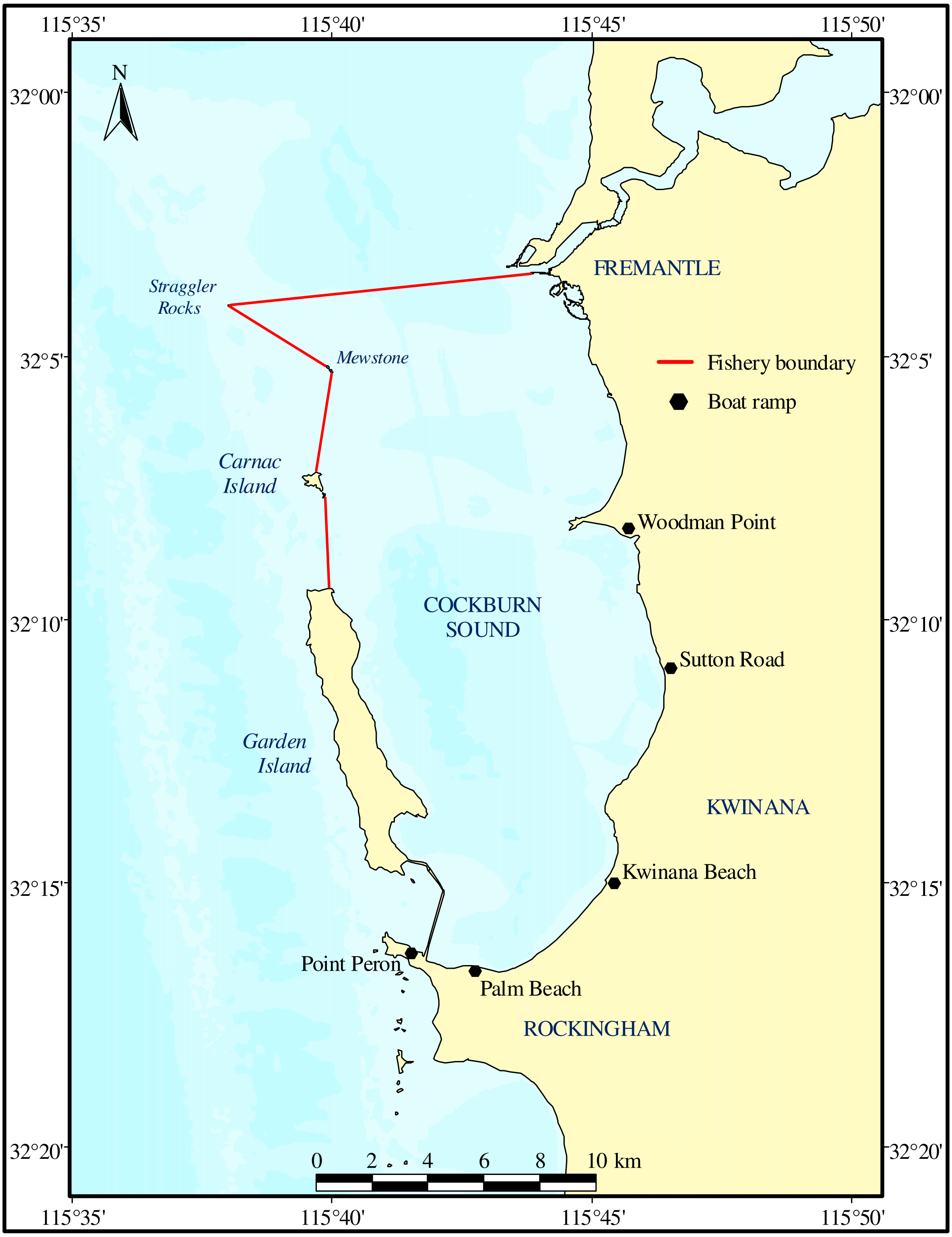

Figure 7.1 Cockburn Sound, the boundaries of the Cockburn Sound Crab Managed Fishery and locations of the boat ramps used in recreational crabbing surveys in the Sound.

Due to its close proximity to Perth, the area is also popular with recreational crab fishers. Recreational catch and effort in Cockburn Sound is dominated by boat-based fishers, with shore-based activity considered to be negligible (Sumner and Malseed, 2003). The boat-based recreational blue swimmer catch for 1978 was estimated at 119 tonnes (Dybdahl, 1979), although this figure included crabs caught outside Cockburn Sound but landed at a boat ramp within the Sound. A subsequent study estimated the boat-based recreational take for 1996/97 to be 18.8 tonnes, representing 5% of the total blue swimmer catch in Cockburn Sound (Sumner and Williamson, 1999).

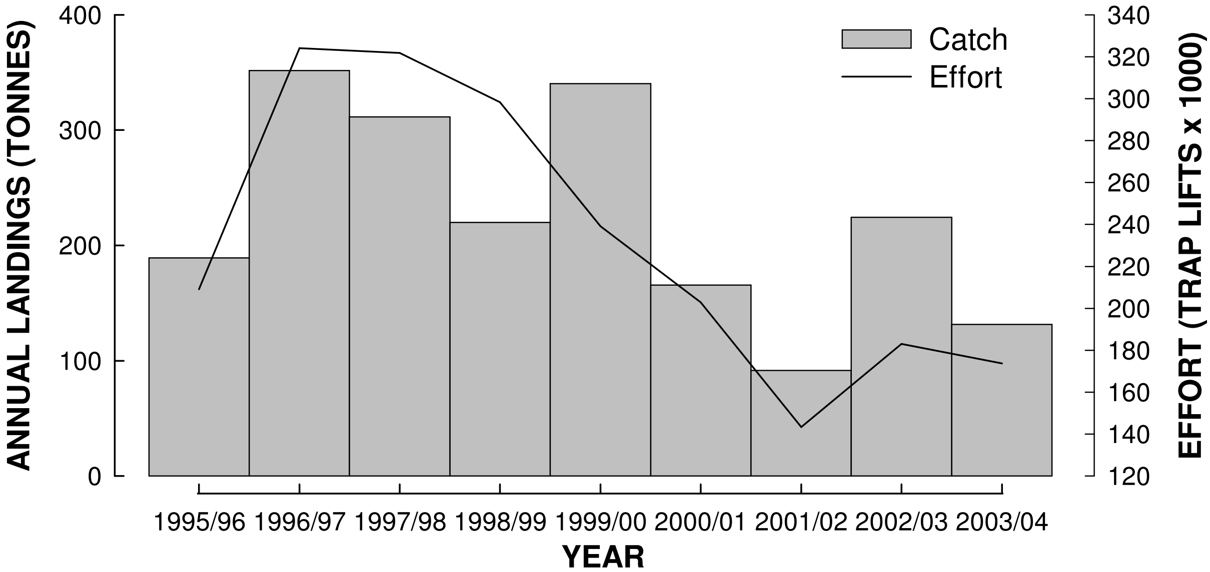

Figure 7.2 Annual commercial catch and effort for the Cockburn Sound Crab Fishery, 1995/96-2003/04.

To address concerns over allocation of the crab resource, the two sectors negotiated a catch-sharing arrangement in 1999. The commercial size limit for blue swimmer crabs was raised from 127mm carapace width to 130mm CW, and commercial effort reduced through the introduction of an 80 trap limit per license. A repeat of the 1996/97 creel survey was conducted between

September 2001 and August 2002, to assist in evaluating the effectiveness of the introduced management initiatives. The survey provided a boat-based recreational catch estimate for Cockburn Sound during 2001/02 of 18.5 tonnes, representing 15% of the total catch (Sumner and Malseed, 2003).

7.1.2 Geographe Bay

The Geographe Bay crab fishery is relatively unique amongst Western Australian crab fisheries in that it is most productive during the winter months, with the majority of catch taken less than 200m from shore (Borg and Campbell, 2003). As with Cockburn Sound, commercial blue swimmer crab fishing in Geographe Bay has expanded over the past decade. The annual catch and effort has increased from 36 boat days producing one tonne in 1993/94, to a peak of 19 tonnes from 303 boat days in 1996/97. Currently, eight license holders have exemptions to use 40 crab traps each. These exemptions are due to expire on 31 December 2004. Fishing for blue swimmer crabs is also a popular pastime in Geographe Bay, with recreational fishers estimated to have taken 17.5 tonnes in 1996/97, representing 49% of the total catch for that year (Sumner and Williamson, 1999).

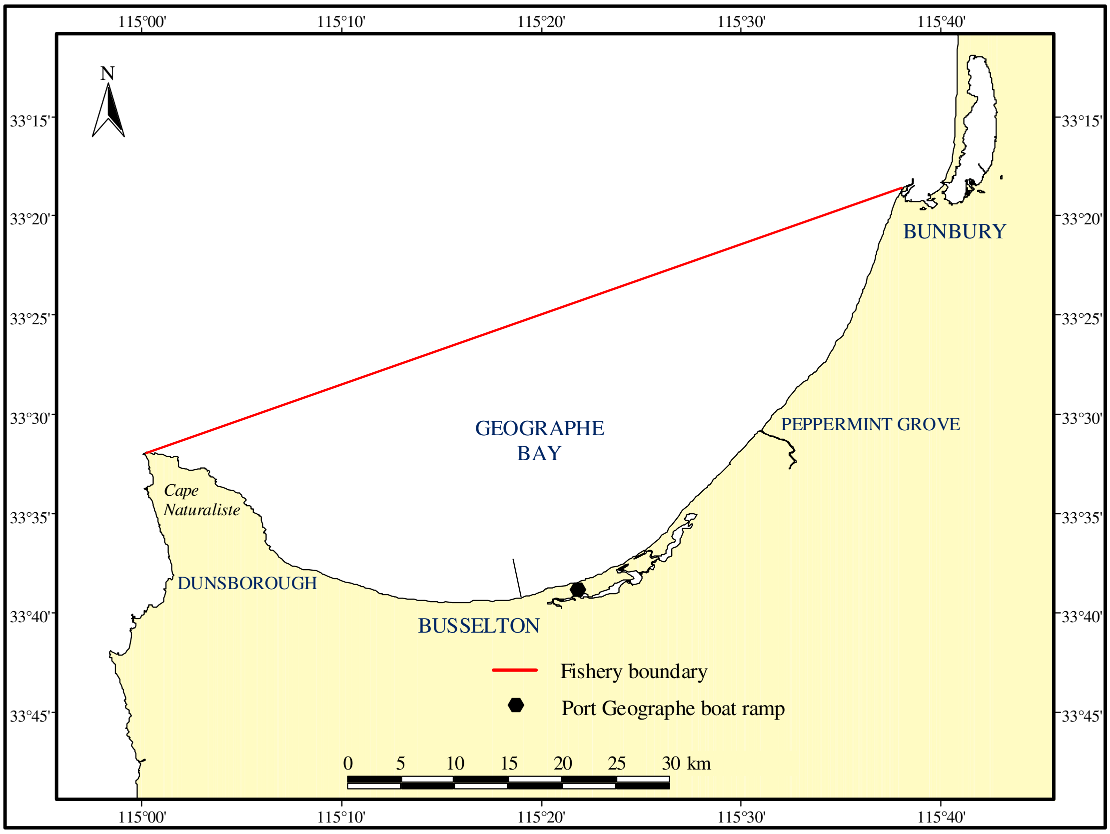

Figure 7.3 Geographe Bay, the boundaries of the Geographe Bay Crab Managed Fishery and the location of the Port Geographe boat ramp.

While specific catch shares have not been prescribed for Geographe Bay, several management initiatives were introduced in June 1999 to address concerns between commercial and recreational fishers. Spatial closures exclude commercial fishers from areas popular with recreational fishers, while temporal closures prohibit commercial fishers from operating over weekends, public and most school holidays, and between an hour after sunrise and an hour before sunset on remaining days. In addition, the commercial minimum size limit was increased from 127mm to 128mm CW. A subsequent survey estimated the recreational catch to be 28.5 tonnes, or 66% of the total catch for 2002 (Sumner and Malseed, 2004).

These new arrangements, however, were still considered unsatisfactory by the commercial sector and some sections of the public. Further consultation between concerned parties has led to Fisheries Management Paper No. 170, 'Management of the Proposed Geographe Bay Blue Swimmer and Sand Crab Managed Fishery'. Reaction to the discussion paper was sought from all interested stakeholders, with comments due by the end of November 2003. New management initiatives proposed in the discussion paper include a total ban on the taking of crabs in Geographe Bay during the month of October, a closed season for commercial fishermen from November through April, a maximum of 320 commercial crab traps (with trap numbers to be reviewed in five years) and additional spatial closures in popular recreational crabbing areas.

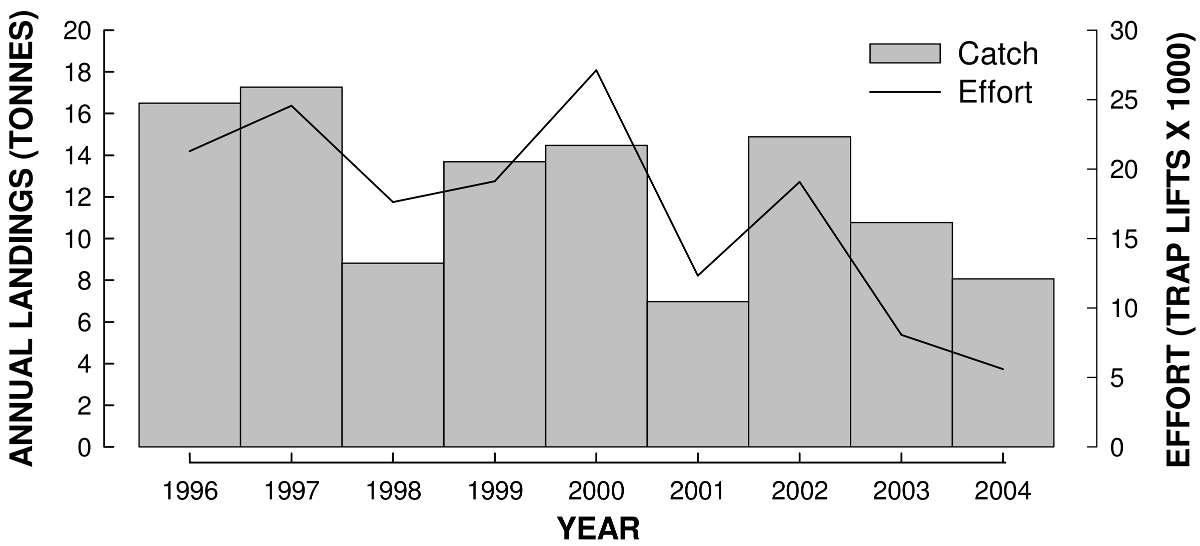

Figure 7.4 Annual commercial catch and effort for the Geographe Bay Crab Fishery, 1996 – 2004.

Annual commercial catches of blue swimmer crabs in Geographe Bay peaked in 1997 at 17.3 tonnes, fluctuated between 8.8 and 14.5 tonnes 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. Inter-annual trends in effort over this period followed the same patterns as annual catch, fluctuating between 17,617 and 24,562 trap lifts in 1996 – 1999, peaking at 27,110 trap lifts in 2000, and progressively declining from 19,085 in 2002 to 5,590 trap lifts in 2004.

7.1.3 Objectives

The objective of this study was to extend the dataset of recreational catch and effort in Cockburn Sound and Geographe Bay, concentrating on the peak periods of recreational activity in each fishery during 2003 - 2004. This additional information would then be used to further evaluate the success of Department of Fisheries management initiatives introduced in 1999, aimed at reallocating definite shares of blue swimmer crab stocks to both commercial and recreational sectors of the community.

Specific objectives were:

1. To develop a cost-effective and efficient method of conducting annual surveys in popular recreational blue swimmer crab areas, using the peak periods of crabbing activity to extrapolate estimates of recreational catch and effort for the entire year.

2. To estimate the boat-based recreational catch, effort and size composition of blue swimmer crabs in Cockburn Sound for the months of January through March for 2002 - 2004.

3. To estimate the boat-based recreational catch, effort and size composition of blue swimmer crabs in Geographe Bay for the months of July through October in 2002 and 2003.

4. To report on the relative catch share for both commercial and recreational fishers in Cockburn Sound for 2003 and 2004 and Geographe Bay for 2003, and compare the results with previous surveys conducted in 1996/97 and 2001/02.

7.2 METHODS

7.2.1 Recreational data

Boat ramp surveys

Two 12-month creel surveys conducted in Cockburn Sound and Geographe Bay during 1996/97 and 2001/02 have identified the key periods of recreational blue swimmer crab fishing in the two fisheries. The periods of peak activity were found to occur during the summer months of January through March in Cockburn Sound, and the winter months of July through October in Geographe Bay (Sumner *et al.*, 2000; Sumner and Malseed, 2004). Ninety-four percent of the total recreational crab catch in Cockburn Sound and 87% of the effort was taken between January and March in 2002 (Sumner and Malseed, 2004). In Geographe Bay during the 2001/2002 survey, the peak catch (33%) and effort were recorded in October (Sumner and Malseed, 2004). As the aim of this survey was to develop a cost-effective and efficient method of conducting annual surveys in popular crabbing areas, the months of peak activity were used to extrapolate estimates of recreational blue swimmer crab catch and effort for the whole year. Furthermore, the recreational catch and effort of shore-based crabbers was found to be negligible, accounting for less than 1% and 6% of the annual catch in Cockburn Sound and Geographe Bay respectively (Sumner and Malseed, 2004). Consequently, this survey was restricted to trailered boats launching from public and private boat ramps.

The bus route method (Robson and Jones, 1989; Jones *et al*., 1990) was used to estimate the recreational catch, effort and size composition of blue swimmer crabs in each fishery. The technique involves a survey interviewer visiting all boat ramps in a region on the one day, and interviewing recreational fishermen about their fishing activities. Interviewers followed a pre-determined schedule specifying the order of boat ramps to visit and the interview time for each boat ramp. The bus route schedules followed Pollock *et al*. (1994). A spreadsheet was used to generate the randomised schedules, ensuring that each boat ramp was visited during all hours of the interview day during the survey period. The spreadsheet was also used to randomly select a starting boat ramp, with the start, travel and wait times at boat ramps rounded to the nearest minute. The bus route method was further 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), and ended with the completion of the interview period at the last ramp. McGlennon and Kinloch (1997) used a similar modification of the bus route method for a survey conducted in South Australia where boat ramps were separated by large distances.

Upon arrival at a boat ramp, the number of recreational boat 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 logged. 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. Any size or undersize blue swimmer crabs retained aboard a boat were counted, along with the number of male and female crabs returned to the water during the fishing trip. Each crab was sexed and the carapace width (CW) measured between the tips of the lateral points to the nearest millimetre (mm). While survey personnel were instructed to measure all blue swimmer crabs retained by interviewed fishers, occasionally several boats would return to a ramp simultaneously leaving insufficient time to measure all of the crabs in a catch. On these occasions, a random sample was measured as it was considered more important to collect 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. One of the survey questions was an estimate of the number of male and female crabs that were released during the fishing trip. The number of recreational trailers was again logged when departing a boat ramp, to validate the number of launch and retrievals recorded during the surveyed period.

The fishing effort (fisher hours) for a day was estimated from the counts of the numbers of trailers at boat ramps. This was converted to fisher days by taking into account the average number of fishers per boat and the average time spent fishing. The unit of effort (number of trailers counted at the boat ramps) for each season was adjusted to correct for the number of recreational boats not involved in crabbing activities.

Cockburn Sound

The Cockburn Sound survey was stratified by weekday and weekend, producing two catch estimates, with the boat fishing effort estimates further stratified by ramp. This ensured that corrections could be made to account for the varying proportions of boats at each ramp; either crabbing or angling within Cockburn Sound, fishing outside Cockburn Sound, or not fishing at all. These estimates were then combined to obtain the total recreational catch and effort during the survey period for Cockburn Sound. Interviews were conducted on four weekday and four weekend days (including public holidays) for each month between November 2001 and August 2002 and between January and March in 2003 and 2004. Sumner and Williamson (2004) during recreational fishing surveys conducted in 2001/02 compared data from two shift periods morning

(7:00 a.m. – 1:00 p.m.) and afternoon (1:00 pm to 7:00 pm) and found that mornings were significantly more popular than afternoons during the summer crabbing season in Cockburn Sound, predominantly due to changes in prevailing weather conditions during the day. Consequently, the surveys conducted in 2003 and 2004 visited five ramps between 7:00a.m. and 1:30p.m. on any given interview day. In order to calculate total catches for the whole day a correction factor was applied in order to account for the reduced amount of fishing effort in the afternoon.

The allocation of survey time to each ramp (Table 7.1) was proportional to use by crabbers, as derived from previous studies (Sumner and Williamson, 1999; Sumner and Malseed, 2004).

Table 7.1 Allocation of Time to Survey Ramps for Cockburn Sound based on proportional use by crabbers from previous studies.

Ramp	Prop. of Time	Time (min)
Woodman Point	39%	120
Sutton Road	5%	16
Kwinana Beach	9%	30
Palm Beach	19%	60
Point Peron	28%	90

Geographe Bay

A number of previous surveys have quantified recreational blue swimmer crab catch and effort in Geographe Bay (Sumner and Williamson, 1999; Sumner *et al.*, 2000; Sumner *et al.*, 2004). The surveys demonstrated that the vast majority of crabbing activity in the area comes from boat-based crabbers fishing the area adjacent to Port Geographe, between the Wonnerup Inlet and the Busselton Jetty, and west to the Vasse boat ramp (Sumner *et al.*, 2004). More than 90% of crabbers fishing this area launched their vessels from the boat ramp at Port Geographe.

Consequently, it was concluded that surveying just this boat ramp would produce enough data to provide an acceptable estimate of catch and effort in Geographe Bay. This protocol also proved the most cost-effective and efficient.

The Geographe Bay surveys conducted in 2001/02 showed that catch was evenly distributed between morning and afternoon shifts therefore the 2003 survey incorporated both morning and afternoon sampling times. The surveys were stratified by time of day (morning or afternoon) and by weekday or weekend (including public holidays). Separate total catch estimates were made for each of these four strata (two for mornings and afternoons × two for weekends and weekdays), and then combined to provide the total catch and effort for the surveyed period. Interviews were conducted on four weekdays and four weekend days (including public holidays) during each month between July and October in 2002, and on eight weekdays and eight weekend days during each month between July and October 2003. The Mathcad spreadsheet generated a randomised schedule of times and dates for the Port Geographe boat ramp.

Statistical analysis of recreational data

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

7.2.2 Commercial data

Commercial catch and effort statistics (CAES)

Under the Fish Resources Management Act 1994 licensees involved in fishing operations and/or the master of every licensed fishing boat, must submit an accurate and complete monthly catch and effort return on forms approved by the Department of Fisheries. The returns record monthly catch totals for each retained species, estimates of daily effort and spatial information in the form of block references. These data are collected and collated by the Department of Fisheries and contained in the Catch and Effort Statistics (CAES) database.

Commercial catch monitoring surveys

Department of Fisheries research staff conducted surveys aboard commercial vessels to monitor the catch of blue swimmer crabs taken by dedicated crab fishers. During each survey the size composition, sex ratio and breeding condition of all animals caught was recorded, along with the presence of any parasites. A number of environmental factors such as salinity, water temperature and the prevailing weather conditions are recorded to provide an environmental and climatic profile for that survey period.

Daily catch monitoring surveys in Cockburn Sound were undertaken three times every month during the commercial crabbing season, from December 2001 through to the following September 2004. While the locations of trap-lines sampled were dependent on the areas being fished at that time, the comprehensive nature of the surveys would suggest that the results could be considered indicative of catch trends over a whole season and the total area fished.

Budgetary restrictions precluded surveys monitoring the catch of Geographe Bay commercial blue swimmer crab fishers being conducted during the period covered by this report. However, Departmental staff undertook several days of catch monitoring during the winter months of 1999 and 2000. The data generated from this catch monitoring has been used in this report to provide a comparison between recreational and commercial catches in Geographe Bay.

7.3 RESULTS

7.3.1 Cockburn Sound

Totals of 338, 374 and 680 interviews were conducted at the five surveyed boat ramps in Cockburn Sound between January and March in 2002, 2003 and 2004 respectively.

Recreational boating activity

During the survey period (January – March, 2002 – 2004) angling for fish surpassed all other activities in popularity including crabbing. The popularity of angling for fish over other boating pursuits has increased throughout this period. In contrast, the proportion of people crabbing in this period has decreased. In 2002, 108 (31.9%) interviewees were fishing, 76 (22.5%) were crabbing, while 17 (5.1%) were both crabbing and fishing (Fig. 7.5) (Sumner and Malseed, 2004). The number of people interviewed who were neither fishing or crabbing was 29 (8.6%), while the remaining 108 (31.9%) people were participating in activities outside of Cockburn Sound (Fig. 7.5). Of the 374 boats surveyed in 2003, 104 (27.8%) targeted blue swimmer crabs compared with 127 boats (33.9%) that were angling for fish species. A further 22 boats (5.9%) were both crabbing and angling. Of the remaining 121 boats, 22 boats (15.9%) did not fish at all while the remaining 99 (26.5%) were outside the waters of Cockburn Sound (Fig. 7.5).

During the 2004 survey, just 119 (17.5%) of the 680 boats interviewed targeted blue swimmer crabs. This compared to 312 (45.9%) fishing parties that were angling, 44 (6.5%) that were both crabbing and angling, 191 boats (28.1%) that were fishing outside of Cockburn Sound and 14 parties (2.1%) engaged in activities other than fishing (Fig. 7.5).

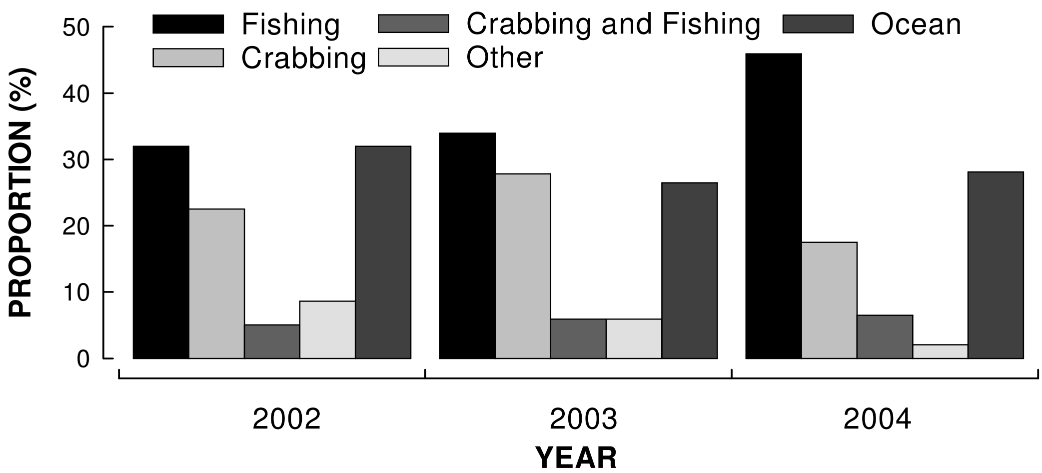

Figure 7.5 Activity of boating occupants interviewed at boat ramps around Cockburn Sound between January and March 2003 – 2004. Results for 2002 are derived from boat ramp surveys conducted by Sumner and Malseed (2004). *n* (2002) = 338, *n* (2003) = 374, *n* (2004) = 680.

Recreational crabbing effort

Between January and March 2002, recreational fishers in Cockburn Sound who were surveyed targeted blue swimmer crabs for 19,826 hours, spread over a combined 14,263 fisher days. Effort on each crabbing trip was an average 3.49 fisher hours, and involved 2.51 crabbers (Table 7.2). Extrapolation of these estimates provides for a recreational crabbing effort of 19,134 fisher days for the 2002 calendar year. Recreational fishers who were surveyed in Cockburn Sound targeted blue swimmer crabs for a similar amount of time between January and March 2003, an estimated 19,725 hours. This effort was spread over a shorter number of fisher days, 11,876, which increased the average effort of each crabbing trip from the previous year to 3.84 fisher hours. The average size of a crabbing party in 2003 fell to 2.31 crabbers (Table 7.2). Extrapolation of these estimates provides for a recreational crabbing effort of 15,932 days for the 2003 calendar year, 17% down from 2002.

Effort remained reasonably constant in 2004, with recreational crabbers fishing for an estimated 18,466 hours over 12,058 fisher days in the January to March period. The average crabbing trip for the year lasted 3.78 fisher hours and involved 2.47 crabbers. Extrapolation of these estimates provides for a recreational crabbing effort of 16,176 fisher days for the 2004 calendar year (Table 7.2).

Table 7.2 Recreational blue swimmer effort in Cockburn Sound for 2002 - 2004. (Numbers in brackets denote standard error).

	2002*	2003	2004
Average number in party (fishers)	2.51	2.31	2.47
Ave. effort of crabbing trip (fisher hours)	3.49	3.84	3.78
Number of fisher hours January – March	19,826 (1,221)	19,725 (1,258)	18,466 (1,038)
Number of fisher days January - March	14,263 (879)	11,876 (781)	12, 058 (678)
Number of fisher days whole year	19,134	15, 932	16,176

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

Recreational crabbing catch

Of the 1,346 blue swimmer crabs caught by recreational fishers during surveys between January and March of 2002, 98.3% of retained catches were male (1.7% female). A higher proportion of released catches compared with retained catches were female (14.7%). The catch rate of crabs kept/boat/trip between January and March 2002 was 11.11 (Table 7.3).

Crab catches as recorded during surveys almost doubled in 2003, with 1,988 crabs retained. The proportion of retained crabs that were male, 98.3%, remained the same as in 2002. The number of crabs that were released in 2003 increased to 37% from 23% the previous year while the composition of this component of the catch by sex remained similar as in the previous year (Table 7.3). The catch rate of crabs kept/boat/trip between January and March 2003 increased slightly over the previous year to 15.78 (Table 7.3).

During 2004, the number of blue swimmer crabs retained by fishers who were surveyed was only slightly higher then the previous year, 2,057, while the proportion of these that were female increased to 5.9%. The proportion of crabs that were released in 2004 increased to 44% of those caught and a far higher proportion of these were female than in previous years, 28.6% (Table 7.3). The catch rate of crabs kept/boat/trip between January and March 2004 fell from the previous year to 12.62 (Table 7.3).

The estimated total numbers of blue swimmer crabs that were retained over the January to March period and the entire 12 months of 2002 were 61,566 (14.5 tonnes) and 77,300 (18.21 tonnes) respectively (Table 7.4). These numbers increased to 76,769 (18.3 tonnes) and 96,388 (22.97 tonnes) respectively in 2003, and decreased to 59,990 (16.65 tonnes) and 75,322 crabs (18.40 tonnes) respectively in 2004 (Table 7.4).

Table 7.3 Numbers of blue swimmer crabs recorded from surveys of recreational boat-based fishers at five boat ramps in Cockburn Sound between January and March 2002-2004.

		2002*		2003		2004	
		Number	%	Number	%	Number	%
Retained	Male	1,016	98.3	1,962	98.7	1,936	94.1
	Female	18	1.7	26	1.3	121	509
	Total	**1,034**		**1,988**		**2,057**	
Released	Male	266	85.3	1,005	83.3	1,176	71.4
	Female	46	14.7	202	16.7	472	28.6
	Total	**312**		**1,207**		**1,648**	
% released		23.2		37.8		44.5	
Catch rate (crabs kept/boat/trip)		11.11		15.78		12.62	

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

Table 7.4 Estimated recreational blue swimmer catch in Cockburn Sound for 2002 - 2004.

			2002*		2003		2004	
			NUMBER	WEIGHT (t)	NUMBER	WEIGHT (t)	NUMBER	WEIGHT (t)
Jan – Mar	Retained	Male	60,494	14.26	75,565	18.03	56,461	13.94
		Female	1,072	0.24	1,004	0.27	3,529	0.71
		TOTAL	**61,566**	**14.50**	**76,569**	**18.30**	**59,990**	**14.65**
	Released	Male	15,142		37,103		31,768	
		Female	2,619		7,458		12,750	
		TOTAL	**17,761**		**44,561**		**44,518**	
Annual	Retained	Male	75,954	17.91	95,127	22.63	70,891	17.50
		Female	1,346	0.30	1,261	0.34	4,431	0.90
		TOTAL	**77,300**	**18.21**	**96,388**	**22.97**	**75,322**	**18.40**
	Released	Male	19,012		46,586		39,886	
		Female	3,288		9,363		16,009	
		TOTAL	**22,300**		**55,949**		**55,895**	

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

Commercial catch and effort

The annual commercial landings in Cockburn Sound followed the same trend as the recreational blue swimmer crab catches but fluctuated much more dramatically between 2002 and 2004. A total of 92 tonnes of blue swimmer crabs was reported for the 2002 season (December 2001 to September 2002), the lowest catch since the fishery converted from using gill nets to crab traps during 1995 (Fig. 7.6). This catch resulted from 143,319 trap lifts, for an average CPUE of 0.6 kg/trap lift (Fig. 7.6). The following season the fishery returned to a more customary level, with annual landings of 224 tonnes from 183,049 trap lifts at a catch rate of 1.2 kg/trap lift , before falling again in 2004 to 132 tonnes from 144,797 trap lifts at a catch rate of 0.9 kg/trap lift (Fig. 7.6).

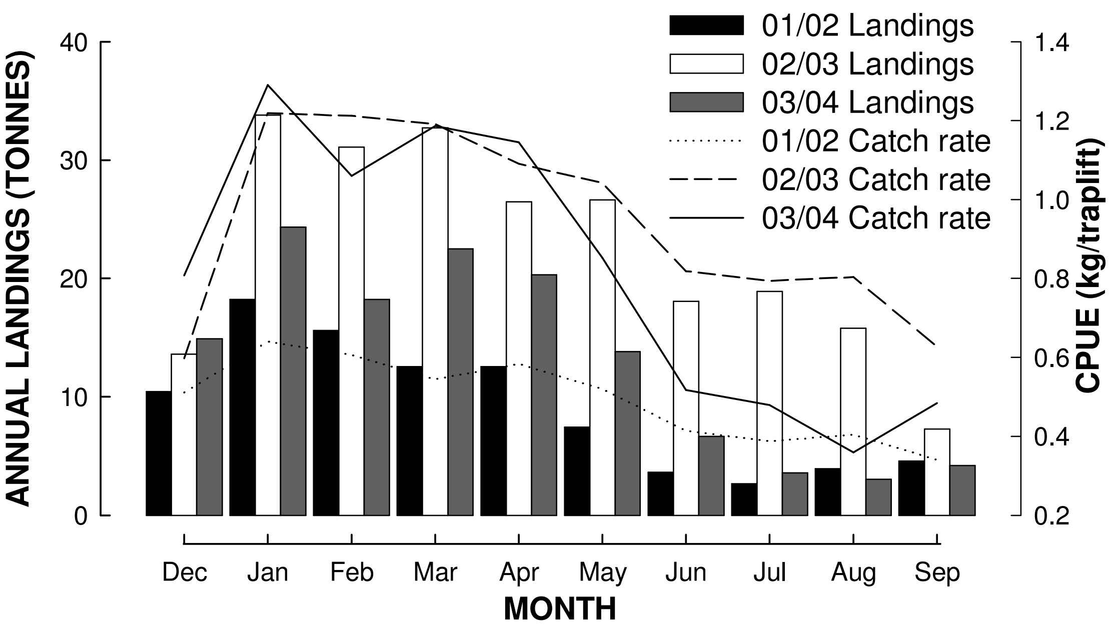

Figure 7.6 Catch and catch per unit effort (kg/trap lift) for the Cockburn Sound Crab Fishery, 2001/02 – 2003/04.

Size distribution of recreational vs commercial catch

During the recreational fishing surveys undertaken in Cockburn Sound between January and March in the years 2002 – 2004, the carapace widths of a total of 1,410 blue swimmer crabs were measured at the boat ramps (Table 7.5). In all years, the vast majority of recreational catches in Cockburn Sound were male (93.0 – 99.1%) (Table 7.5). For the years combined, the mean carapace width of males was similar to that of females, while the variations between years in the mean size of females between years was much greater due to the small sample sizes (Table 7.5).

A total of 49,178 blue swimmer crabs (including crabs returned to the sea) were measured aboard commercial vessels during catch monitoring surveys in Cockburn Sound between December 2001 and September 2004 (Table 7.6). A comparison of the ratios of undersize versus legal size males, females and ovigerous females as a proportion of total catches showed that differences in the ratios of these two size groups were least for males and ovigerous females and highest for non-ovigerous females. The ratio of undersize males was approximately equal to the ratio of legal sized males in all seasons except summer when the catches of legal sized males as a proportion of the total catches was highest and approximately twice that of undersize males. Legal size non-ovigerous females were generally more abundant than sub-legal non-ovigerous females.

While the annual catches were almost evenly distributed between male and female crabs, ranging between 37.6 – 50% males, sex ratios fluctuated dramatically during the season and patterns were generally consistent between years. At the beginning of the commercial season (December), the catch was mostly female crabs (78 – 88%) with a comparatively high proportion of these berried (33.2 – 42.3% of all females) (Table 7.6). During the summer months from January to March, however, the composition changed markedly with male crabs representing 60 – 88% of the catch. Then from April through to the end of the season in September, the catch gradually shifted back to consist predominantly of female crabs. Throughout 2002 – 2004, catches of ovigerous females were lowest in April – June and highest in December (Table 7.6).

Table 7.5 Length composition of blue swimmer crabs caught by recreational fishers interviewed at boat ramps in Cockburn Sound between January and March, 2002 – 2004.

	MALE			**FEMALE**			
	NUMBER	**%**	**CW**	**NUMBER**	**%**	**CW**	**TOTAL**
2002*	410	98.5	137	6	1.5	140	416
2003	434	99.1	137	4	0.9	154	438
2004	517	93.0	138	39	7.0	136	556
TOTAL	**1361**	**96.5**	**137**	**49**	**3.5**	**138**	**1410**

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

Table 7.6 Compositions of blue swimmer crabs caught by commercial fishers during catch monitoring surveys of retained and non-retained crabs in Cockburn Sound between December 2001 and September 2004.

		MALE			NON-BERRIED FEMALES			BERRIED FEMALES			
Year	Period	NUMBER	%	CW	NUMBER	%	CW	NUMBER	%	CW	TOTAL
2001	**Dec**	450	18	128.3	1,156	47	128.4	847	35 (42.3)	129.7	**2,453**
2002	**Jan-Mar**	3,986	80	133.1	846	17	128.1	149	3 (19.0)	131.6	**4,981**
	Apr-Jun	2,465	45	124.5	3,048	55	132.4	20	0.4 (0.6)	127.2	**5,533**
	Jul-Sep	1,205	37	130.5	1,858	58	136.6	151	5 (7.5)	135.2	**3,214**
	Season	**8,106**	**50.0**		**6,908**	**42.8**		**1,167**	**7.2**		**16,181**
	Dec	644	22	129.5	1,503	50	137.5	848	28 (36.1)	137.5	**2,995**
2003	**Jan-Mar**	9,468	88	134.5	1,089	10	131.4	256	2 (19)	130.6	**10,813**
	Apr-Jun	1,802	28	128.8	4,565	71	134.2	28	0 (0.6)	123.9	**6,395**
	Jul-Sep	614	12	130.1	4,199	84	134.3	185	4 (4.2)	131.1	**4,998**
	Season	**12,528**	**49.7**		**11,356**	**45.1**		**1,317**	**5.2**		**25,201**
	Dec	354	11	127.2	1,860	59	131.2	925	28 (33.2)	131.4	**3,139**
2004	**Jan-Mar**	2,472	60	135.3	1,380	33	135.7	294	7 (17.6)	134.3	**4,146**
	Apr-Jun	88	24	131.8	274	76	134.1	0	0	--	**362**
	Jul-Sep	15	10	132.7	122	82	137.3	12	8 (8.9)	131.5	**149**
	Season	**2,929**	**37.6**		**3,636**	**46.6**		**1,231**	**15.8**		**7,796**
	Total	23,563	47.9	134.3	21,900	44.5	132.3	3,715	7.6	132.4	**49,178**

There was also a noticeable change in the size of crabs caught by commercial fishers as the season progressed in years 2002 – 2004. The mean CW of male crabs caught in December was 127.2 – 129.5mm, generally less than the minimum commercial size limit of 130 mm CW. The mean male CW increased to 133.1 – 135.3mm between January and March, as the warmer water temperatures over the summer months induced moulting and an associated size increase. The mean male CW then fell to 124.5 – 131.8mm between April and June, as the majority of the mature male stock was fished and the smaller recruits began to filter into the fishery. In contrast, the mean CW of female crabs caught by commercial fishers increased as the season progressed, from 128.4 – 137.5mm in December to 134.3 – 137.3mm between July and September (Table 7.6).

Just over 13% (6,627 crabs) of the blue swimmer crabs caught by commercial fishers in Cockburn Sound in the three seasons from 2002 to 2004, had a CW greater than the recreational minimum size limit of 127mm CW but less than the commercial size limit of 130mm CW (Fig. 7.7). The group of crabs within this size range represents the three most abundant (1 mm) size classes of crabs recorded within this period. The returned crabs that were available to the recreational sector were roughly equal in proportion between male and female crabs, this is most likely not reflected in recreational catches due to differences in the selectivity between the traps used by commercial versus recreational fishers. The proportion amongst commercial catches of ovigerous females 127 – 130mm was similar as in other size classes above the size at maturity.

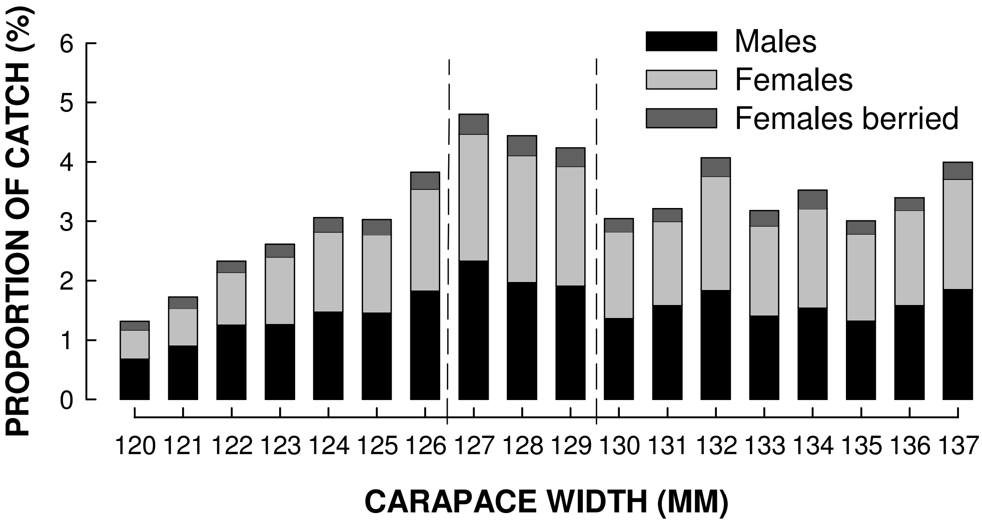

Figure 7.7 Proportions of blue swimmer crabs greater than the recreational minimum size limit (127mm CW) but less than the commercial size limit (130mm CW), caught by commercial fishers operating in Cockburn Sound between December 2001 and September 2004.

7.3.2 Geographe Bay

Between July and October 2002, 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.

Recreational boating activity

In Geographe Bay between 2002 and 2003 crabbing was either more or equally as popular as angling for fish and the popularity of crabbing has remained relatively constant while that of angling has increased. Of the fishers surveyed in 2002, 24 (40.7%) were fishing for blue swimmer crabs, only 14 (23.7%) specifically sought to catch finfish, while 15 (25.4%) fished for both (Fig. 7.8). The remaining six (10.2%) participated in activities other than fishing (Fig. 7.8).

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 solely targeting finfish increased to 38.9%, from 23.7% in 2002 (Fig. 7.8). Boating parties undertaking activities other than fishing in 2003 comprised 6.7% of those surveyed, a similar proportion to the previous year (Fig. 7.8).

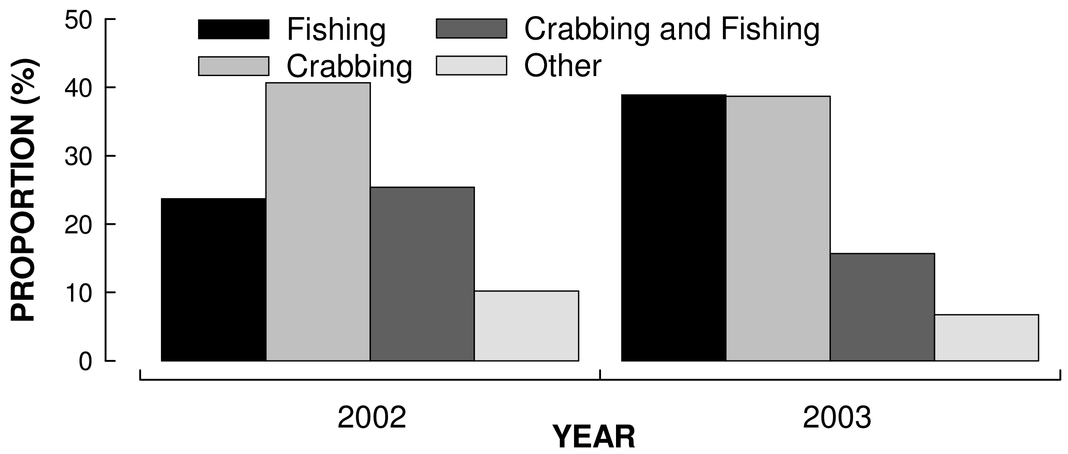

Figure 7.8 Activity of boating occupants interviewed at boat ramps around Geographe Bay between July and October 2002 and 2003.

Recreational crabbing effort

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 fisher days. The mean effort during each crabbing trip was 3.28 fisher hours and involved 2.44 crabbers (Table 7.7). Extrapolation of these estimates to all year provides for a recreational crabbing effort of 19,424 fisher days for the 2002 calendar year.

The recreational crabbing effort in 2003 decreased slightly between July and October compared with 2002. Recreational crabbers fished for an estimated 4,315 fisher hours over 3,566 fisher 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, the same as 2002. The estimated fishing effort, for the whole of 2003 was 16,926 fisher days, down 13% on the previous year (Table 7.7).

Table 7.7 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 fisher days July – October	4092	(943)	3566	(460)
Number of fisher days whole year	19 424		16 926	

Recreational crabbing catch

In contrast to Cockburn Sound, 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 7.8). The estimated total number of blue swimmer crabs caught in Geographe Bay for 2002 is 49,934 (10.24 tonnes) (Table 5.9). The catch rate of crabs between July and October 2002 in Geographe Bay (28.31 kept/boat/trip) was nearly three times that recorded for Cockburn Sound, i.e. 11.11 kept/boat/trip (Table 7.8).

A total of 477 males and 4,567 females were retained by interviewees between July and October 2003. The proportions of males and females that were kept and released out of the total number caught were the same as the previous year. The estimated total number of blue swimmer crabs caught by recreational fishers in Geographe Bay in 2003 is 37,958 (7.53 tonnes), less than the previous year. The catch rate of crabs in 2003 (26.00 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 7.8).

Table 7.8 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	

Table 7.9 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**	

Commercial catch and effort

Annual commercial blue swimmer crab catches in Geographe Bay between 1994 and 2004 have fluctuated between 5.7 tonnes in 1994 and 17.3 tonnes at their peak in 1997. In the last three years annual catches have steadily declined from 17.9 tonnes in 2002 to 8.1 tonnes in 2004 (Fig. 7.4). Intra-annual trends in commercial landings of blue swimmer crabs reflect the seasonal nature of the fishery with negligible catches between December and May 2002, increasing progressively from 1,106 kg in June to a peak of 5,038 in September before declining to 803 kg in November.

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 (Fig. 7.9).

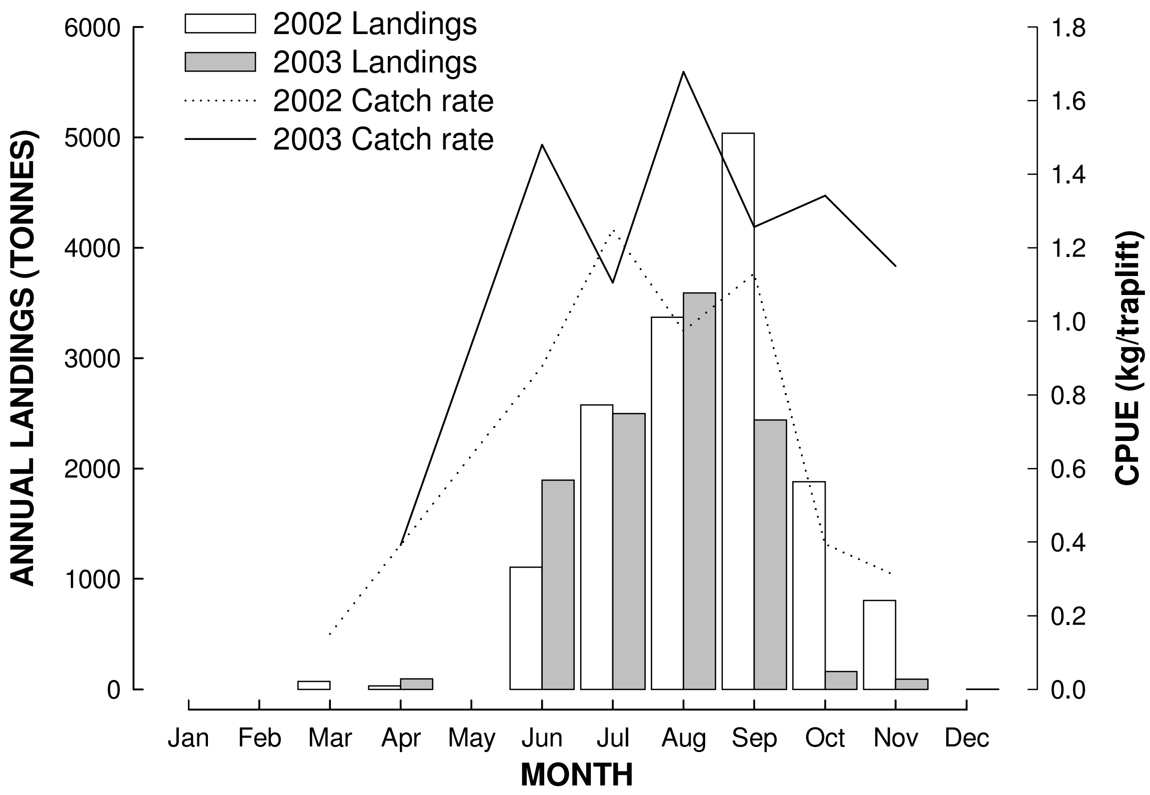

Figure 7.9 Catch and catch per unit effort (kg/trap lift) for the Commercial Geographe Bay Fishery, 2002 – 2003.

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 7.10). The mean carapace widths of blue swimmer crabs retained by recreational fishers were well above the legal size limit of 127mm. Variations between respective years in the mean carapace widths of males (133.9 – 135.8mm) and females (134.8 – 136.2mm) were small, as were the differences between the mean carapace width of males and females in each year (0.4 – 1.1mm).

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 ~ 1: 3. 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 7.11).

Table 7.10 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	NUMBER	%	CW	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**

Table 7.11 Composition of blue swimmer crabs caught (retained and returned) 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			
	NUMBER	%	CW	NUMBER	%	CW	NUMBER	%	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**

The size class of blue swimmer crabs which are smaller than the commercial legal size and larger than the recreational legal size in Geographe Bay represents 3.4% of the total number caught by commercial fishers (Fig. 7.10).

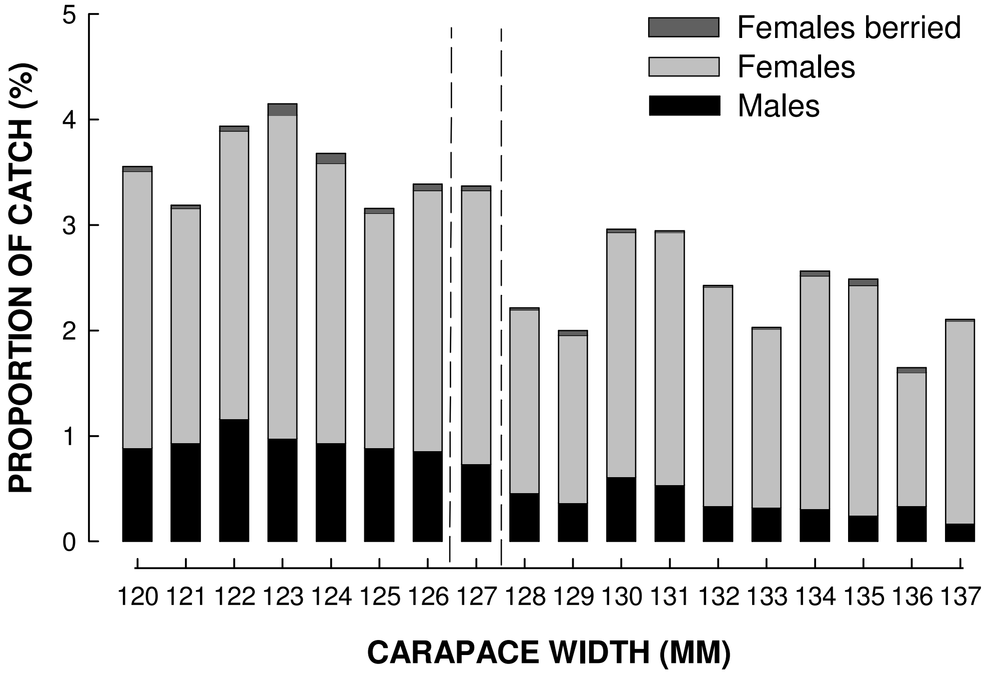

Figure 7.10 Proportions of blue swimmer crabs greater than the recreational minimum size limit (127mm CW) but less than the commercial size limit (128mm CW), caught commercial fishers operating in Geographe Bay between August 1999 and October 2003.

7.4 DISCUSSION

7.4.1 Cockburn Sound

Resource sharing agreements

Blue swimmer crabs are an important recreational and commercial species in Cockburn Sound. While commercial catches can be quantified from fishers monthly returns, data available for recreational fishers in Cockburn Sound is restricted to a limited number of surveys i.e. 1977 (Fielman Planning Consultants, 1978); 1996 – 1997 (Sumner and Williamson, 1999); 2001 –

2002 (Sumner and Malseed, 2004) and from January to March in 2003 and 2004 during the present study.

Over the past 20 years, commercial fishers have changed their primary method for capturing blue swimmer crabs in Cockburn Sound, shifting from set-nets to crab traps. This change coincided with a marked increase in total commercial crab landings, during the mid to late 1990s, which was primarily linked to an incorrect net to trap conversion factor (100 traps: 1200m set net) that resulted in fishers being allocated too many traps. As a result, commercial fishers took 92% of the total catches in 1996/97. Melville-Smith *et al.* (1999) re-calculated the conversion factor and produced a ratio (67 traps: 1200m of net), which was 33% less than that introduced into the fishery in 1994. This revised ratio was implemented in 1999 when the total number of traps in the Cockburn Sound fishery was reduced from 1600 to 1280.

Subsequently, resource-sharing agreements were established to restabilise and reallocate catches back to the recreational sector, including a 5/8 (62.5%) allocation to commercial fishers and 3/8 (37.5%) catch allocation to recreational fishers. This was achieved by introducing a larger legal size limit (130mm carapace width) compared with 127mm CW for recreational fishers in 1998 and restricting the number of commercial traps used in the fishery to 800 in 2003 - 2004 (from 1600 in 1998). A seasonal closure between October 1 and November 30th to protect ovigerous females during the breeding season was introduced in 1999.

The commercial effort restrictions were successful in contributing to an initial increase in the proportion of total catches taken in Cockburn Sound by the recreational sector, from 8% in 1996/97 to 15% in 2001/2002 (Sumner and Malseed, 2004). Although the catch share remained below the 3/8 (37.5%) allocated. The current study has subsequently illustrated that the proportion taken by the recreational sector declined to 9.3% in 2003 and 12.3% in 2004. Although recreational crabbing effort was steady with 19,048 fisher hours in 1996/97 to 19,134 crabbing days in 2002, recreational fishing effort in 2003 and 2004 decreased to 15,932 and 16,176 fisher days respectively. In contrast, commercial fishing effort increased from 143,319 trap lifts in 2002 to 183,049 and 173,756 trap lifts in 2003 and 2004. Therefore, despite a net rise in both commercial and recreational catch rates between 2002 and 2004, it appears that the share taken by the recreational sector decreased over this period because of a reduction in the amount of recreational fishing effort and an increase in commercial fishing effort.

Although recreational crabbing is popular in Cockburn Sound it is surpassed in popularity by angling for finfish. The popularity of crabbing increased from 22.5% of interviewees in 2002 to 27.8% in 2003 followed by a decrease to 17.5% in 2004. The increase in the popularity of crabbing between 2002 and 2003 reflects an increase in catch rate within both the commercial and recreational sectors during this period. However, the downturn in the popularity of recreational crabbing in 2004 is larger than the slight decrease in the catch rate of both sectors, and is more likely to be coupled with a surge in the popularity of angling which has consistently increased over these years from 31.9% of interviewees in 2002 to 45.9% of interviewees in 2004. The inter-annual variations in commercial and recreational catch rate also reflect annual variation in recruitment of blue swimmer crabs, due primarily to environmental effects. Some of the variation in the popularity of crabbing is also related to the levels of recruitment, as recreational fishers are more likely to go crabbing in years of strong recruitment when crabs are more abundant.

Between 6.7 – 18.1% of males and between 10.2 – 17.6% of female blue swimmer crabs caught during commercial catch monitoring in Cockburn Sound between January and March 2002 – 2004 were 127 – 129mm CW, less than the commercial legal size (130mm). This size cohort of crabs represents a significant proportion of the total population. Furthermore, crabs ≥ 127mm and < 130mm represented between 12.8 – 15.9% of male and 0 – 16.7% of female catches taken by recreational fishers between January to March 2002 – 2004. This size cohort of crabs represents the most abundant single size class of crabs within recreational catches. Therefore the different legal size limits between the two sectors is effective at redistributing catch to the recreational sector.

The high proportion of females caught in September and the high number of ovigerous crabs caught in December confirm that the closed spawning season during October and November is effective at protecting breeding females.

In Cockburn Sound between January and March 2002 – 2004, females comprised 42.8 – 46.6% of commercial catches and 4.6 – 15.6% of estimated annual recreational catches. These differences are due primarily to spatial separation of fishing between the sectors with recreational fishers favoring the shallow waters of Mangles Bay, the inside of Garden Island and north of Woodman Point, while commercial fishing is spread throughout Cockburn Sound. The sex ratio of crabs in Cockburn Sound displays a seasonal pattern with females comprising 65% of catches in April to June, 75% from July to September and 80% during December (Sumner and Malseed, 2004).

7.4.2 Geographe Bay

In Geographe Bay 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. 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, resulting in a finalised management agreement in December 2002.[1]

The management arrangement restricts 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 < 400m offshore between "old Dunsborough" boat ramp and the Quindalup boat ramp; in waters < 400m offshore between Dolphin Road (Busselton) and the Port Geographe Marina; in waters within 800m of the Busselton jetty and in the Port Geographe marina between the two groynes.

The annual commercial crab catch in Geographe Bay has increased from 1.6 tonnes in 1989 to 14.9 tonnes in 2002 with a peak catch of 17.3 tonnes in 1997. A few surveys of recreational fishing have been collected from Geographe Bay since 1996/97. Since then, total catches taken by recreational fishers have always been greater than those taken by commercial fishers. In fact, the recreational share of total catches has increased from 51% (of a total of 34.0 tonnes) in 1996/97 to between 64.4% and 66.0% (of a total of 30.6 – 43.5 tonnes) between 2002 and 2004.

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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.

The perception that commercial fishers take the majority of the crab resource in this region may be due to the fact that the majority of crabs occur within 200m of shore therefore commercial fishing activities are visible to the public.

Recreational and commercial 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 fisher days in 2002 to 16,926 fisher 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. Both the commercial and recreational catch rates have remained relatively constant between 2002 and 2003, despite the reductions in effort.

In Geographe Bay within the recreational sector and in contrast to Cockburn Sound, crabbing was more popular than angling in 2002 and equally as popular as angling in 2003. Geographe Bay is renown for crabbing and is a popular past-time amongst holiday makers who, lacking a local knowledge, may be less familiar with the techniques required to catch fish in the region.

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 > 127mm. 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 127mm comprised 5.8% of the retained catches of recreational fishers.

The blue swimmer crab fishery in Geographe Bay is primarily a winter fishery, which governed the time of year that surveys were conducted. 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 heavy exploitation by commercial and primarily local recreational fishers. This also explains why females comprise such high proportions of both of commercial (69.6 – 74.4%) and recreational (~ 81.3 – 81.9%) catches. During summer months mature crabs, particularly females, move offshore into deeper waters and become less accessible to the fishery (Sumner and Malseed, 2004).

The recreational fishing surveys conducted during the present study were designed specifically to quantify recreational catch and effort for blue swimmer crabs in Cockburn Sound and Geographe Bay within the periods 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 each fishery, particularly those associated with the implementation of catch share arrangements. A large component of both of these fisheries is caught by the recreational sector. These 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.

8.0 THE DEVELOPMENT OF EXPLORATORY COMMERCIAL BLUE SWIMMER CRAB FISHERIES IN PREVIOUSLY UNEXPLOITED AREAS OF THE WEST AUSTRALIAN COAST by Bellchambers and Harris

8.1 INTRODUCTION

The blue swimmer crab (*Portunus pelagicus* Linnaeus) is found along the entire West Australian (WA) coast. It inhabits a wide range of inshore and continental shelf ecosystems, from the intertidal zone to at least 50m in depth (Kangas, 2000). The species supports an important commercial and recreational fishery, concentrated in the embayments and estuaries between Geographe Bay in the south and Port Hedland in the north (Kangas, 2000).

Commercial blue swimmer crab catches in WA have risen steadily since the early 1990s, from 216 tonnes in 1991/92 to 890 tonnes in 2002/03. There has also been an increase in recreational fishing, with blue swimmer crabs now dominating the inshore recreational catch in the southwest of WA in terms of numbers caught for a single species (Sumner and Williamson, 1999). As a consequence, concerns have been raised that blue swimmer crab stocks in some areas of the state are under considerable pressure (Sumner *et al*., 2000).

Continued conflict between recreational and commercial blue swimmer crab fishers, along with the implementation of an Integrated Fisheries Management model, required that the resource-sharing issue between the two sectors be addressed. Through the State Government's Resource Sharing process, various management initiatives have been introduced to reallocate shares of crab stocks between recreational and commercial sectors (Sumner and Malseed, 2004). One such initiative involves the expansion of commercial blue swimmer crab fishing operations into previously unexploited areas of the West Australian coast. This is intended to:

- ease fishing pressure in areas such as Geographe Bay and Peel Harvey where there is significant conflict between commercial and recreational fishers over the available crab resource;

- provide baseline data on areas that have minimal recreational interest but have the potential to become commercial crab fisheries;

- provide the potential for commercial crab fishers to improve existing markets and develop new ones, at a time when existing fisheries are increasingly subjected to tighter controls on access and effort.

Expressions of Interest were sought to explore the commercial viability of targeting blue swimmer crabs along the Northern coastline, between Mandurah and Bunbury and in Exmouth Gulf (Fig. 8.1). The opening of these areas to commercial exploration is consistent with the zone approach to developing the state's inshore crab fishery that has been in progression since 1997 (see Campbell, 1997).

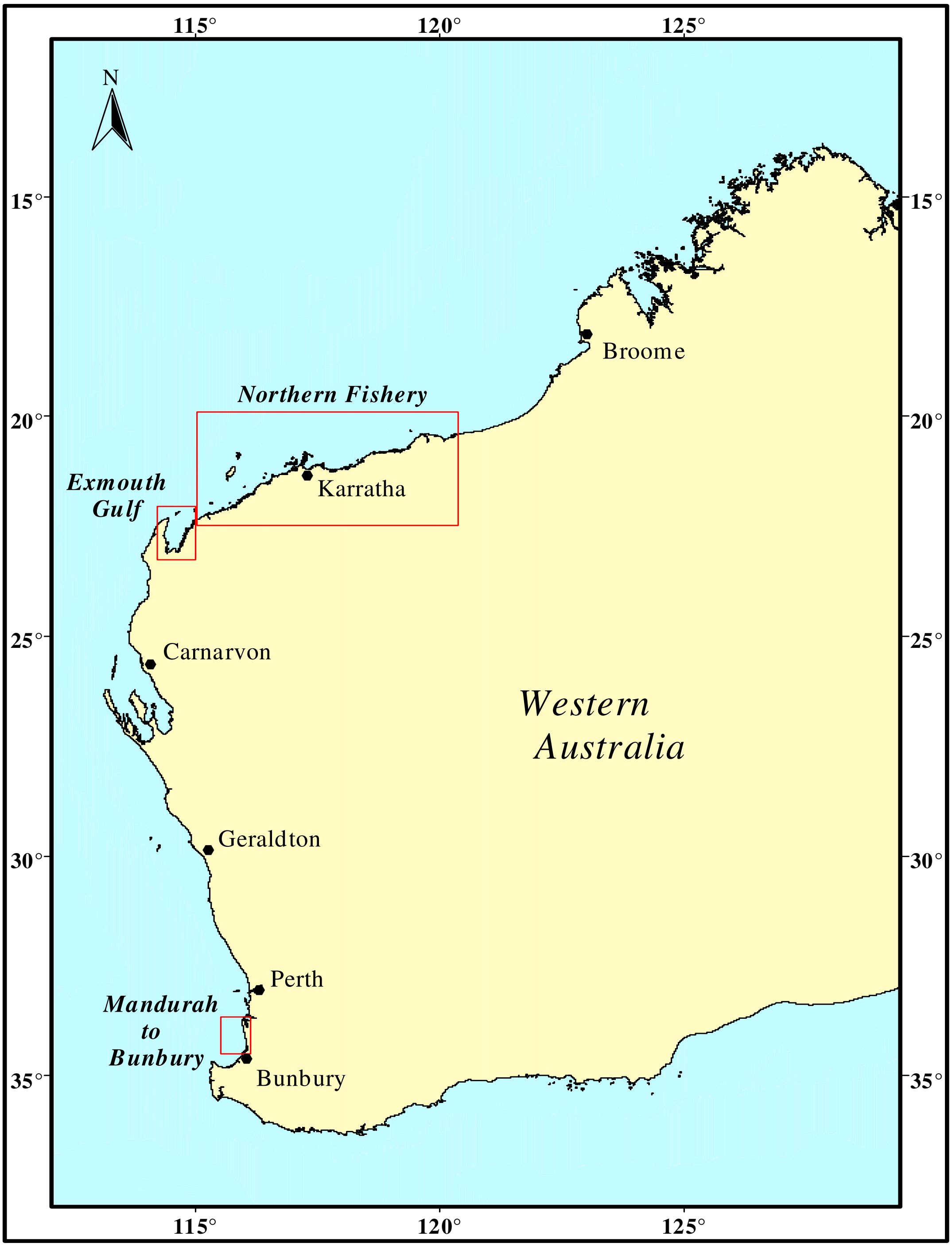

Figure 8.1 Location of the Northern, Exmouth Gulf and Mandurah to Bunbury Exploratory Blue Swimmer Crab Fisheries.

8.1.1 The northern fishery

Commercial fishing in the coastal waters from Onslow to Port Hedland (Fig. 8.2) is primarily targeted at fish species. Both the Pilbara Trap Managed Fishery and Pilbara Fish Trawl (Interim) Managed Fishery operate in the waters from 30m to 200m in depth. In addition, the Onslow Prawn Fishery operates between Locker Island west of Onslow and Dampier, while the Nickol Bay Prawn Fishery covers the waters from Dampier to east of Port Hedland. The fish trawl and trap operators rarely record blue swimmer crabs amongst their by-product, however, both prawn fisheries have a history of retaining blue swimmer crabs. Between 1991 and 2004, the prawn trawler fleets operating between Onslow and Port Hedland retained one to six tonnes of blue swimmer crabs annually (Fig. 8.6).

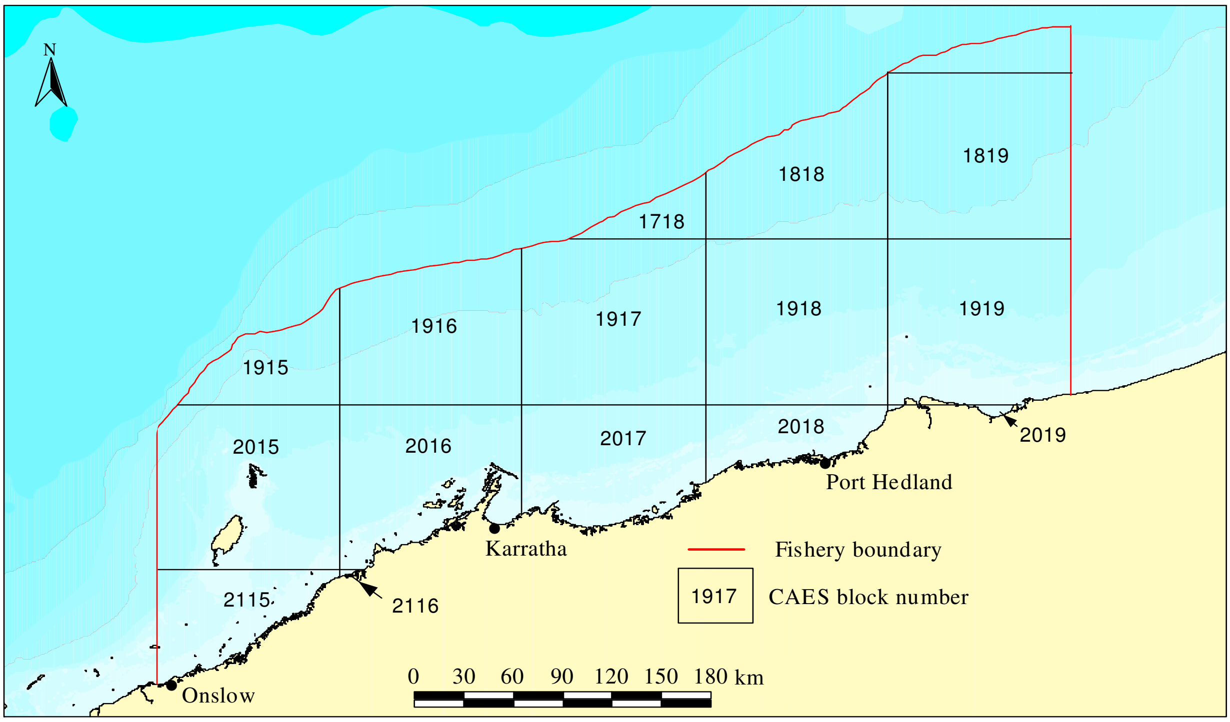

Figure 8.2 Boundaries and Catch and Effort Statistics (CAES) Blocks of the Northern Blue Swimmer Crab Exploratory Fishery.

There is also a significant recreational blue swimmer crab fishery in the Pilbara region, focused primarily on Nickol Bay. Recreational crabbers fishing along the Pilbara coastline from Onslow to Port Hedland retained 22 tonnes of blue swimmer crabs between December 1999 and November 2000 (Sumner and Malseed, 2004). Nineteen tonnes of this catch was taken from Nickol Bay (Anon., 2001/02).

In 2001, exemptions were issued to two Cockburn Sound crab fishers permitting them to target blue swimmers in the waters of the Pilbara coast in the north-west of WA. One exemption allows for fishing from the high water mark to the 200m isobath between longitudes 115^0E and 120^0E, i.e. Onslow to Port Hedland (Fig. 8.2). One exemption provided for two fishing units, with a maximum of 200 crab traps to be used per fishing unit. The other exemption limits fishing from the high water mark to the 200m isobath between longitudes 117^0E and 120^0E, i.e. Point Samson to Port Hedland. This exemption provides for one fishing unit with a maximum of 200 traps. A minimum size limit of 135mm CW was set for both exemptions.

8.1.2 Exmouth Gulf

Exmouth Gulf is an open, shallow marine embayment surrounded by tidal mud flats, located 1,400km to the north of Perth on the arid northwest coast of Western Australia (Fig. 8.3). It covers 2,200 km^2, and ranges to 22m in depth at the northern mouth (White, 1975).

The Exmouth Gulf Prawn Fishery dominates commercial fishing operations in the Gulf, with trawlers targeting western king, brown tiger, endeavour and banana prawns. Various secondary species are retained as by-product, including blue swimmer crabs. From 1991 to 2004, Exmouth

Gulf trawlers reported annual landings of between six and 43 tonnes of blue swimmer crabs (Fig. 8.11). One commercial trap fisher has a history of targeting blue swimmer crabs in Exmouth Gulf, operating under an exemption issued by the Executive Director in 1989. After minimal activity during the early 1990s, annual fishing effort increased to over 2,000 trap lifts between 1997 and 2000. The annual catch during this period was between three and nine tonnes of blue swimmer crabs (Fig. 8.11).

While significant recreational fishing effort is targeted at fish species within Exmouth Gulf, recreational effort directed at blue swimmer crabs is minimal.

In 2002, two exemptions were issued to target blue swimmer crabs and the sand crab *Ovalipes australiensis* in the waters of Exmouth Gulf, south of a line drawn between North West Cape and Locker Point. Each exemption allowed for a maximum of 200 hour glass crab traps, with a minimum size limit set at a carapace width (CW) of 135mm measured from tip to tip of the posterior carapace spines.

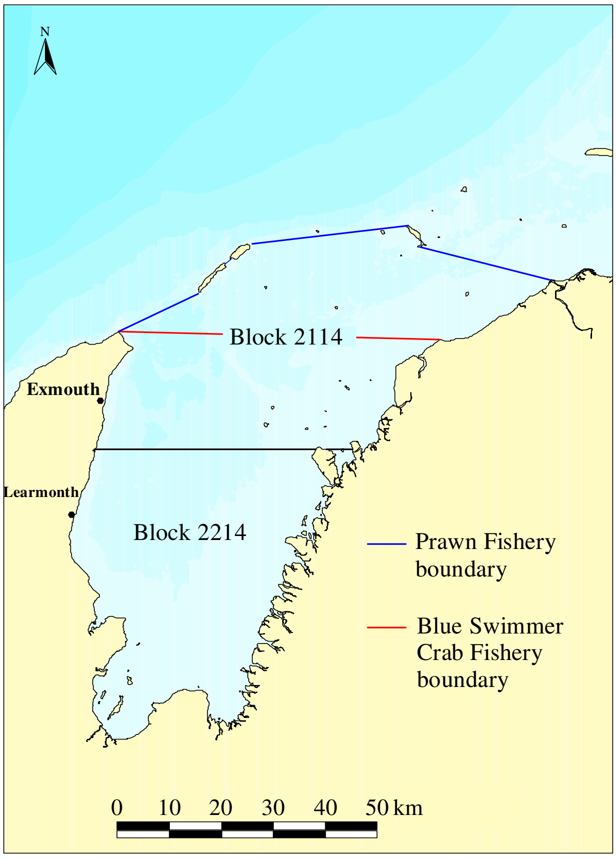

Figure 8.3 Boundaries and CAES Blocks of the Exmouth Gulf Prawn and Blue Swimmer Crab Fisheries.

8.1.3 Mandurah to Bunbury

The Mandurah-Bunbury Inshore Crab Fishery covers the waters south of the Shoalwater Islands Marine Park to just north of 'The Cut', and offshore to 115^0 30'E. The Fishery is further divided into a northern (Comet Bay Oceanic Crab Pot Trial zone) and southern area (waters between Cape Bouvard and the southern boundary of the Fishery), with the zone separating the two areas closed to commercial fishing (Fig. 8.4).

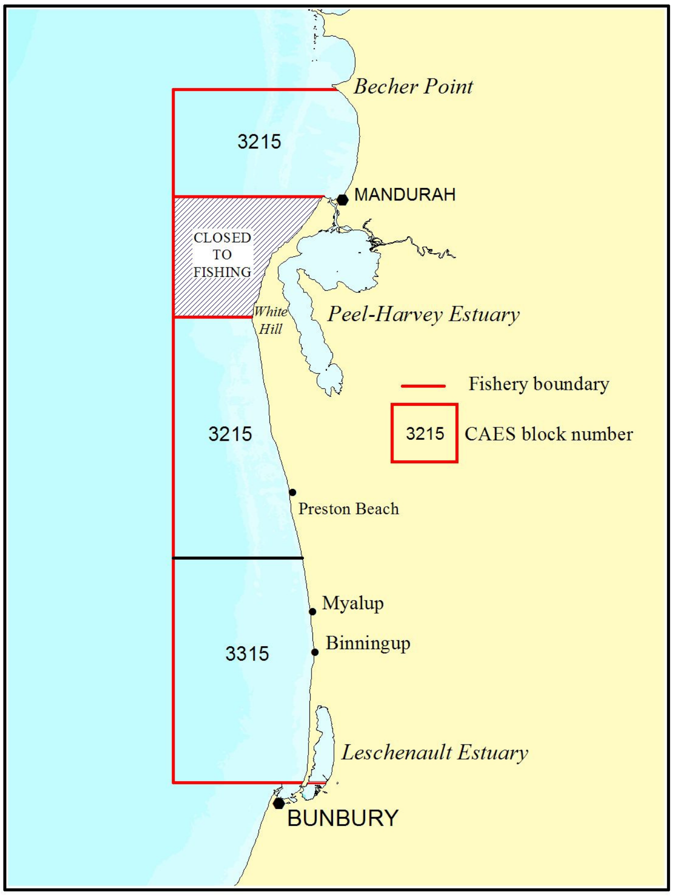

Figure 8.4 Boundaries and CAES Blocks of the Mandurah to Bunbury Blue Swimmer Crab Exploratory Fishery.

Since the early 1970s, the coastal waters in and around Mandurah have supported substantial commercial catches of blue swimmer crabs. Catches of between 20 – 40 tonnes have been reported since 1990, taken by a variety of fishing methods including trawling, drop netting and gill and haul netting, as well as with dedicated crab traps. The statutory monthly catch and effort returns submitted by commercial fishers, however, do not provide the spatial resolution required to accurately determine the catch specifically from the waters covered by the Mandurah to Bunbury fishery as the method for reporting CAES for this area in the past has sometimes included catches from Geographe Bay.

The estuaries and inshore waters of southwest Western Australia are subject to the majority of the State's recreational crabbing effort. The Peel-Harvey Estuary near Mandurah and the Leschenault Estuary adjacent to Bunbury, represent two of the state's most popular recreational blue swimmer crab fisheries (Fig. 8.4). The recreational catch for the Peel-Harvey Estuary for 1998/99 was 289 tonnes, greatly exceeding the commercial catch of 57 tonnes (Malseed and Sumner, 2001). Recreational fishers crabbing in the Leschenault Estuary during 1998 retained 46 tonnes of blue swimmer crabs, again significantly more than the commercial catch of 2.8 tonnes (Malseed *et al*., 2000). Historically however, there has been minimal recreational fishing for blue swimmer crabs in the coastal waters covered by the Mandurah to Bunbury crab fishery.

In 2002 four exemptions were issued to fishers who had demonstrated a consistent history of taking commercial quantities of blue swimmer crabs in these waters. Each exemption was valid for a period of two years and permitted the taking of blue swimmer and sand crabs using a maximum of 60 hourglass crab traps. A minimum legal size limit was set at 128mm CW, the same size limit is in place in the Geographe Bay fishery, for both the blue swimmer and sand crabs.

8.2 METHODS

8.2.1 Commercial catch and effort statistics (CAES)

Under the Fish Resources Management Act 1994 licensees involved in fishing operations and/or the master of every licensed fishing boat, must submit an accurate and complete monthly catch and effort return on forms approved by the Department of Fisheries. The returns record monthly catch totals for each retained species, estimates of daily effort and spatial information in the form of Block references. The exemption that allows for fishing in the Pilbara region does require logbooks, that contain more specific catch data, to be completed by the fishers or licensees.

8.2.2 Commercial catch monitoring surveys

Department of Fisheries research staff conducted annual surveys between 2002 and 2004 (July to August) to monitor the catch of blue swimmer crabs taken by commercial crab fishers operating along the Pilbara coastline. During each survey the size composition, sex ratio and breeding condition of all animals caught was recorded, along with various environmental factors such as salinity, water temperature and the prevailing weather conditions.

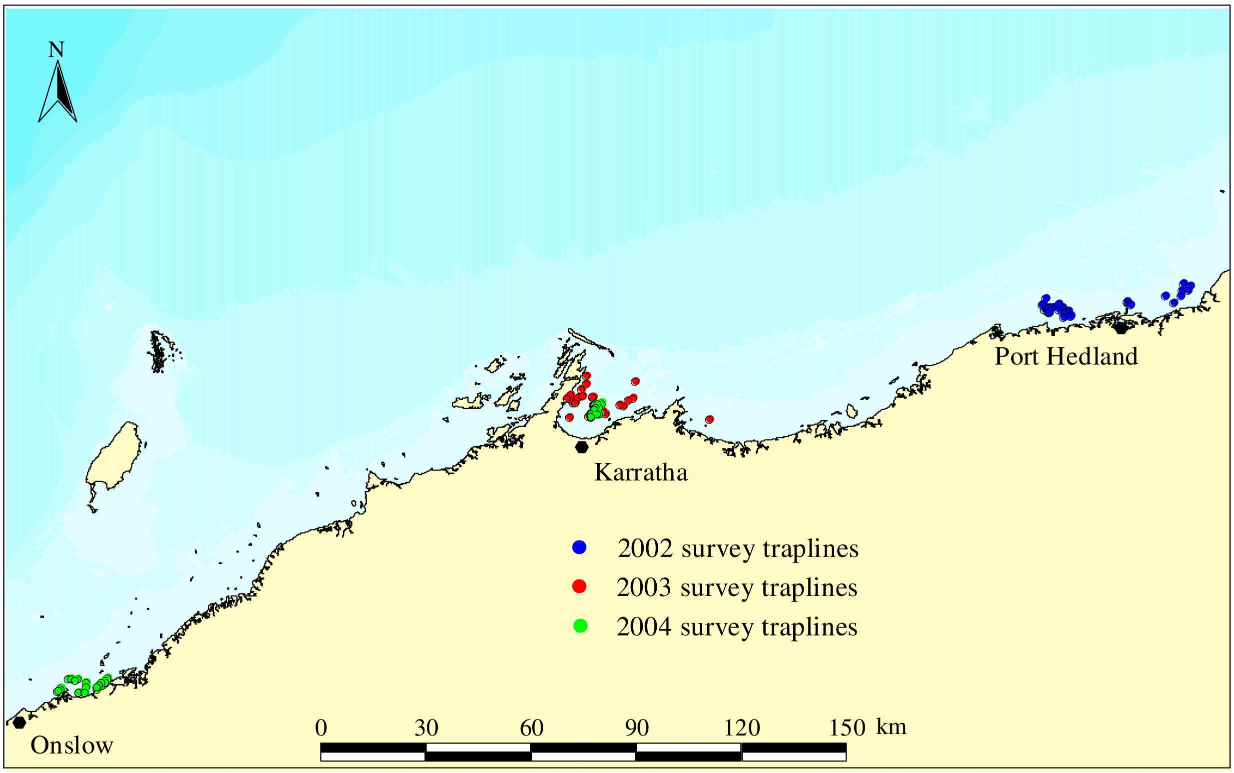

Figure 8.5 Locations of trap-lines sampled during catch monitoring surveys aboard commercial crab vessels operating in the Northern Blue Swimmer Crab Exploratory Fishery between 2002 and 2004.

The locations of trap-lines sampled during catch monitoring surveys were dependent on the areas being fished by the commercial fishers at that time (Fig. 5). Therefore, the results are unlikely to be representative of catch trends over an entire year, nor the whole area the fishermen operated in. Surveys were conducted in the waters off Port Hedland from 23rd – 25th July in 2002, and Nickol Bay from the 12th – 15th August in 2003. The 2004 survey was carried out between 6th – 10th July and involved two days fishing off Onslow and two days in Nickol Bay.

Surveys were not conducted in Exmouth Gulf, as there was no commercial activity in the fishery between July 2002 and June 2004. Surveys were also not cond ucted in the Mandurah to

Bunbury fishery as the boats operating in this fishery were unable to accommodate extra personnel.

8.3 RESULTS

8.3.1 Northern fisheries

Commercial catch and effort statistics

Small catches of blue swimmer crabs have been landed as by-product by commercial trawlers between 1991 – 2004 and catches spiked in 2002 with the introduction of traps to the fishery in 2001 (Fig. 8.6).

The two licensees granted exemptions to target blue swimmer crabs in the waters of the Pilbara coast, operated intermittently between October 2001 and September 2004. Most of the fishing that occurred during this period involved two vessels operating 200 hourglass crab traps each, with a third vessel fishing an additional 200 traps in Nickol Bay between July and September 2003.

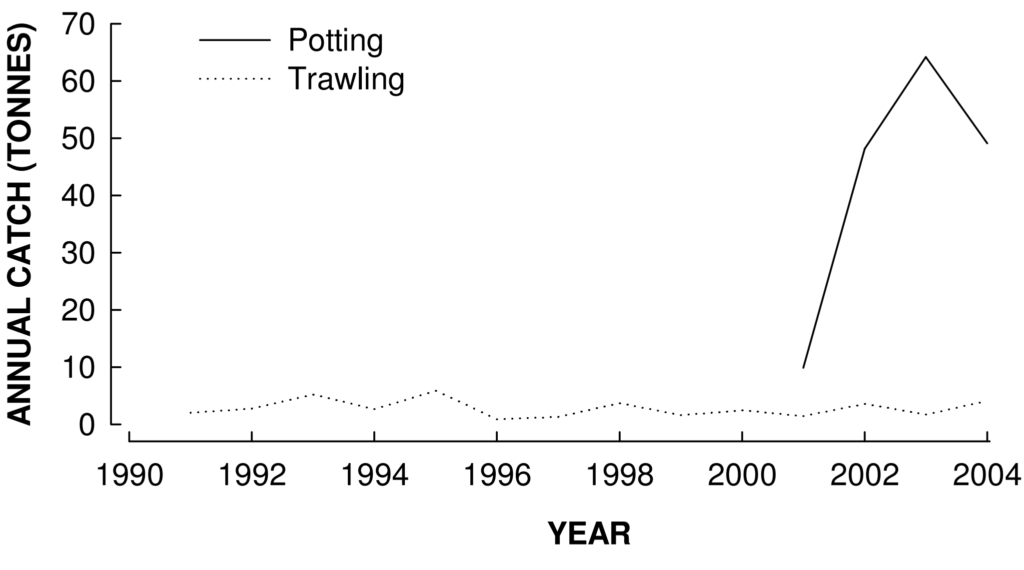

Figure 8.6 Annual catches (tonnes) of blue swimmer crabs taken in the waters of the Pilbara coastline between 1991– 2004 (see Table 1, Appendix IV).

The majority of catch and effort attributable to the dedicated blue swimmer crab fishers between October 2001 and September 2004 occurred in the CAES Blocks fringing the coast. Some 46.8 tonnes of crabs were taken from Block 2017, at an average catch rate of 1.1 kg/trap lift (Table 8.1). During the same period, Block 2115 produced 41.5 tonnes of crabs at a catch rate of 1.1 kg/trap lift, Block 2018 produced 39.6 tonnes at 0.8 kg/trap lift and Block 2016 produced 35.5 tonnes at 1.1 kg/trap lift (Table 8.1).

Crab fishermen fished for crabs from August to November during 2001, primarily in the waters between Nickol Bay and Port Hedland. They landed 9.9 tonnes of blue swimmer crabs from 19,200 trap lifts at an average catch rate of 0.5 kg/trap lift (Table 8.1).

There was a significant increase in effort during 2002. Fishing occurring from May through to December as the licensees began to explore the areas east of Port Hedland. Most of the effort, however, was again focused on the coastal waters between Nickol Bay and Port Hedland. The total catch reported for the 2002 season was 48.1 tonnes, resulting from 60,800 trap lifts at an average catch rate of 0.7 kg/trap lift (Table 8.1). More than 50% of this effort (35,600 trap lifts) was focused on the waters around Port Hedland (Block 2018), which produced 65% (31.3 tonnes) of the annual catch at 0.8 kg/trap lift (Table 8.1).

Effort continued to increase during 2003, as fishing expanded to include the coastal areas around Onslow. Most of the effort (61%) was again focused on the waters in and around Nickol Bay (Block 2116), with the second fishing unit attached to one of the exemptions utilised to fish the region between July and September. No fishing occurred in the Port Hedland region during 2003, as fishers explored new grounds further west. A total of 68,500 trap lifts were reported between March and November, resulting in 64.2 tonnes of blue swimmer crabs (Table 8.1). The average catch rate for 2003 increased to 1.0 kg/trap lift, reflecting the fisher's improved understanding of the crab stocks within the region and how they are affected by local environmental influences.

During 2004, commercial blue swimmer crab fishing was again focused on the waters stretching from west of Onslow to east of Nickol Bay. The continued development of the fishery, and the fisher's knowledge of the region, was again evident in 2004 with the average catch rate increasing to 1.8 kg/trap lift (Table 8.1). While the 2004 catch of 49.1 tonnes was down 25% on the previous year, it was landed from 30,700 trap lifts over 160 fishing days, representing a 56% decrease in effort that was primarily due to inclement weather conditions.

Monthly trends in catch rate are not consistent between years but tend to indicate that catch rates are highest between May and August.

Table 8.1 Annual catch (tonnes), effort (days fished; trap lifts) and catch rate (kg/trap lift) by CAES Block for dedicated crab fishers operating in the Northern Blue Swimmer Crab Fishery, 2001 – 2004.

YEAR		CAES BLOCK 1918	1919	2015	2016	2017	2018	2115	2116	TOTAL
2001	Catch				0.6	1.0	8.3			**9.9**
	Days Fished				30	19	77			**126**
	Trap lifts (x1000)				3.0	3.8	12.4			**19.2**
	Catch Rate				0.2	0.3	0.6			**0.5**
2002	Catch	0.9	1.6		4.1	10.2	31.3			**48.1**
	Days Fished	10	19		34	71	182			**316**
	Trap lifts (x1000)	1.6	3.2		6.6	13.8	35.6			**60.8**
	Catch Rate	0.6	0.5		0.6	0.7	0.8			**0.7**
2003	Catch			4.2	18.0	22.8		19.2		**64.2**
	Days Fished			26	105	127		108		**366**
	Trap lifts (x1000)			5.2	18.9	22.8		21.6		**68.5**
	Catch Rate			0.8	1.0	1.0		0.9		**1.0**
2004	Catch				12.8	12.8		22.3	1.2	**49.1**
	Days Fished				33	32		81	14	**160**
	Trap lifts (x1000)				5.9	5.7		16.2	2.8	**30.7**
	Catch Rate				2.2	2.2		1.4	0.4	**1.8**

Commercial catch monitoring surveys

A total of 6,936 blue swimmer crabs were measured during the three catch monitoring surveys undertaken in the waters off the Pilbara coastline between 2002 and 2004.

Some 764 crabs were captured during the 2002 survey off Port Hedland, of which 68% were male. Thirty nine (5%) of the crabs sampled were berried (Table 8.2). While there were twice as many males caught as females, the size distributions of each sex were similar (Fig. 8.7). The mean carapace width (CW) of males measured was 152mm compared to 153mm CW for females (Table 8.2).

Table 8.2 Numbers and mean carapace widths (mm) of blue swimmer crabs caught by commercial vessels during catch monitoring surveys along the Pilbara coastline between 2002 and 2004.

			No OF ANIMALS	PROPORTION (%)	MEAN CW (mm)
Jul 02	**Port Hedland**	MALE	522	68	152
		FEMALE	203	27	153
		BERRIED	39	5	151
		TOTAL	**764**	**100**	**152**
Aug 03	**Nickol Bay**	MALE	1,199	39	150
		FEMALE	1,776	57	143
		BERRIED	119	4	143
		TOTAL	**3,094**	**100**	**146**
Jul 04	**Onslow**	MALE	1,043	87	158
		FEMALE	129	11	156
		BERRIED	23	2	157
		TOTAL	**1,195**	**100**	**157**
Jul 04	**Nickol Bay**	MALE	2,458	80	158
		FEMALE	583	19	148
		BERRIED	37	1	148
		TOTAL	**3,078**	**100**	**153**

In contrast, there was more female blue swimmer crabs caught during the 2003 survey in Nickol Bay. Of the 3,094 blue swimmer crabs measured, 57% (n = 1,895) were female and 119 (4%) of the total catch were berried (Table 8.2). They were also generally smaller, with a mean CW of 143mm compared to 150mm for the male crabs. The high relative abundance of females may indicate an inshore movement by females for breeding.

Male blue swimmer crabs dominated the catch from the 2004 monitoring survey, accounting for 87% (*n* = 1,043) of the crabs measured off Onslow and 80% (*n* = 2,458) in Nickol Bay (Table 8.2). The male size distributions from each location were also very similar, with a mean CW of 158mm for both areas. Although significantly fewer in number (*n* = 152), the size distribution of the female sample (mean CW of 156mm) caught off Onslow was very similar to the male distribution. Two percent of the crabs were berried, a similar proportion to the 5% recorded during the survey off Port Hedland in July 2002. In comparison, only 1% of the 620 female crabs caught in Nickol Bay during the 2004 survey were berried. This was a repeat of the proportion of berried females sampled in the previous Nickol Bay survey. The difference in size between sexes was again evident, with a mean CW of 148mm for females compared to 158mm for males (Table 8.2).

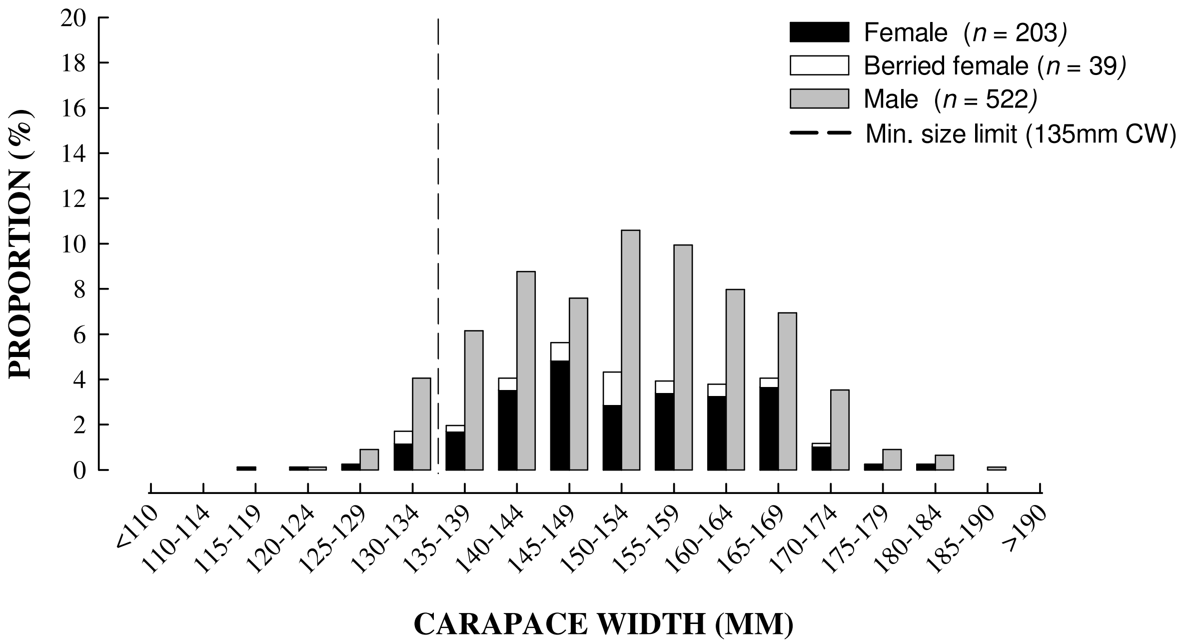

Figure 8.7 Size distributions of blue swimmer crabs caught during catch monitoring surveys aboard commercial vessels in the waters off Port Hedland during July 2002.

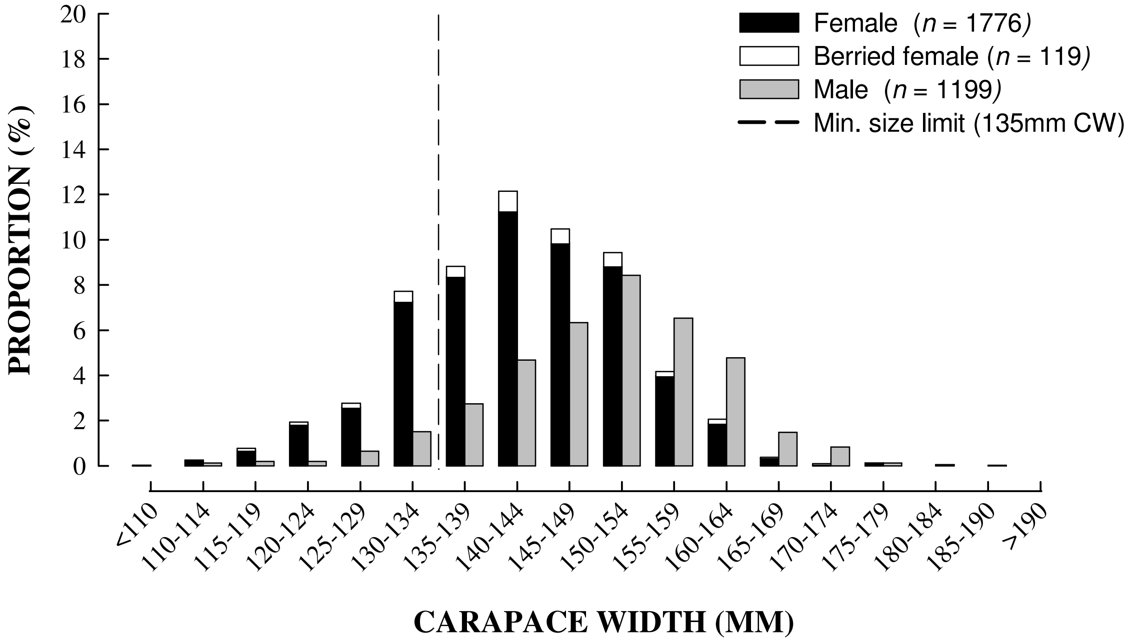

Figure 8.8 Size distributions of blue swimmer crabs caught during catch monitoring surveys aboard commercial vessels in Nickol Bay during August 2003.

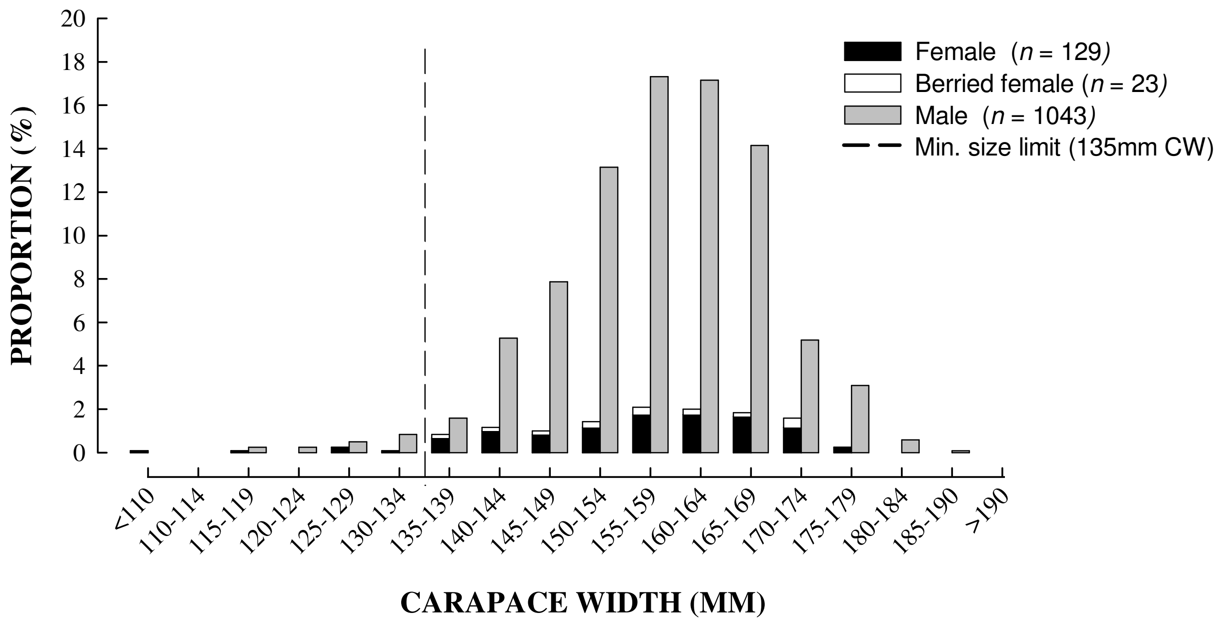

Figure 8.9 Size distributions of blue swimmer crabs caught during catch monitoring surveys aboard commercial vessels in the waters off Onslow during July 2004.

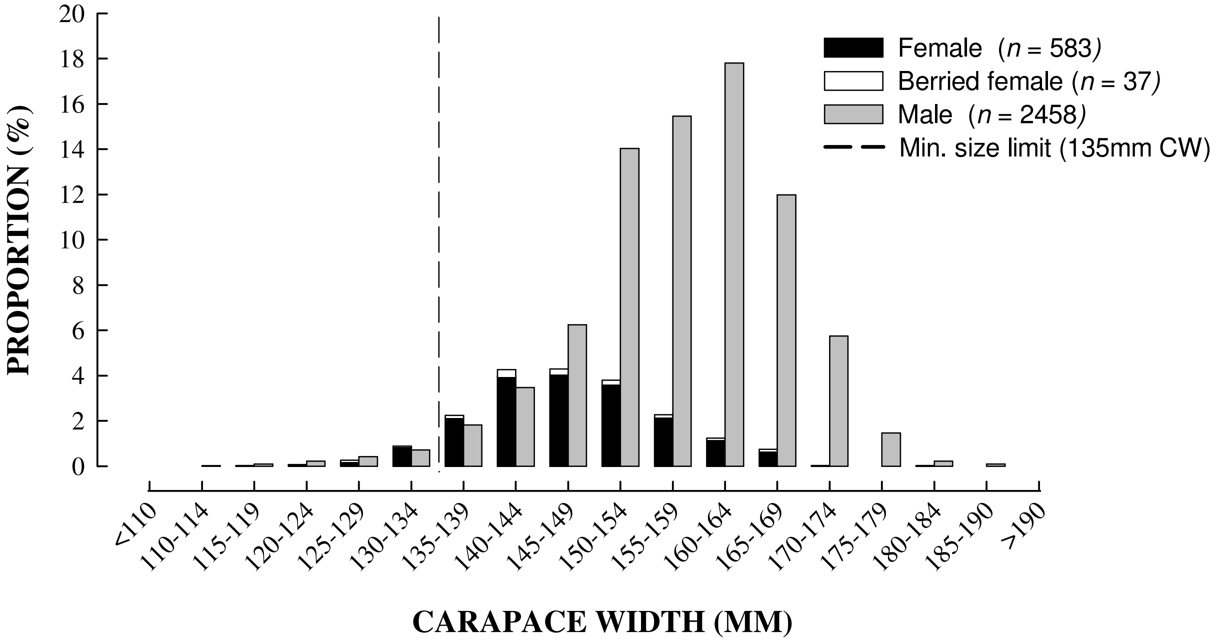

Figure 8.10 Size distributions of blue swimmer crabs caught during catch monitoring surveys aboard commercial vessels in Nickol Bay during July 2004.

8.3.2 Exmouth Gulf

Commercial catch and effort statistics

While the Exmouth Gulf trawl fleet continued to retain significant quantities of blue swimmer crabs between 2002 and 2004, a variety of logistical concerns resulted in minimal fishing by the two fishers granted exemptions to target blue swimmer and sand crabs. There was no fishing during 2002 and 2003, with a total of 2,000 kg of blue swimmer crabs reported from July, August and September 2004 (Table 8.3). Three quarters of this catch was taken from the southern half of the Gulf (CAES Block 2214).

Table 8.3 Annual catch and effort of commercial fishers operating in Exmouth Gulf from 2002 – 2004.

		CAES BLOCK								TOTAL			
		2114				**2214**							
YEAR	METHOD	CATCH (t)	No of VESSELS	FISHER DAYS	TRAP LIFTS	CATCH (t)	No of VESSELS	FISHER DAYS	TRAP LIFTS	CATCH (t)	No of VESSELS	FISHER DAYS	TRAP LIFTS
2002	**TW**	17.2	14	2,247						17.2	14	2,247	
2003	**TW**	2.7	10	305		18.6	12	2,097		21.3	22	2,402	
2004	**PT**	0.5	1	6	600	1.5	1	18	1,400	2.0	2	24	2,000
	TW	15.1	13	830		0.5	1	27		15.6	14	857	

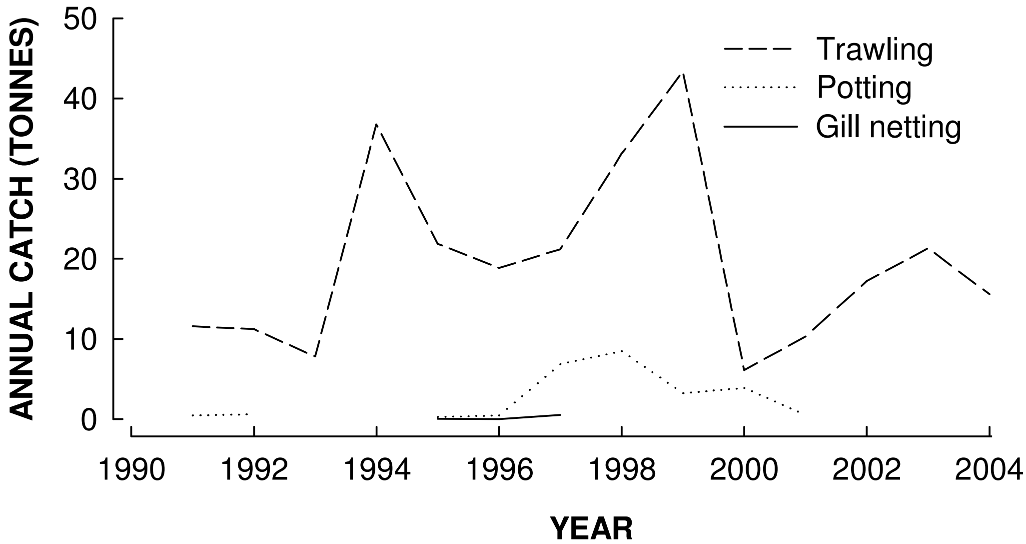

Figure 8.11 Annual catches (tonnes) of blue swimmer crabs taken in Exmouth Gulf from 1990 – 2004 (see Table 2, Appendix IV).

8.3.3 Mandurah to Bunbury

Minimal fishing was undertaken in the Mandurah to Bunbury Inshore Crab Fishery during 2002, with a total of 1,060 trap lifts pulled over just 13 days of fishing (Table 8.4). A total of 937 kg of blue swimmer crabs was reported for the year, at a catch rate of 0.9 kg/trap lift. Most of this catch and effort came from Block 33151.

Effort increased noticeably in 2003, as the exemption holders began to investigate the strength of blue swimmer crab stocks within the fishery's boundaries. They operated intermittently from January to June and again from September to November, for a combined total of 143 days fishing. Over this time, the fishers completed 11,175 trap lifts to land 9,404 kg of blue swimmer crabs, at a catch rate of 0.8 kg/trap lift (Table 8.4). The majority of the catch (63%) and effort (61%) was again concentrated in Block 33151.

As understanding of the local crab stocks developed, effort in the Mandurah to Bunbury fishery during 2004 was concentrated between March and June. However, catch rates in the Mandurah to Bunbury fishery are highest between October and March. Concentrating their fishing efforts between March and June also allowed the fishers to maximise their return in other fisheries for which they carry endorsements. Some 10,320 trap lifts from a combined 100 fishing days were reported for this period, resulting in landings of 11,079 kg (Table 8.4). The average catch rate increased to 1.1 kg/trap lift for 2004, reflecting the ongoing development of the fishery. As in previous years, the majority of fishing was done in Block 33151, which accounted for 70% of the 2004 catch and effort.

Table 8.4 Annual catch (kg), effort (trap lifts) and catch rate (kg/trap lift) by CAES Block for dedicated crab fishers operating in the Mandurah to Bunbury Blue Swimmer Crab Fishery, 2001 – 2004.

		YEAR		
CAES BLOCK		**2002**	**2003**	**2004**
32150	Catch	137	3 434	3 151
	Trap lifts	120	4 320	3 120
	Catch Rate	1.1	0.8	1.0
33151	Catch	800	5 970	7 928
	Trap lifts	940	6 855	7 200
	Catch Rate	0.9	0.9	1.1
TOTAL	Catch	937	9 404	11 079
	Trap lifts	1 060	11 175	10 320
	Catch Rate	0.9	0.8	1.1

8.4 DISCUSSION

Between August 2001 and June 2004, exploratory fishing for the blue swimmer crab, *Portunus pelagicus*, took place in several unexploited regions of the Western Australian coast. These areas had been identified as potentially suitable for commercial fishing, while being subject to minimal recreational crabbing effort. This study provided the opportunity to monitor the exploration of the Pilbara coastal region, Exmouth Gulf and the coastal waters between Mandurah and Bunbury.

Considerable exploration took place in the coastal waters of the Pilbara region. Fishers operated along most of the accessible coastal areas from west of Onslow through to east of Port Hedland, with commercial quantities of blue swimmer crabs landed from a number of different areas along this stretch of coast. Catch rates increased from an average of 0.5 kg blue swimmer crabs/trap lift in 2001 to 1.8 kg/trap lift in 2004, as new stocks were discovered and the fisher's understanding of the area grew. However, the remoteness of many of these locations combined with the harsh climatic conditions prevalent over the summer months, presented logistical problems in getting the landed product to market. The majority of crabs from the Pilbara region were sold through Perth and Sydney markets. As methods for freezing landed crab product have proved largely unacceptable, air freight was required to transport the product to market in an acceptable timeframe. Consequently, it was the stocks uncovered near suitable access to airfreight available in Karratha and Port Hedland that appear the most commercially viable at this point in time. Fishers in the Pilbara do not tend to operate over the summer months due to the heat, and if they possess the required license fish Cockburn Sound instead at that time of year. On the whole, the market considered crabs from the Pilbara region to be of a very high standard. As the licensees tended to operate in separate areas of the coast, they were less likely to retain crabs that had lost claws or recently moulted. They were also considerably larger than crabs landed from the state's more southern fisheries. Consequently, the blue swimmer crabs landed along the Pilbara coastline attracted comparatively high prices at the Perth and Sydney markets.

Exploration of the blue swimmer crab stocks in the Pilbara region also uncovered the first occurrence on the west coast of Australia of infestation by the parasitic barnacle *Sacculina granifera* (see Appendix III). While endemic to blue swimmer crab stocks along the eastern Australian seaboard, there had previously been no record of the parasite on the west coast. *Sacculina granifera* is known to have a number of effects on its crab host, including degeneration of the sex organs in both sexes and modification of the male crab to a more female form. Infection usually results in castration for both sexes, however, infected hosts are still capable of mating and some females are still able to produce a clutch of eggs. The parasite consists of two sections: an internal root system and an external sac. As the sac is easily removed and the internal hyphae have no major impact on meat quality, there do not appear to be any concerns in the marketing of infected crabs. Consequently, it is unlikely the parasite will impact on the commercial viability of crabbing operations along the Pilbara coastline.

Substantial effort was also invested in the exploration of the coastal waters that had yet to be commercially fished for blue swimmer crabs between Mandurah and Bunbury. Reasonable quantities of crabs were reported for the Mandurah to Bunbury exploratory fishery in each of the years from 2002 to 2004, with the average catch rate ranging from 0.8 – 1.1 kg/trap lift. While this is lower than some of the more productive crab fisheries in the state, ease of access to the crab stock and proximity to local markets meant that fishing operations could be run at a comparatively low cost. Consequently, the fishery is likely to prove commercially viable for periods of the year. Initial exploration has suggested that there is unlikely to be sufficient stock to make the fishing of blue swimmer crabs in the Mandurah to Bunbury crab fishery commercially viable throughout the year.

Despite the issuing of two exemptions to fish for blue swimmer crabs in Exmouth Gulf in 2002, minimal fishing has taken place in the area. The licensees reported similar logistical problems to those faced by the commercial fishers exploring the Pilbara region. A lack of access to suitable air freight, and excessive heat in the summer months have been presented as obstacles to fishing taking place. Issues of access are also to be resolved, as the local prawn industry operates in the most productive areas of Exmouth Gulf for large parts of the year. Consequently, insufficient data has been gathered to be able to provide any analysis of the viability of commercial fishing for blue swimmer crabs in the Gulf.

Conclusion

The targeting of blue swimmer crabs in the coastal waters between Mandurah and Bunbury and the Pilbara region has proved largely successful. Commercially viable quantities of crabs were landed from both fisheries, although it is still unclear as to whether either could sustain fishing throughout the year. Furthermore, commercial operations appear to have had no discernible impact on the recreational catch and effort in these regions. It is expected that the viability of operations in both of these areas will continue to improve as the fishers consolidate their knowledge of local crab stocks and further refine their fishing and marketing operations. However, further exploratory work is required before the long-term productivity of both the Pilbara coast and the waters between Mandurah and Bunbury as commercial crab fisheries can be determined. As there was little fishing undertaken by the exemption holders in Exmouth Gulf, it was not possible to provide an assessment on the viability of trap fishing for blue swimmer crabs in this area. Several years of exploratory fishing are still required before the viability of commercial operations, and any impact on the recreational blue swimmer crab catch and effort, in the Gulf can be considered. The by-catch from the trawl fishery, however indicates that there is a significant but variable stock of blue swimmer crabs in the area.

The ongoing development and future expansion of these fisheries requires research monitoring and the implementation of a logbook program. This will provide important data on spatial and seasonal trends within the fisheries and indicate how the crab populations respond to sustained fisheries pressure. If we assume that the size at maturity in the northern fishery is the same as in Shark Bay (of females: 92.0 mm CW, and males: 97.0 mm CW [de Lestang et al., 2003c]) then the minimum legal size (135 mm CW) is well above the size at maturity and therefore protects a breeding stock that is sufficient to sustain the populations. The size at maturity in the northern fishery needs to be determined. Similarly, the minimum legal size in the Mandurah to Bunbury fishery (128 mm) is well above the size at maturity of females (88.0 mm) and males (86.9 mm CW; de Lestang et al., 2003c). Current effort limits should be maintained given the paucity of research data available on these stocks, and the short time period for which these fisheries have been in operation.

9.0 STOCK ASSESSMENT OF BLUE SWIMMER CRABS, *PORTUNUS PELAGICUS*, IN SHARK BAY, WESTERN AUSTRALIA by Bellchambers and Smith

9.1 INTRODUCTION

9.1.1 History of the blue swimmer crab fishery in Western Australia

Commercial fishermen in Shark Bay have retained blue swimmer crabs since the early 1950s, primarily as incidental catch from prawn and scallop trawlers. Blue swimmer crabs were first targeted with traps in the western gulf of Shark Bay during the 1980s. However, until 1998 only 450 traps had been allocated in Shark Bay with fishing limited to the waters of the Shark Bay Beach Seine and Mesh Net Fishery i.e. within the western and eastern gulfs (Fig. 9.1). In 1998 the Experimental Carnarvon Crab Trap Fishery was formalised and three experimental fishery endorsements, with a maximum of 200 traps, were issued to undertake fishing in the northern section of Shark Bay. The area described extended from Quobba Point in the north, to Bernier and Dorre Islands in the west, and south to Cape Peron (Fig. 9.1). The purpose of the fishery was to determine the potential of crab trap fishing in the region with the policy to be reviewed after a period of three years. With the three new endorsements and two prior license exemptions permitted to fish in the southern region within the Gulfs, there are now five vessels potting for blue swimmer crabs in Shark Bay.

Following the three-year period, applications were received from two endorsement and one exemption holder to increase their maximum number of traps in the Experimental Carnarvon Crab Trap Fishery from 200 to 300. To allow further development of the fishery by enabling fishers to test more ground, trap numbers were increased in July 2001 for a trial period of one year. There are currently (September 2004) 1,500 traps allocated in the Shark Bay region, with

1,100 of those to be used exclusively in the waters of the Experimental Carnarvon Crab Trap Fishery while the remaining 400 can be used in the western and eastern gulfs.

The Experimental Carnarvon Crab Trap Fishery has undergone a number of changes since its implementation in 1998. During 2004 the Department of Environment and Heritage (DEH) certified the fishery as environmentally sustainable under the provisions of the Environment Protection and Biodiversity Conservation Act 1999. While subject to a number of conditions, certification allows product from the fishery to be exported from Australia for a period of five years before reassessment. This report analyses data collected since the implementation of the fishery and discusses the results in relation to previous work conducted in the Shark Bay region and other semi-tropical portunid fisheries. The report aims to examine any trends in the data and provide recommendations to aid the implementation of a management plan.

9.1.2 Physical description of Shark Bay

Shark Bay is a marine embayment situated 800km north of Perth, Western Australia (Fig. 9.1). Covering 13,000km^2, it is the largest marine embayment in Australia and has the most extensive seagrass meadows in the world (Walker, 1985). The area is important with the recreational, commercial and conservation sectors and was inscribed on the World Heritage List in 1991 (Francesconi and Clayton, 1996).

Shark Bay is a shallow embayment with an average depth of nine metres and is comprised of a series of broad gulfs, narrow inlets and basins. The Peron Peninsula divides the southern portion of Shark Bay into eastern and western gulfs, while the Bernier and Dorre Islands border the northern area to the west. Oceanic waters that are influenced by the Leeuwin Current, enter the bay through the broad Geographe and Naturaliste channels in the north and the narrow South Passage in the western gulf. Due to limited freshwater input and restricted water flow resulting from the extensive seagrass meadows, Shark Bay contains three distinct water body types: oceanic (salinity of 35 – 40‰), metahaline (40 – 56‰) and hypersaline (56 – 70‰). These distinct salinity regimes influence habitat and species distribution, leading to three different biotic zones within Shark Bay (Francesconi and Clayton, 1996).

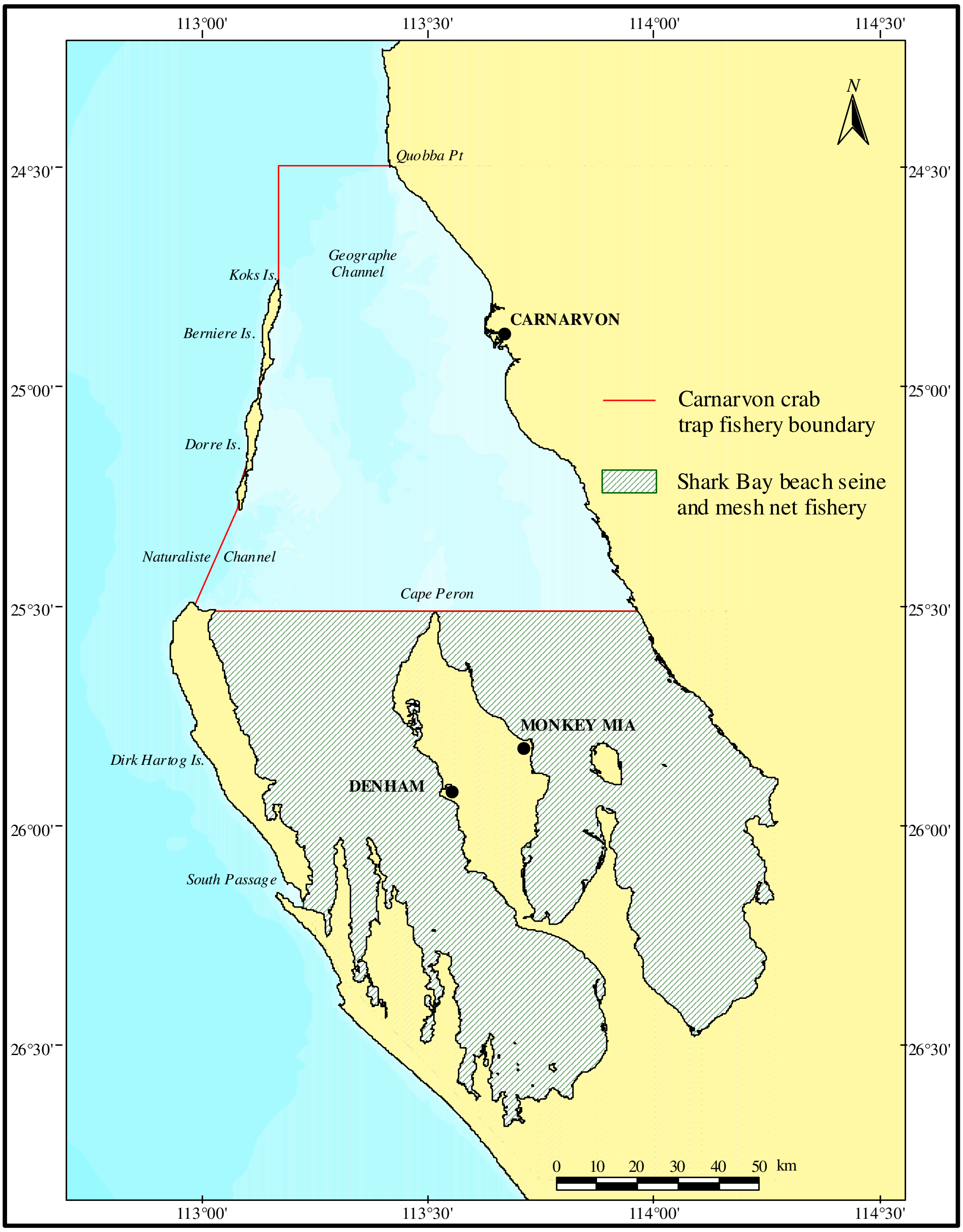

Figure 9.1 Map showing the boundaries of the Shark Bay Beach Seine and Mesh Net Fishery and Experimental Carnarvon Crab Trap Fishery.

9.2 CAES DATA

9.2.1 Introduction and methods

Under the Fish Resources Management Act 1994 licensees involved in fishing operations and/or the master of every licensed fishing boat, must submit an accurate and complete monthly catch and effort return on forms approved by the Department of Fisheries. These data are collected and collated by the Department of Fisheries and contained in the Catch and Effort Statistics (CAES) database. Catches of blue swimmer crabs have been recorded in the CAES database since July 1975. Fishers operating in the Experimental Carnarvon Crab Trap Fishery, beach seine fishers with trap endorsements and trawl licensees record monthly catch totals for each retained species, estimates of daily effort and spatial information in the form of block references (Fig. 9.2).

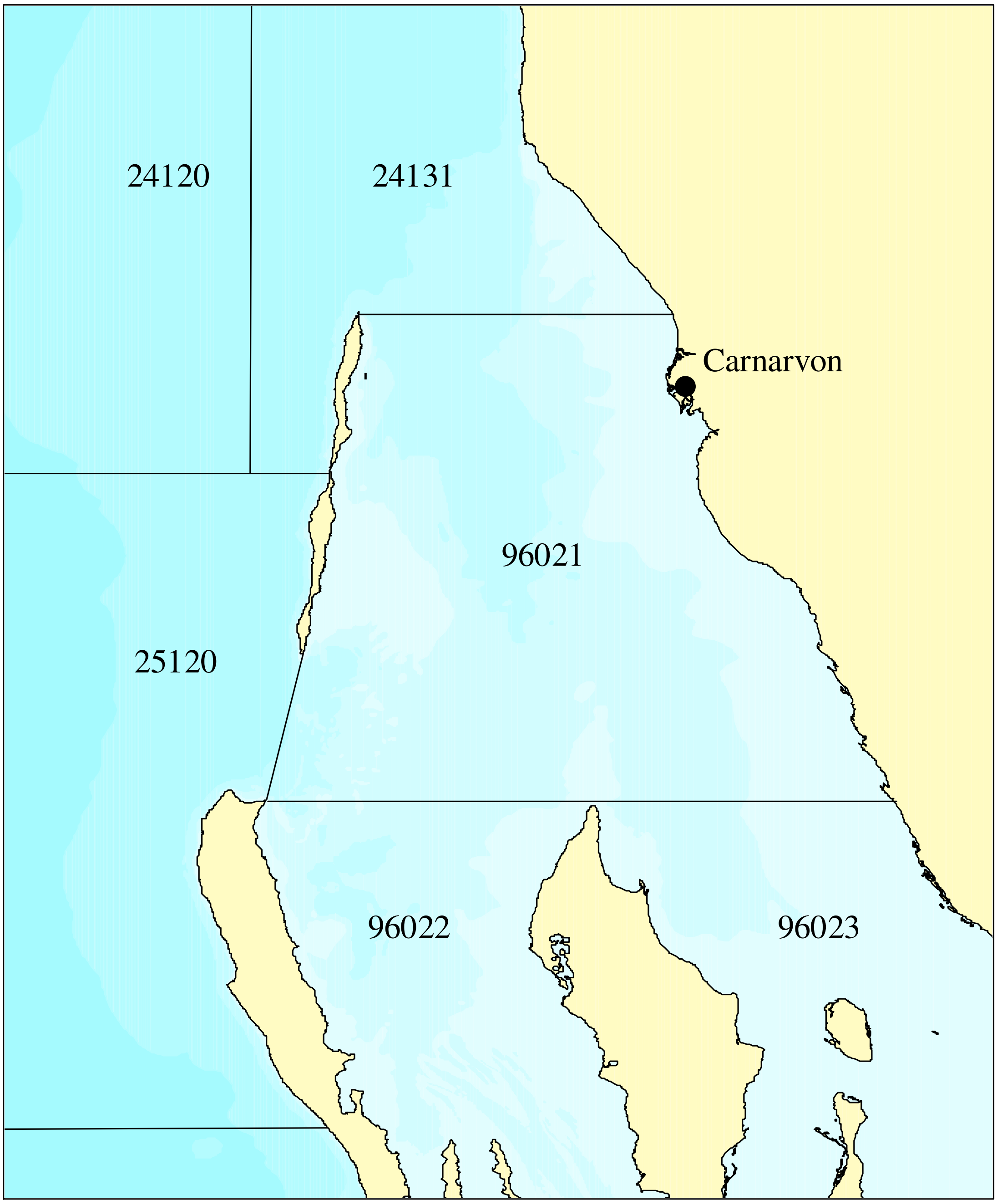

Figure 9.2 Block numbers used by the Department of Fisheries WA catch and effort statistics (CAES) database for Shark Bay.

9.2.2 Results and discussion

CAES indicates that total catch (tonnes) of blue swimmer crabs in Shark Bay has steadily increased from 1991, reaching a peak of 557.8 tonnes in 2002 (Table 9.1). Potting and trawling contribute the vast majority of blue swimmer crabs catches in Shark Bay. While potting has shown a steady increase, since 1998 trawl catches have fluctuated. This may in part reflect variations in the availability of other trawl caught species in the corresponding year, as trawlers often land more crabs when the target species catch (i.e. prawns, scallops) decreases. Trawl fishers must freeze their crab, which occupies valuable freezer space, and makes trawl caught crabs less appealing than trap caught crabs that are sold fresh. A similar situation is evident in trawl catches of blue swimmer crabs in Moreton Bay, Queensland, during times when scallop and prawn catches are low (Sumpton *et al.,* 1999).

Table 9.1 Annual catch (tonnes) by method, with effort (no. trap lifts) and CPUE (kg/trap lift) for vessels using traps, in the Shark Bay Crab Fishery 1991 – 2003.

Year	Trapping	Trawling	Drop Net	Fish Trap	Wading	Total	N°. trap lifts	CPUE (kg/trap lift)
1991	18.6	9.2	0	0	0	27.8	18240	1.0
1992	22.7	9.3	0	0	0	32.0	20274	1.1
1993	20.5	25.0	0	0.05	0	45.6	21212	1.0
1994	31.8	44.9	3.8	0	0	80.5	27825	1.1
1995	30.3	39.7	3.9	0	0	73.9	23565	1.3
1996	34.0	33.3	0.9	0	0	68.2	38050	0.9
1997	33.5	57.7	0	0	0	91.2	35791	0.9
1998	92.1	86.3	0	0	0	178.3	100174	0.9
1999	154.8	25.7	0.776	0	0	181.3	133078	1.2
2000	238.4	24.7	0	0	0	263.1	140275	1.7
2001	270.4	76.7	0	0	0.1	347.2	200342	1.4
2002	398.3	159.5	0	0	0	557.8	228750	1.7
2003	433.7	91.4	0	0	0	525.1	279800	1.6

Total catches of blue swimmer crabs increased dramatically in 1998 with the introduction of the Experimental Carnarvon Crab Trap Fishery (Table 9.1), which is reflected by the increase in trap catches (Fig. 9.3). Similarly CPUE has also increased since 2000 as fishers have refined their fishing practices and become more knowledgeable and familiar with blue swimmer crab stocks in Shark Bay.

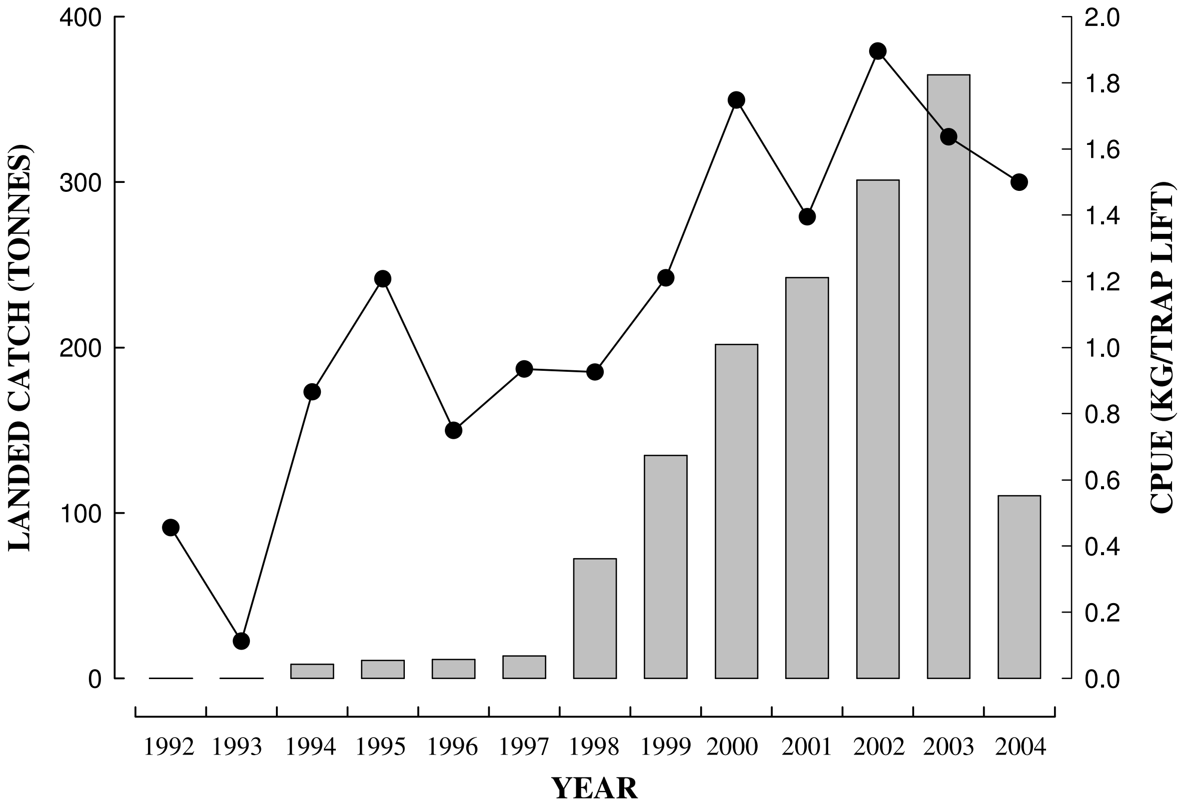

Figure 9.3 Annual trap catches (tonnes) and CPUE (kg/trap lift) in the Experimental Carnarvon Crab Trap Fishery 1991 – 2004. Note that the catches in 2004 are for only the first half of the year.

To investigate the seasonality in both trap and trawl catches, data was extracted from CAES by month and year. Although the Experimental Carnarvon Crab Trap Fishery commenced in 1998, blue swimmer crabs were not targeted consistently throughout the year using traps until 1999

(Fig. 9.4). Since 1999, monthly trends in CPUE for traps have varied. There is a general trend of CPUE increasing from low levels in January and February to reach peaks in April/May before gradually declining until August. CPUE in the final months of the year is generally low, particularly in December but also in January, when many operators stop for the Christmas break. In 2003 there was increased catch in January and February and hence an earlier peak in CPUE in March. Annual trends in catches follow the same trends as CPUE and secondary peaks in catches were recorded in October/November in most years (Fig. 9.4). Sarada (1998) working on the Calicut Coast, India, with a closely related species *Portunus sanguinolentus* states that duration as well as peak fishing period fluctuate widely from year to year, but in general the season was October to May. Sumpton *et al.* (1999) describe similar patterns in CPUE in blue swimmer crab catches in Moreton Bay, Queensland. Winter represents a period of reduced growth and feeding in blue swimmer crabs, presumably reducing the movement of crabs and their attraction to baited traps (Sumpton *et al.*, 1999). Trawl catches display large fluctuations on a month-by-month basis, peaks in trawl landings of crabs occur between March and June (Fig. 9.4).

CAES data was also used to determine the effect of increasing the number of traps per license in the Experimental Carnarvon Crab Trap Fishery from 200 to 300 (Table 9.2), which occurred at the start of the financial year 2001/02. An ANOVA was performed using the CAES data, in Microsoft® S-Plus, with the only interaction considered being those of year × vessel and month × vessel. It was not possible to include other interactions (or a location factor) due to confounding effects that would not allow an estimate for “pot restriction”.

Table 9.2 ANOVA for catch rate of blue swimmer crabs using traps in Experimental Carnarvon Crab Trap Fishery (block 96021 and 24131). Data was restricted to trapping method only (*i.e.* drop net method was not included) for the years 1998 onwards (start of the Experimental Carnarvon Crab Trap Fishery).

Factor	df	SS	MS	F	*P*
Year	6	326.7	54.5	6.2	< 0.01
Vessel	5	199.7	39.9	4.5	< 0.01
Month	11	270.8	24.6	2.8	< 0.01
Trap restriction	1	17.1	17.1	1.9	0.17
Year ×Vessel	22	338.0	15.4	1.7	0.03
Month × Vessel	38	273.0	7.2	0.8	0.77
Residuals	174	2699.7	15.5		

All three factors, i.e. year, month and vessel, had a significant effect upon catch rates of blue swimmer crabs ($P < 0.01$) (Table 9.2). The interaction between year and vessel was significant ($P < 0.05$). ANOVA showed that increasing the number of traps per license from 200 to 300 did not have a significant effect on the catch rate of blue swimmer crabs ($P = 0.38$). The LSM for catch rate in individual months reflect the monthly trends already described for catch and CPUE. Catch rates were highest between February and June and lowest in December and January (Table 1, Appendix V). Catch rates were lowest in 1998, the first year of the trap fishery. Catch rates peaked in 2002 and have remained high although declining slightly in 2003 (Table 2, Appendix V). Increased catch rates in 2000, 2002 and 2003 despite increases in effort, indicate either better recruitment or fishers finding new grounds or becoming more efficient. While these results indicate that the increase in trap number does not appear to have a significant impact upon catch rate, little can be said about the long-term impact of trap increases because for accurate assessment of the effects of increased exploitation levels a long-term comprehensive dataset is required. However, given the extent of crab stocks in Shark Bay it is unlikely that the effects of additional effort will be evident for some time. Furthermore, during this period, although fishers were permitted to use 300 traps, some fishers continued to use 200 traps due to the logistics of finding additional fishing grounds and obtaining additional traps as well as space limitations on some vessels.

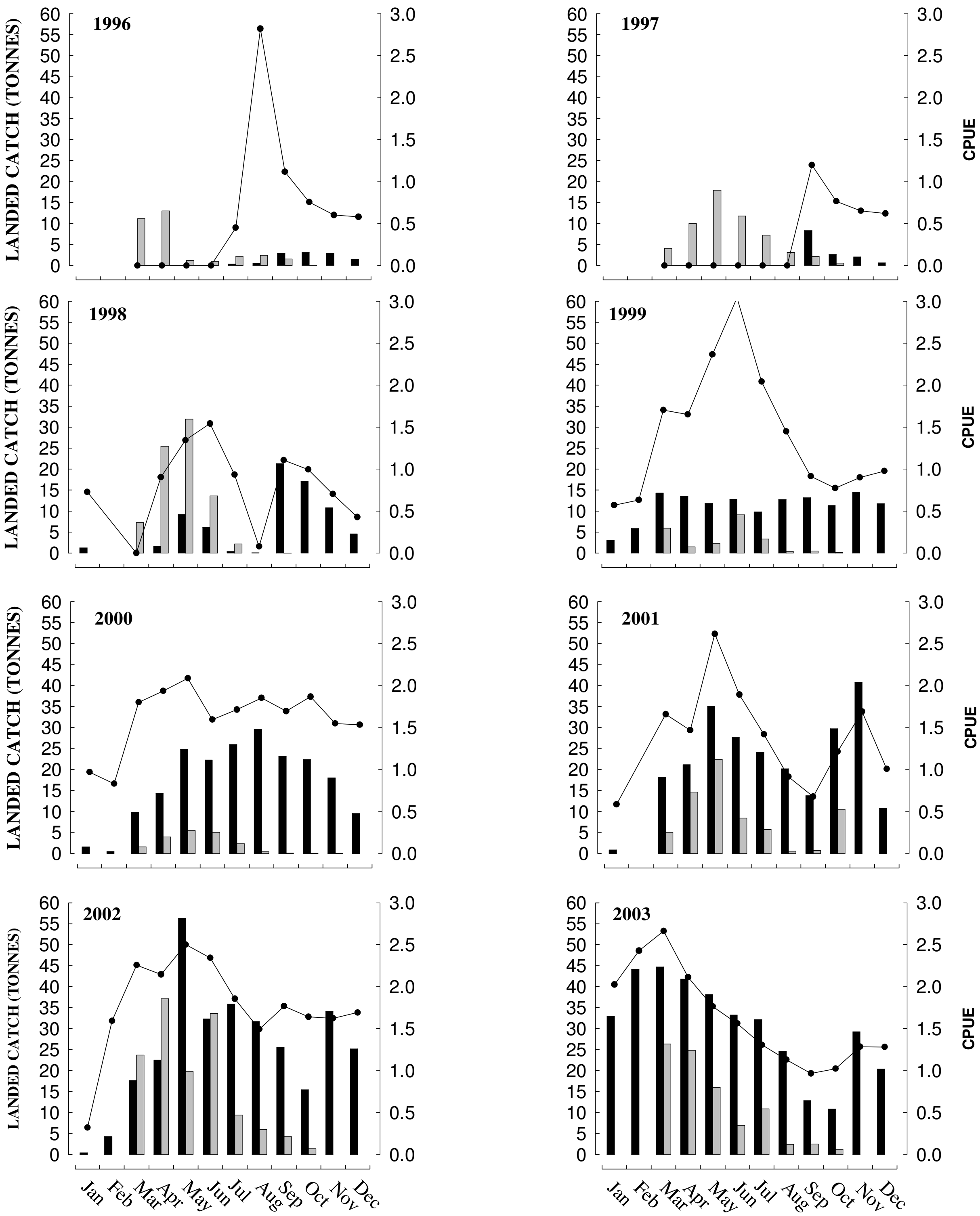

Figure 9.4 Comparison of monthly catches (tonnes) for potting (■) and trawling (■) and catch per unit effort (kg/trap lift), in the Experimental Carnarvon Crab Trap Fishery, 1996 2003.

9.3 VOLUNTARY LOGBOOK DATA

9.3.1 Methods

Catch and effort of blue swimmer crabs have been recorded in the CAES database since July 1975. While this data is useful information for monitoring the fishery, its' application is restricted by a lack of spatial resolution. Therefore, a crab research logbook was specifically designed. The logbook was not intended to replace the existing CAES logbook but to act as a supplement providing more detailed and accurate information for calibration and interpretation of historical data. The daily research logbook gives more detail on daily catches, discards (undersize, egg bearing, other), by-catch, average size of crabs (male and females) caught per week, number of traps and more detailed spatial and temporal information (Fig. 9.5). Participation in the logbook program was initially voluntary but has been made a condition of license for the participants in the Experimental Carnarvon Crab Trap Fishery in 2004.

Sufficient information was provided in the logbook data to analyse: Catch rate of legal size crabs (kg/trap lift), catch rate of berried crabs (numbers/trap lift) and catch rate of sub legal sized crabs (numbers/trap lift).

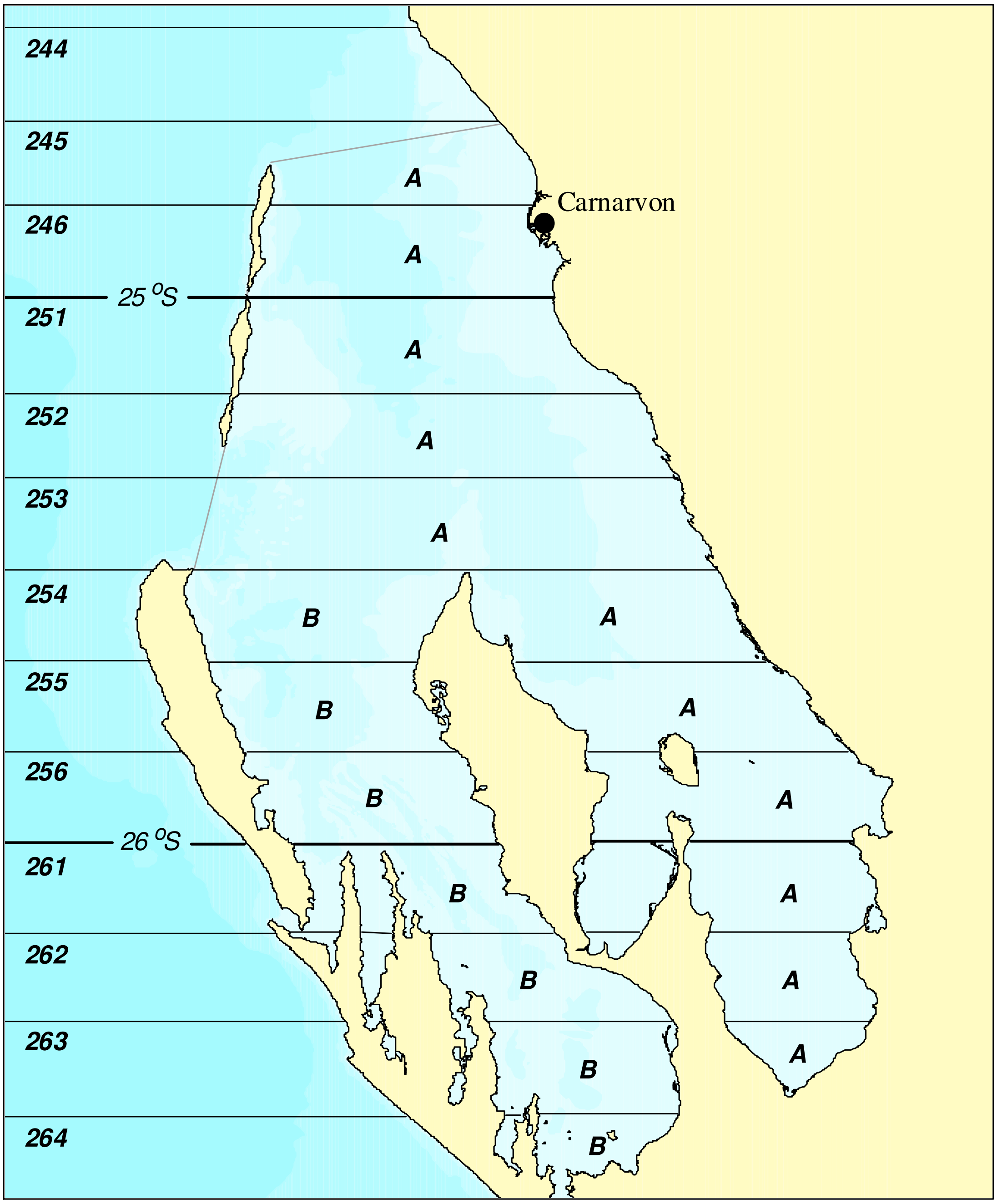

Figure 9.5 Map showing spatial blocks used by commercial fishers to record catches in the voluntary logbook program. For each numbered transect, A and B define sub-transects that increase the spatial resolution of the catch and effort data.

Data collected from the voluntary logbook program is stored electronically in an Access database. To eliminate discrepancies, which may have occurred, logbook data was validated with the relevant CAES data. Where significant discrepancies occurred between the two datasets that could not be corrected by checking the originals of both the logbook and the CAES, the corresponding data was omitted from the analysis. The data were analysed using ANOVAs of catch rates that were log-transformed to remove the skewness in the catch rate distribution. The following factors were examined: month, depth and vessel. It was not seen beneficial to include area/transect in the ANOVA. Not all logbooks were completed with transect information and hence, were lost from the analysis when including an area factor, the resulting R^2 was smaller than when these data were included but omitting transect/area as a factor.

9.3.2 Results and discussion

Distribution of catch

Total catch in the fishery is not distributed evenly amongst the spatial blocks designated in the blue swimmer crab logbook (Fig. 9.5). In fact only a very small portion of the total area of Shark Bay is fished. In 2000 and 2001 the majority of the commercial catch, approximately 70%, was caught in transect 246. Transect 246 is directly west of Carnarvon and east of Bernier Island, this zone is easy to access from the port of Carnarvon and appears to have an abundant blue swimmer crab population. It is important to note that currently not all fishers participate in the voluntary logbook program, therefore, catches recorded in CAES were higher than catches recorded in logbooks in every month for all years (Fig. 9.6). Also, CAES data included trawling data as well. Generally, catches for both logbook and CAES increased from very low levels in January to peaks usually between March and June before declining gradually to low levels in December (Fig. 9.6). The declining trends in catch in the latter part of the year were often interrupted by a slight increase in catch during October/November. Therefore caution must be taken when examining catch trends based on voluntary logbook data, as trends evident may not be representative of the fishery as a whole due to logbooks not being consistently recorded.

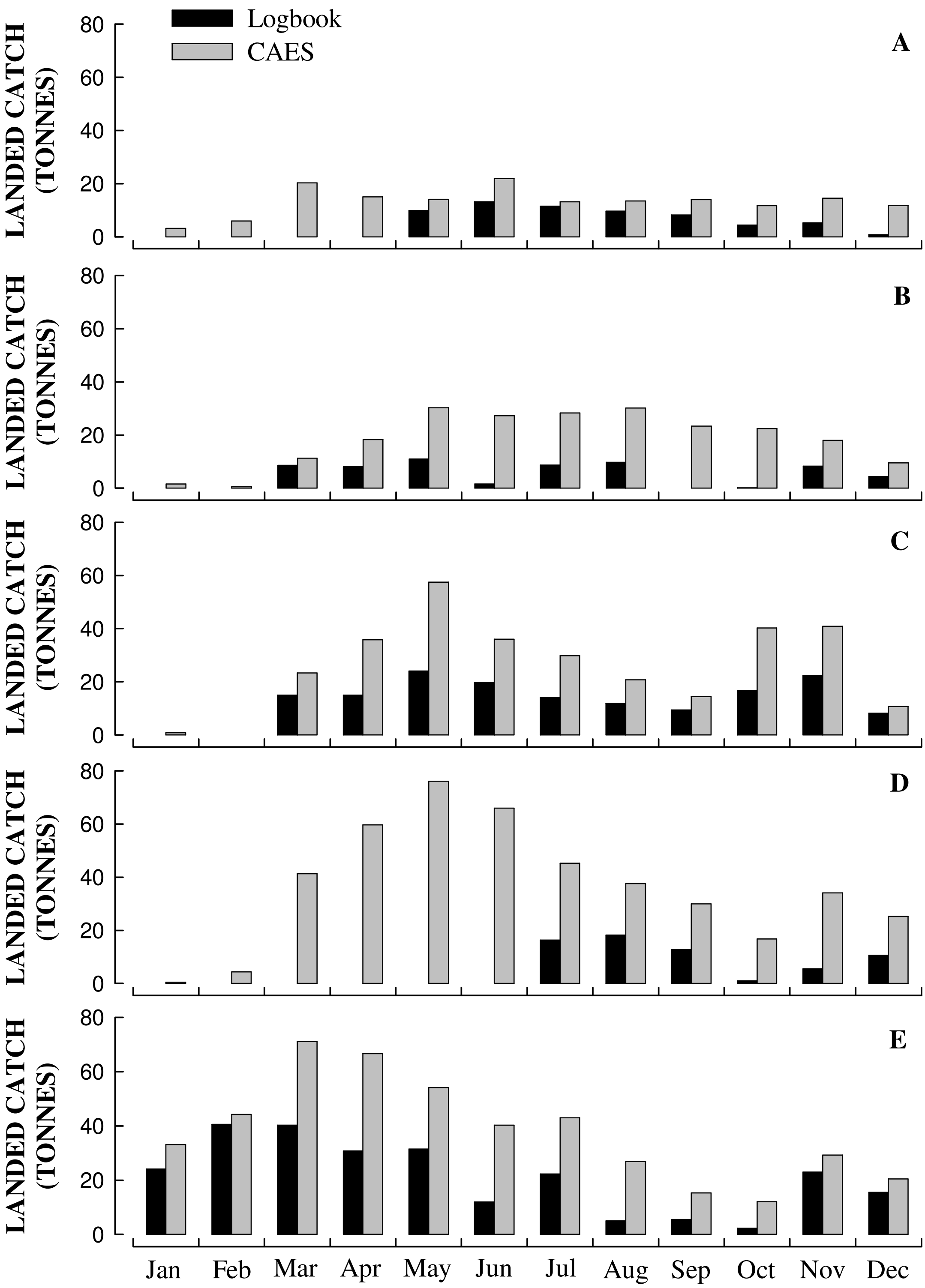

Figure 9.6 Comparison of total catch (tonnes) of blue swimmer crabs reported in CAES returns and voluntary logbook for 1999 – 2003. (A) 1999 (B) 2000 (C) 2001 (D) 2002 (E) 2003.

Legal size

All of the factors tested had a significant effect on the catch rate of legal size (≥ 135mm CW, non berried) crabs as reported in logbooks ($P \leq 0.02$) (Table 9.3). Vessel was the most influential factor affecting catch rate, followed by month, depth and year respectively. Vessel was an influential factor because different vessels fished different areas. The interaction between year and month was also significant ($P < 0.01$). Catch rate of legal sized crabs was highest in the two intermediate depth zones (10 – 15m and 15 – 20m) and was lowest in depths > 20m (Table 3, Appendix V).

The highest LSM for catch rates of legal sized crabs was recorded in March 2003, however for most years catch rate was highest in May/June (Table 4, Appendix V). The lowest catch rates reported in logbooks were generally recorded between July and November. Catch rates of legal sized crabs were lowest in 2002 and highest in 2003 (Table 4, Appendix V). This does not correlate with the CPUE calculated from CAES data (Table 9.1) as there were no logbook data in the first half of the year in 2002 when catch rates are highest (Fig. 9.6). These CAES data showed that CPUE was low in 1999 (1.2 kg/trap lift) displayed a sharp increase, peaking in 2000 and 2002 (1.7 kg/trap lift) and declined only slightly in 2003 (1.6 kg/trap lift) (Table 9.1). Another explanation for this discrepancy in the two datasets may be that the voluntary logbooks were only introduced into the Carnarvon fishery in 1999 and at least initially not all of the fishers were participating in the logbook program. Secondly, the accuracy of logbook entries may also have improved over time. Thus these early logbook entries must be viewed with caution as inaccuracies or omissions in the entries may skew the dataset giving biased results.

Berried crabs (numbers)

The only factor that did not significantly affect the catch rate of berried crabs was depth ($P <$ 0.01) (Table 9.4). The LSMs for each month of the logbook program indicate that the catch rate of berried crabs is highest in July to September for each year except 2000 when they were highest in May (Table 5, Appendix V).

Table 9.3 ANOVA of the log transformed catch rate of legal size (non-berried) crabs (May 1999 – Dec 2003) ($R^2 = 0.46$).

Factor	df	SS	MS	F	*P*
Year	5	184.00	36.8	2.68	0.02
Month	11	3665.60	333.20	24.30	< 0.01
Depth	4	312.60	78.20	5.70	< 0.01
Vessel	5	3828.00	765.60	55.82	< 0.01
Year × Month	36	12937.50	359.40	26.20	< 0.01
Residuals	1822	24987.50	13.70		

It should be noted however, that 2000 is the only year with data for the months February to May. The lowest catch rates of ovigerous females were recorded in various months throughout different years but very rarely in winter. In contrast, previous studies in Shark Bay have suggested that spawning is consistent throughout the year (Potter *et al*., 2001) however the majority of previous work has been conducted in the southern region of Shark Bay that has vastly different environmental conditions such as higher water temperatures and salinities both of which have been suggested to be important in determining the duration and timing of reproductive cycles (Batoy *et al*., 1987). Also the methods used to collect crabs varied between the studies, which may also account for some of the differences.

Table 9.4 ANOVA of the log transformed catch rate of berried crabs.

Factor	df	SS	MS	F	*P*
Year	5	652.90	130.60	11.98	< 0.01
Month	11	457.50	41.60	3.81	< 0.01
Depth	4	39.50	9.90	0.90	0.46
Vessel	4	257.20	64.30	5.90	< 0.01
Year × Month	18	755.70	42.00	3.85	< 0.01
Residuals	604	6586.00	10.9		

Undersize crabs (numbers)

All of the factors tested except year had a significant effect on the catch rate of undersize crabs ($P < 0.01$) (Table 9.5). Catch rates of undersize crabs were highest in May, June and August (Table 6, Appendix V). This period occurs slightly before that of the highest catch rates of berried crabs (July to September). One explanation is that the larvae of the previous year's spawning are by April to July, at just below the legal commercial size (≥ 135mm CW) and are entering the commercial traps having taken approximately a year to reach this size (Melville-Smith *et al*., 2001). While Potter *et al*. (2001) suggested that spawning and therefore recruitment to the fishery in Shark Bay is continuous throughout the year, data presented here suggest that there are periods when recruitment and spawning are above and below average. The contrasts of each depth range used in the logbook program also indicated that undersize crabs were more prevalent in depths of 0 – 5 meters (Table 9, Appendix V). Previous research has also suggested that early growth of smaller individuals occurs in shallow inshore areas and that a high proportion of small crabs are found in these regions (Sumpton *et al*., 1994; Potter *et al*., 2001).

Table 9.5 ANOVA for the log transformed catch rate of undersized crabs (May 1999 – Dec 2003).

Factor	df	SS	MS	F	*P*
Year	4	12.30	3.10	0.29	0.88
Month	11	2612.00	237.50	22.45	<0.01
Depth	4	360.5	90.10	8.52	<0.01
Vessel	4	204.70	51.20	4.84	<0.01
Year × Month	16	2627.80	164.20	15.53	<0.01
Residuals	582	6155.90	10.6		

9.4 COMMERCIAL CATCH MONITORING

9.4.1 Introduction

The volunteer logbook was supplemented by a commercial catch monitoring system, where Department of Fisheries research staff board commercial fishing vessels seasonally to record size composition, sex ratio, breeding condition of animals and various environmental factors, such as salinity and water temperature. Catch monitoring commenced in May 1999 and with the exception of 1999, catch monitoring has been conducted seasonally (once every three months) since commencement. The locations of trap lines during catch monitoring surveys were dependent on the areas being fished by the commercial fishers during 1999 – 2003 (Fig. 9.7 – 9.11) therefore the results may not be indicative of catch trends over an entire year and the whole area fished.

Data collected from catch monitoring is stored electronically in an Access database. The catch rates (number/trap lift) of a number of categories were considered in the analysis of the length monitoring data:

- Legal size male crabs (≥ 135mm CW)
- Legal size female crabs (≥ 135mm CW)

- Soft crabs
- Sexually mature females ($CW_{50} > 92.4$mm CW)
- Sexually mature males ($CW_{50} > 115.1$mm CW)
- Berried female crabs
- Undersize crabs (< 135mm CW)

The sex ratio of catches was also analysed.

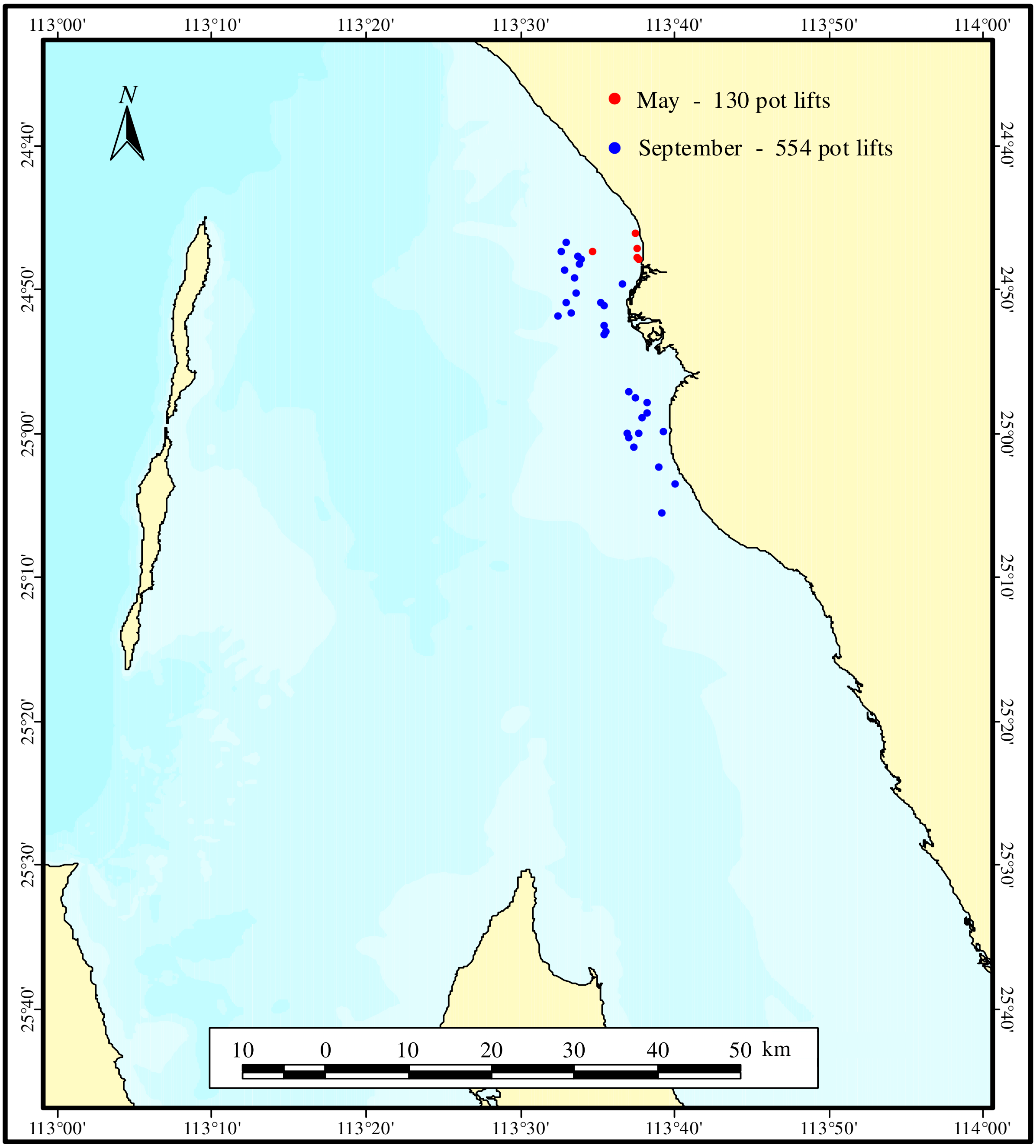

Figure 9.7 Locations of trap lines on commercial catch monitoring surveys in the Canrnarvon Experimental Crab trap Fishery during 1999.

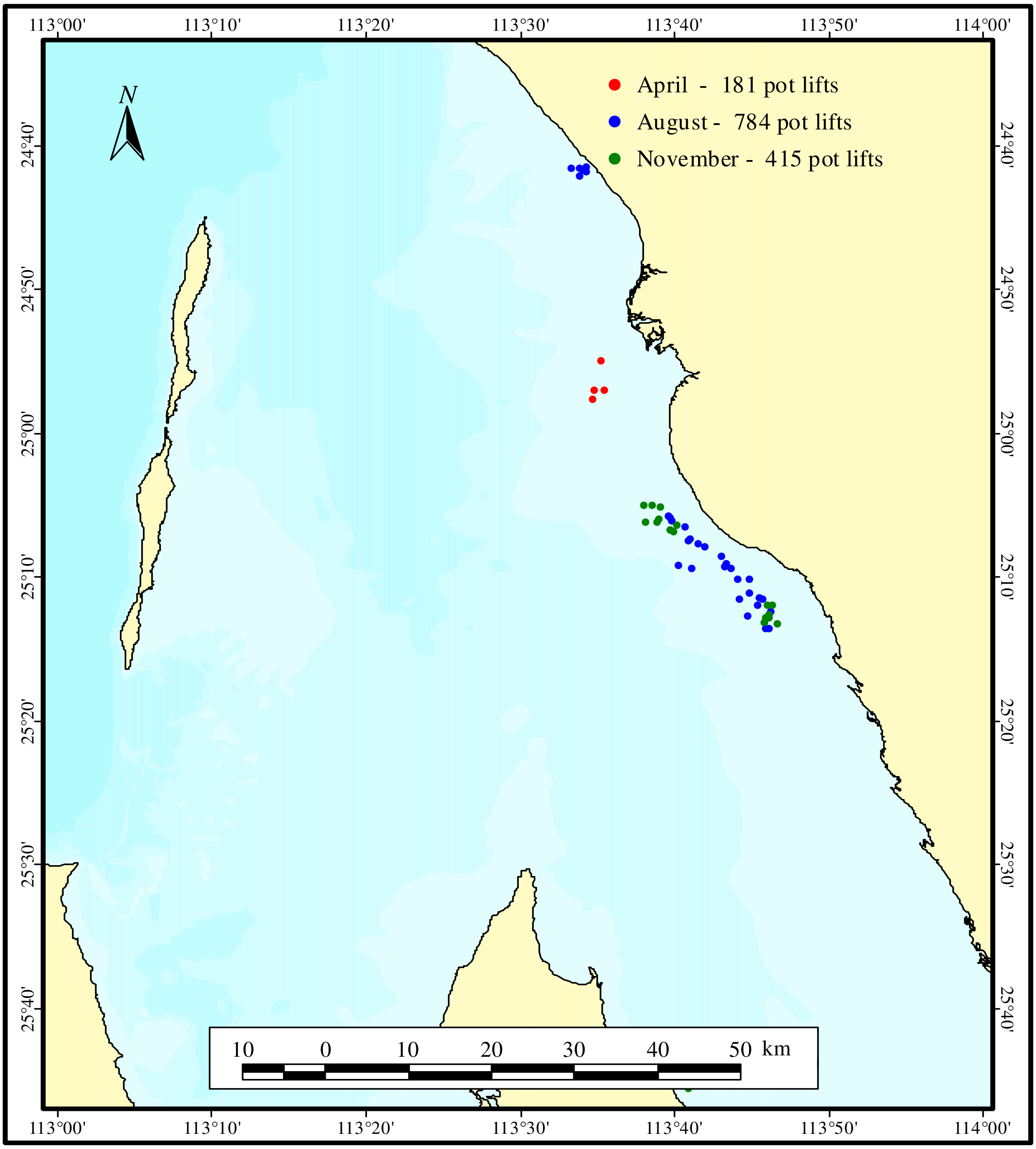

Figure 9.8 Location of trap lines on commercial catch monitoring surveys in the Experimental Carnarvon Crab Trap Fishery during 2000.

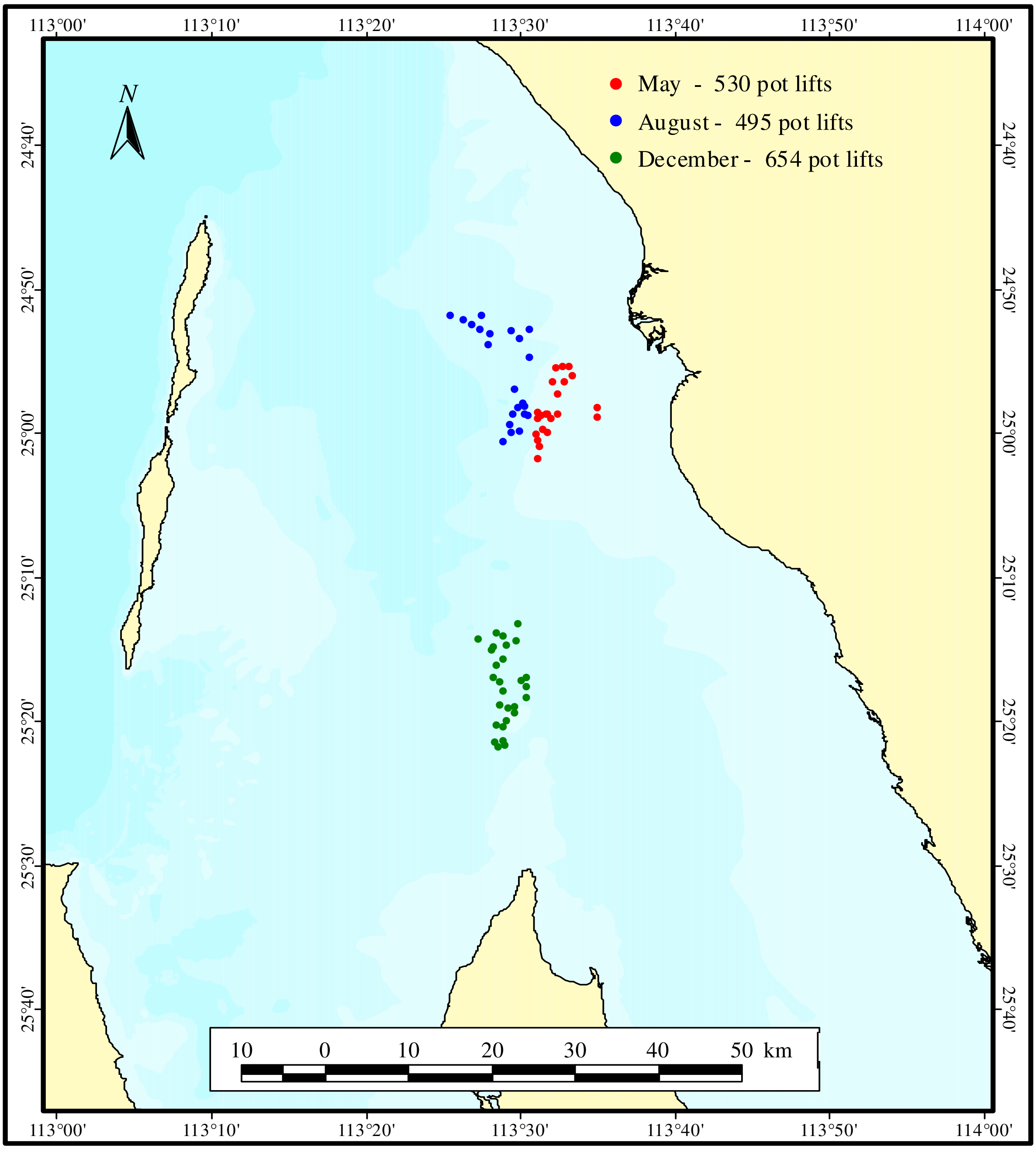

Figure 9.9 Locations of trap lines on commercial catch monitoring Surveys in the Experimental Carnarvon Crab Trap Fishery during 2001.

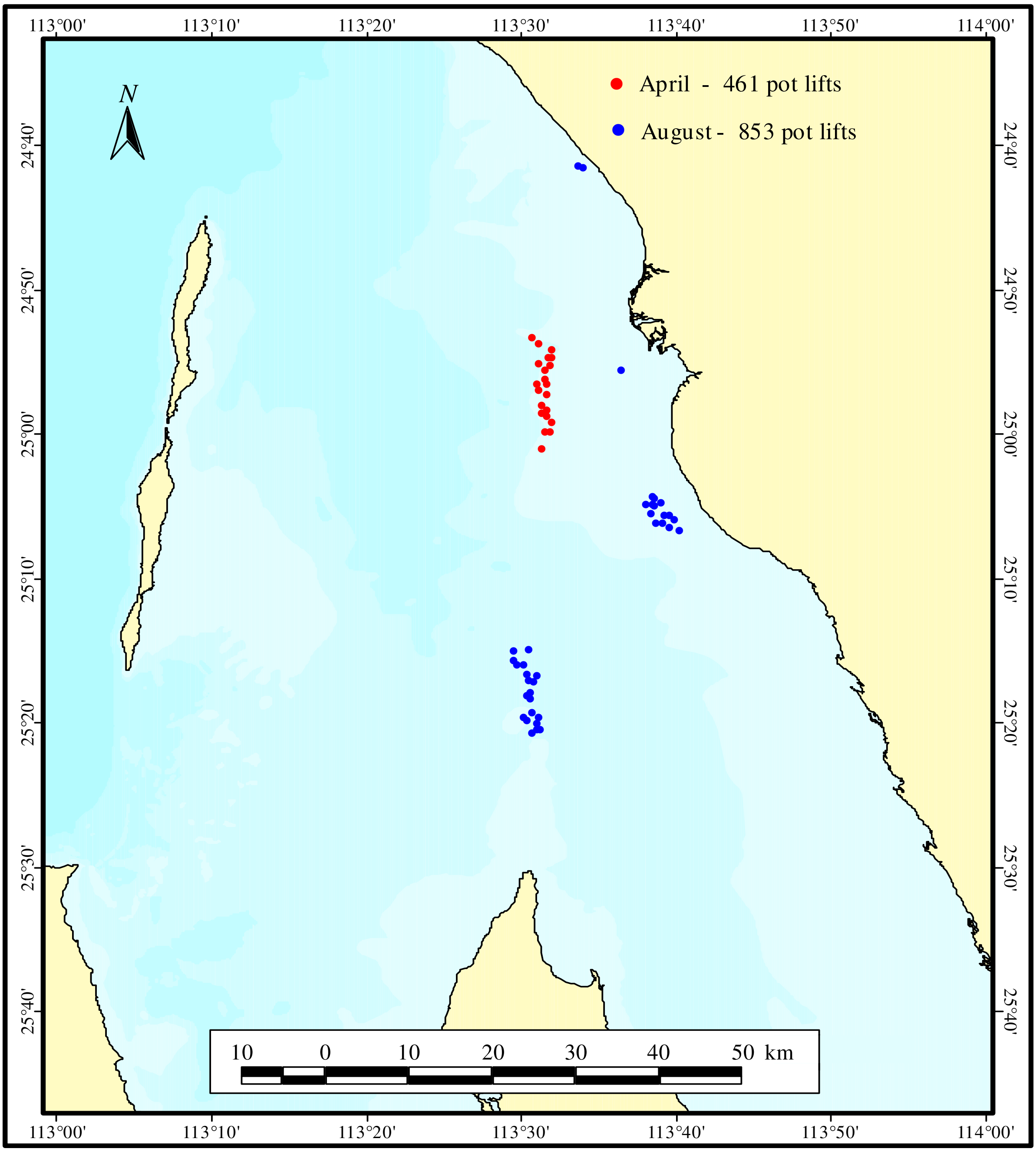

Figure 9.10 Locations of trap lines on commercial catch monitoring Surveys in the Experimental Carnarvon Crab Trap Fishery during 2002.

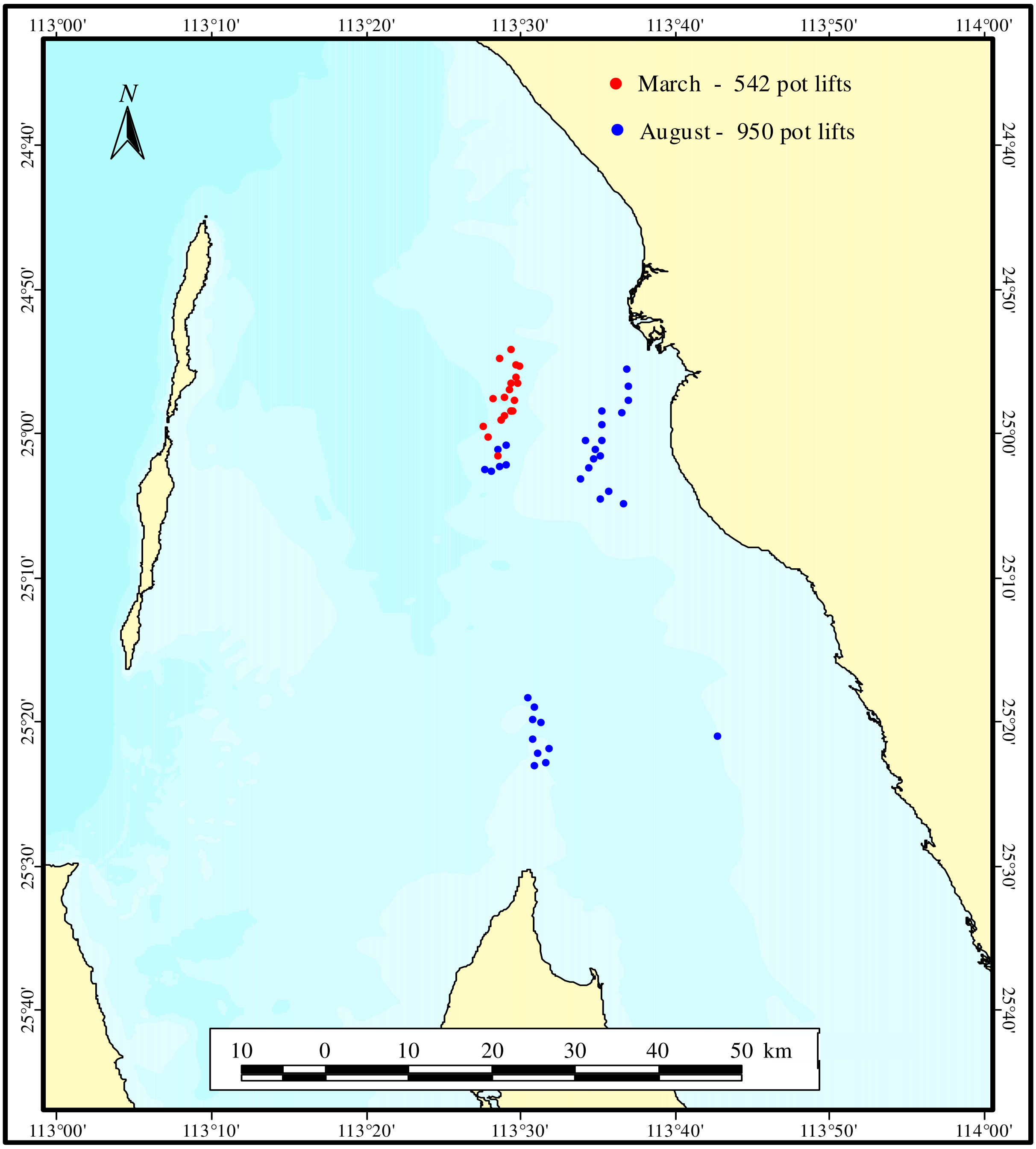

Figure 9.11 Locations of trap lines on commercial catch monitoring Surveys in the Experimental Carnarvon Crab Trap Fishery during 2003.

The catch rate of each of these categories was analysed by trap line, using ANOVA with the number of traps comprising the line weighting the analysis. The sample months were combined into season, as sample months varied between years, which may have caused an unbalanced design when considering year. Combining the various months into season creates a more balanced design to examine the changes between years. Season was defined as the following:

Autumn – March, April and May

Spring – August and September

Summer – November and December

9.4.2 Results and discussion

Catch rates of legal size crabs

ANOVA of the catch rates of legal size male crabs (≥ 135mm) indicated that all factors tested had a significant effect on the catch rates of legal size crabs ($P < 0.01$) (Table 9.6). The largest mean square was recorded for season. Comparing the LSMs for years (Table 8, Appendix V) indicates that catch rates were lowest in 1999, highest in 2000 and 2001 and declined consistently in subsequent years. While the low catches in 1999 can be partly attributed to the fact that this was a developmental year of the fishery when fishers were learning how to attain the best catches of crabs, between 1999 and 2001, fishers operated in different locations therefore, apparent differences between years may be due to different areas being fished. While CAES data (Fig. 9.3, section 9.2.2) also indicate that CPUE spiked in 2000 (1.7 kg/trap lift) from a relatively low level in 1999 (1.2 kg/trap lift), the general trend in CPUE in the subsequent years is upward. The increasing catches reported in CAES must therefore be attributed to an increasing relative component of females. LSMs of season, latitude and depth indicated that catch rates of legal size male crabs were highest in autumn (Table 9, Appendix V). Similarly

CAES data (Fig. 9.4, Section 9.2.2) indicate that CPUE was highest in the autumn months (May/June). Previous studies in Moreton Bay, Queensland, suggest that blue swimmer crabs are more abundant in samples in summer and autumn when large males are the targets of recreational and commercial fisheries (Sumpton *et al.,* 1994; Sumpton *et al.*, 1999). Seasonal catches have also been reported in a number of other crab fisheries (Sarada, 1998; Potter *et al.*, 2001).

ANOVA of the catch rates of legal size (non-berried) female crabs (≥ 135mm) indicated that year, season and depth had significant effects on the catch rates of legal size females ($P < 0.05$) while the effect of latitude was not significant ($P > 0.5$) (Table 9.7). The largest MS was recorded for season, which is consistent with males. LSMs for years (Table 10, Appendix V) indicate that catch rates for legal sized females show a general increasing trend to 2001 before declining to 2003, with an increase in 2004 (Table 8, Appendix V). This is a similar trend as legal sized males except for 2004. Catch rates of legal sized females were lowest in 1999 and highest in 2004. CAES data (Fig. 9.3, section 9.2.2) also indicates that CPUE showed an overall increase throughout that period. LSMs of season, latitude and depth indicate that catch rates of legal size female crabs were highest in spring (Table 11, Appendix V). CAES data (Fig. 9.4, Section 9.2.2) indicate that CPUE generally starts to increase in spring following minimum values in winter.

The LSMs for the contrasts of the Season × Latitude × Depth interaction show that the highest catch rates of legal size male crabs were usually recorded in different water depths in each season (Table 9, Appendix V). For example, the highest catch rates of legal size males were recorded in 5 – 10m during autumn, 15+m in spring and 10 – 15m in summer. In contrast, the highest catch rates of legal size females in each of the three seasons were recorded in 15+m (Table 11, Appendix V). For legal size males there is generally little consistency between the catch rates in different latitudes however the high catch rates recorded for legal size (non-berried) females in spring in the majority of latitudes coincides with females moving into shallow water to spawn.

Table 9.6 ANOVA of the catch rates of legal size male crabs (≥ 135mm) from the catch monitoring program ($R^2 = 0.63$).

Factor	df	SS	MS	F	*P*
Year	5	119.3	23.9	10.01	< 0.01
Season	2	590.1	295.1	123.85	< 0.01
Latitude	3	97.8	32.6	13.69	< 0.01
Depth	3	84.3	28.1	11.8	< 0.01
Latitude × Depth	7	77.3	11.0	4.64	< 0.01
Season × Latitude × Depth	11	176.6	16.1	6.74	< 0.01
Residuals	285	679.0	2.4		

Table 9.7 ANOVA of the catch rates of legal size (non-berried) female crabs (≥ 135mm) from the catch monitoring program ($R^2 = 0.54$).

Factor	df	SS	MS	F	*P*
Year	5	20.9	4.2	2.76	0.02
Season	2	121.9	61	40.29	< 0.01
Latitude	3	2.7	0.9	0.6	0.61
Depth	3	19.5	6.5	4.29	0.01
Latitude × Depth	7	11.8	1.7	1.12	0.35
Season × Latitude × Depth	11	31	2.8	1.86	0.04
Residuals	285	431.2	1.5		

Proportion of male and female crabs

The proportions of males and females in the catches varied with season. However, with the exception of two catch monitoring occasions, males dominated the catches (Table 9.8). Sumpton *et al.* (1999) reported that male and female sex ratios of blue swimmer crab catches in Moreton Bay were in the order of approximately 3:1. In contrast, trawl catches of *P. sanguinolentus*, a closely related species, on the Calicut coast off India do not show a regular pattern of dominance of one sex over the other (Sarada, 1998). However, sex ratios in many crab fisheries are heavily skewed towards males, this does not necessarily reflect an inequality in the sex ratios of the stocks but is due to differences in the catchabilty of males and females (Miller, 1990; Montaño Ferrer, 1997) with males generally more prone to capture in traps (Montaño Ferrer, 1997; Potter and de Lestang, 2000). It is difficult to obtain a representative population sample using commercial fishing, as due to market demands fishers generally target males of a certain size therefore samples are heavily biased. Secondly, the catchability of the two sexes changes throughout the year as a result of varying levels of vulnerability to baited traps that occur during phases of the moult and reproductive cycles (Sumpton *et al*., 1999). There are variations in the proportions of females in the catch throughout the year, with the lowest numbers of females in autumn and summer and highest numbers in spring. Mature *P. pelagicus* display sexual segregation at times (Thomson, 1951; Weng, 1992) and females are more abundant in shallow areas, particularly on the tops of sandbanks (Potter *et al*., 1986). Females are known to require a sandy substrate for successful egg extrusion and migration of females to sandbanks for egg extrusion may be partly responsible for the variation of sex ratios especially prior to spawning (Sumpton *et al*., 1994).

Table 9.8 Proportion (%) of males and females in catch from the catch monitoring program.

Month	% Male	% Female
May 99	24	76
Sept 99	64	36
Apr 00	86	14
Aug 00	62	38
Nov 00	85	15
May 01	87	13
Aug 01	53	47
Dec 01	89	11
Apr 02	96	4
Aug 02	73	27
Nov 02	56	44
Mar 03	81	19
Aug 03	73	27
Nov 03	49	51

Sexually mature females

Year, season and depth had significant effects on the catch rates of sexually mature females ($P \leq 0.01$) (Table 9.9). In fact immature females were rarely caught during the catch monitoring program (Figs. 9.12 – 9.16), in part due to the traps used by commercial fishers that are designed to allow the escape of juvenile crabs. The size of 50% sexual maturity of female blue swimmer crabs in Shark Bay is 92.0mm CW (de Lestang *et al.,* 2003c). Comparing the contrasts, catch rates of sexually mature female crabs were highest in 2001 and lowest in 1999 (Table 12, Appendix V).

Catch rates of sexually mature females were more consistently higher in the different regions of the bay in spring, corresponding with the breeding period when females are most active (Table 13, Appendix V). Although the single highest catch rate of sexually mature females was recorded in 0 – 5m during summer, the catch rates in shallow waters (0 – 5m) in spring was generally high, which corresponds with the shoreward movement of crabs for spawning (Table 13, Appendix V).

Table 9.9 ANOVA of catch rates of sexually mature female crabs (≥ 92.4mm CW) from the catch monitoring program ($R^2 = 0.40$)

Factor	df	SS	MS	F	*P*
Year	5	48.20	9.60	3.18	0.01
Season	2	299.50	149.8	49.46	< 0.01
Latitude	3	9.50	3.20	1.04	0.37
Depth	3	40.5	13.5	4.46	< 0.01
Latitude × Depth	7	26.40	3.80	1.24	0.28
Season × Latitude × Depth	11	145.60	13.20	4.37	< 0.01
Residuals	285	862.90	3.00		

Sexually mature males

All of the factors tested affected the catch rates of sexually mature males (Table 9.10). A larger portion of males than females were not sexually mature (Figs. 9.17 – 9.21), with < 5% of the total catch of males under the size of 50% sexual maturity (97.0mm [de Lestang *et al.*, 2003c]) while < 1% of the total catch of females were under the size at sexual maturity. This may in part be due to the larger size at sexual maturity of males or differences in behavior that generally make males more susceptible to capture in traps (Sumpton *et al.*, 1994). Seasonal changes in the sex ratios can be attributed to behavioral changes in males and females and the effects of fishing (Potter *et al.*, 1983).

Table 9.10 ANOVA of the catch rates of sexually mature males (≥ 115.1mm CW) from the catch monitoring program ($R^2 = 0.67$).

Factor	df	SS	MS	F	*P*
Year	5	150.40	30.10	11.36	<0.01
Season	2	628.00	314.00	118.56	<0.01
Latitude	3	128.80	42.90	16.21	<0.01
Depth	3	97.30	32.40	12.24	<0.01
Latitude × Depth	7	82.50	11.80	4.45	<0.01
Season × Latitude × Depth	11	195.50	17.80	6.71	<0.01
Residuals	285	754.80	2.60		

Catch rates of sexually mature males were highest in 2001 and lowest in 1999, the same pattern recorded for sexually mature females (Tables 12, 14, Appendix V). The highest catch rates of sexually mature males were recorded during autumn in all water depths which contrasts with the trends shown by mature females (Table 15, Appendix V). However in spring, the catch rates of sexually mature males showed the same trends as mature females, with the highest rates recorded in 15+m, but also in the shallows, corresponding with the inshore breeding activity.

Berried females

All of the factors except latitude had a significant effect on the catch rate of berried female crabs with the highest mean square value recorded for season ($P \leq 0.02$) (Table 9.11). Catch rates of berried females were highest in 2000 (Table 16, Appendix V) and between 5 – 10m depth (Table 18, Appendix V). The Latitude × Depth interaction was significant as was the Season × Latitude × Depth interaction. While season LSM indicated that catch rates of berried females were highest in spring (Table 17, Appendix V) this peak also coincides with the highest catch rates of sexually mature females from the catch monitoring program indicating that mature females are either more prevalent during this period or that their behavior has been modified thus making them more susceptible to capture in traps. Similarly, catch rates of berried females in the logbook program are also highest in the months of July, August and September all of which appears to indicate that spawning activity does peak in spring. Previous studies have suggested that in tropical regions *P. pelagicus* breeds throughout the year with peak periods during the first and last quarter of the year (Batoy *et al*., 1987) whereas in temperate regions reproduction is restricted to the warmer months (Meagher, 1971; Smith, 1982). In temperate regions ovigerous crabs are caught primarily during the November to January (Penn, 1977; Smith, 1982), which coincides with the warmest part of the year. However if temperatures are in the range of 15 – 25°C a few females with eggs can be found throughout the year (Kangas, 2000). A tendency for reproductive activity to be spread more evenly throughout the year reflects maintenance of far higher water temperature in winter and early spring. This is consistent with other studies that show water temperature influencing ovulation and egg development in blue swimmer crabs and other species of decapods (Pollock, 1995; Kumar *et al.,* 1999). Water temperatures in Shark Bay are in the range of 17 – 27°C throughout the year (Pearce *et al*., 1999) therefore in accordance with previous studies continuous spawning activity would be expected. However, the spawning cycle in blue swimmer crabs is known to be highly variable (Sumpton *et al*., 1994). Potter *et al*. (2001) also working in Shark Bay state that ovigerous females were found in the embayment each of the 10 months sampled and that their monthly contribution to the overall number of adult females did not vary markedly throughout the year. In contrast, Pillay and Nair (1976) working on *P. pelagicus* in India reported that spawning peaks varied annually and geographically. A number of other authors have also suggested that while spawning in semi tropical regions is continuous throughout the spawning peaks are evident (Batoy *et al*., 1987; Sumpton *et al.,* 1994; Sarada, 1998).

Table 9.11 ANOVA of the catch rates of berried females from the catch monitoring program ($R^2 = 0.27$).

Factor	df	SS	MS	F	*P*
Year	5	21.60	4.30	2.67	0.02
Season	2	97.20	48.60	29.94	< 0.01
Latitude	3	4.90	1.60	1.01	0.39
Depth	3	36.20	12.10	7.43	< 0.01
Latitude × Depth	7	13.10	1.90	1.16	0.33
Season × Latitude × Depth	11	31.60	2.90	1.77	0.06
Residuals	285	462.60	1.60		

Undersize crabs

With the exception of water depth, all of the factors had a significant effect on the catch rate of undersize crabs ($P < 0.01$) (Table 9.12). Year LSMs indicate that catch rates of undersize crabs were highest in 2001 (Table 17, Appendix V), which is the year following (2000) when catch rates of legal size male crabs were highest (Table 8, Appendix V), and the same as when catch rates of legal sized females were highest (Table 10, Appendix V). Catch rates of undersized crabs were highest in spring throughout a range of water depths and in most latitudes (Table 18, Appendix V). The catch rate of undersize crabs was highest in a different depth for each season. Furthermore, there were no consistent trends between the lowest catch rates and water depth between the different seasons.

Table 9.12 ANOVA of catch rates of undersize crabs (< 135mm CW) from the catch-monitoring program ($R^2 = 0.45$). The number of pots used in calculating the individual catch rate weighted the catch rates. The full model, where location is defined in terms of latitude and longitude, has been used in this analysis.

Factor	df	SS	MS	F	*P*
Year	5	175.00	35.00	10.31	< 0.01
Season	2	285.50	142.80	42.04	< 0.01
Latitude	3	65.80	21.90	6.46	< 0.01
Depth	3	11.60	3.90	1.14	0.33
Latitude × Depth	7	64.50	9.20	2.71	0.01
Season × Latitude × Depth	11	179.70	16.30	4.81	< 0.01
Residuals	285	967.70	3.40		

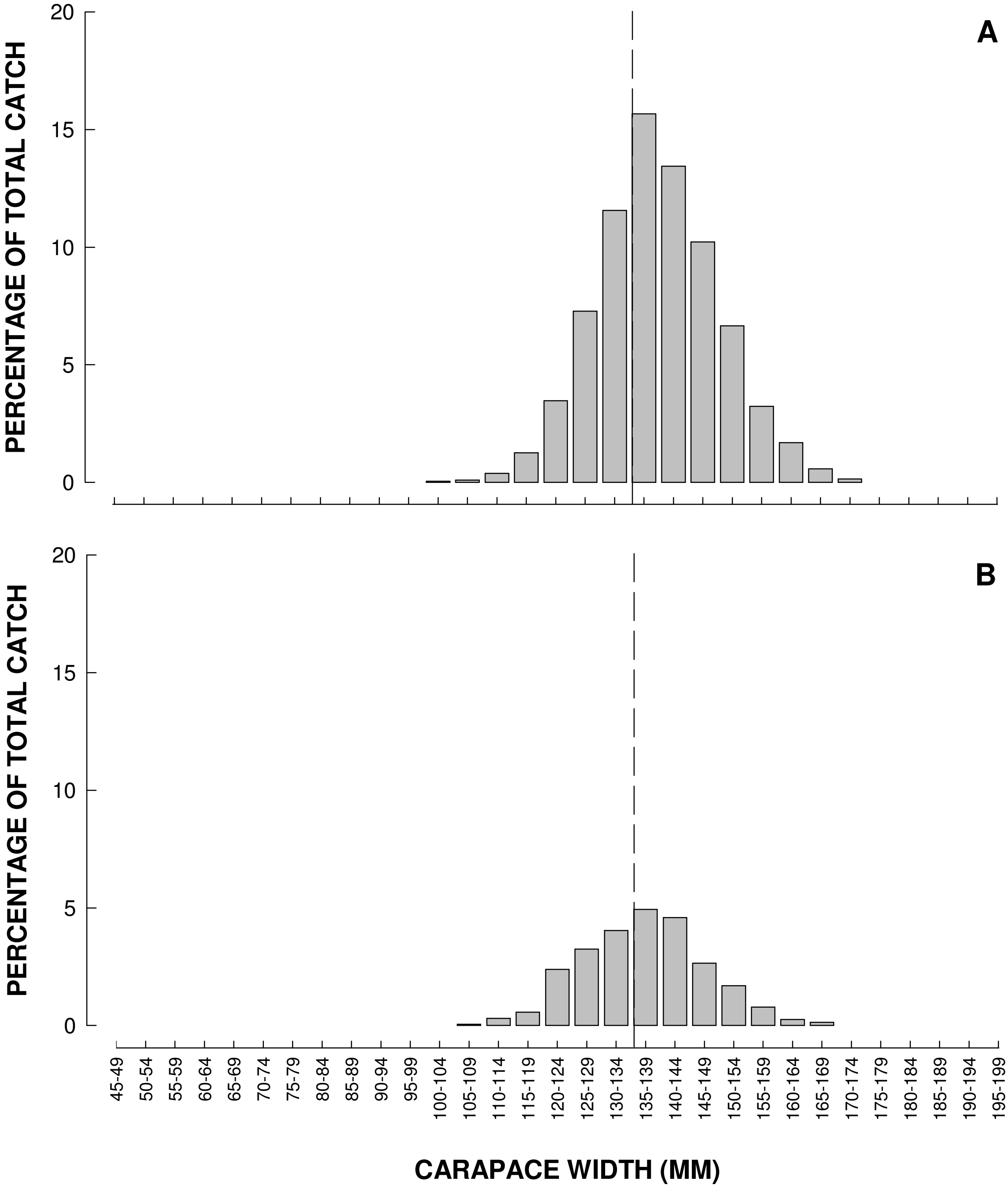

Figure 9.12 Length frequencies of female blue swimmer crabs measured during catch monitoring on commercial vessels in 1999. The dashed line indicates minimum legal size. (a) May (*n* = 1571, 68% retained), (b) September (*n* = 591, 59% retained).

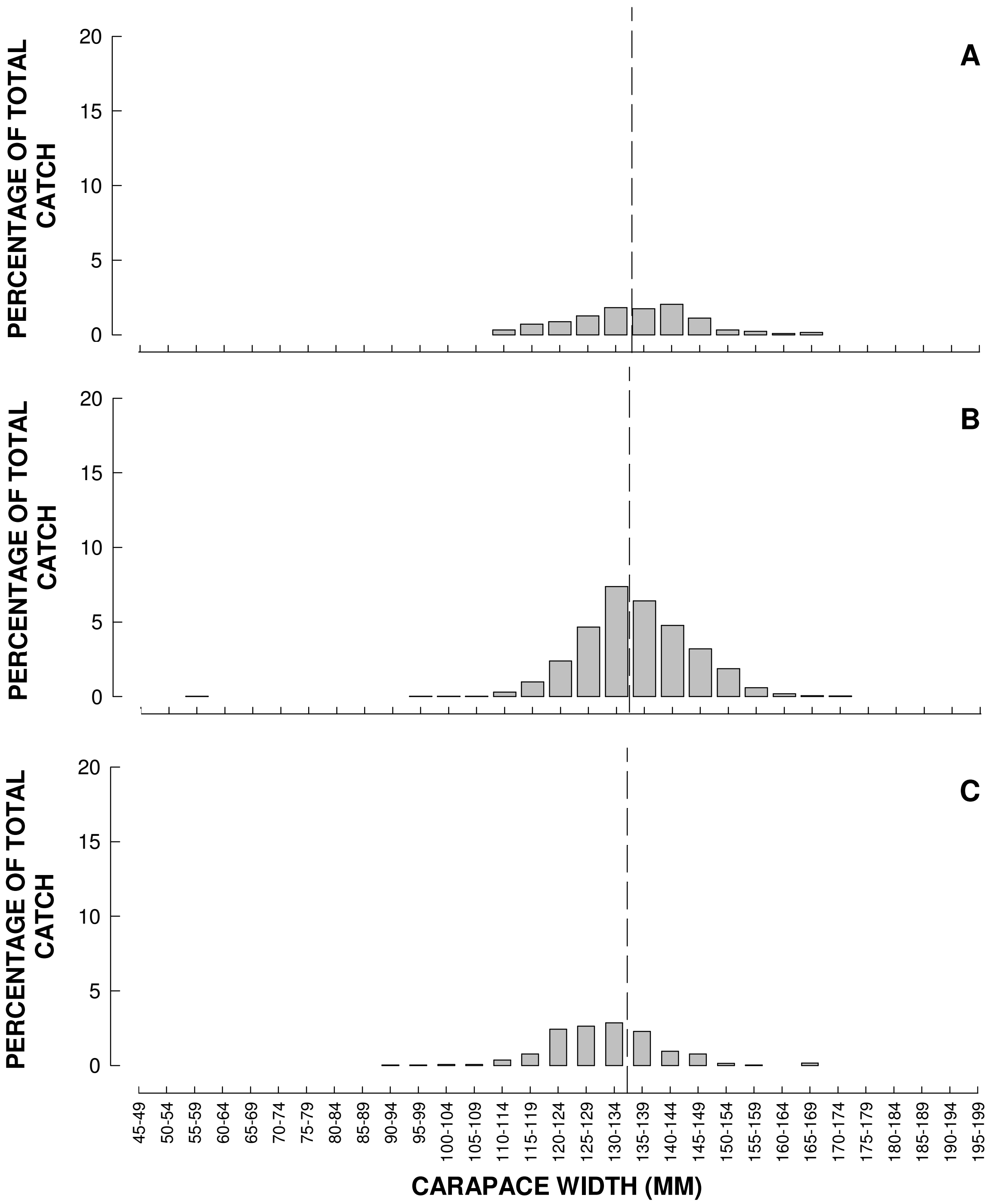

Figure 9.13 Length frequencies of female blue swimmer crabs measured during catch monitoring on commercial vessels in 2000. The dashed line indicates minimum legal size. (a) May (*n* = 135, 53% retained), (b) August (*n* = 3164, 52% retained), (c) November (*n* = 404, 32% retained).

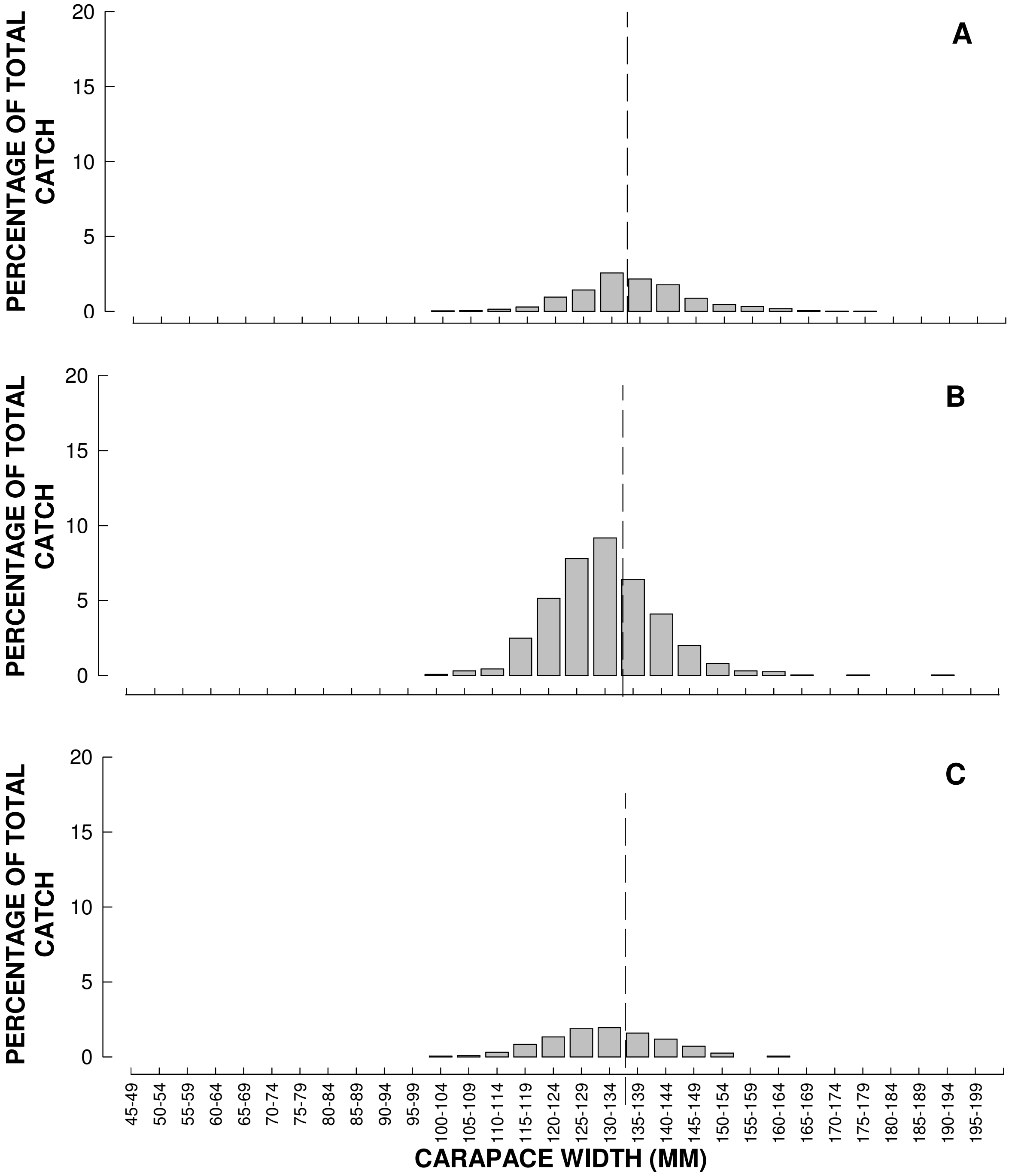

Figure 9.14 Length frequencies of female blue swimmer crabs measured during catch monitoring on commercial vessels in 2001. The dashed line indicates minimum legal size. (a) May (*n* = 781, 52% retained), (b) August (*n* = 1451, 35% retained), (c) December (*n* = 500, 37% retained).

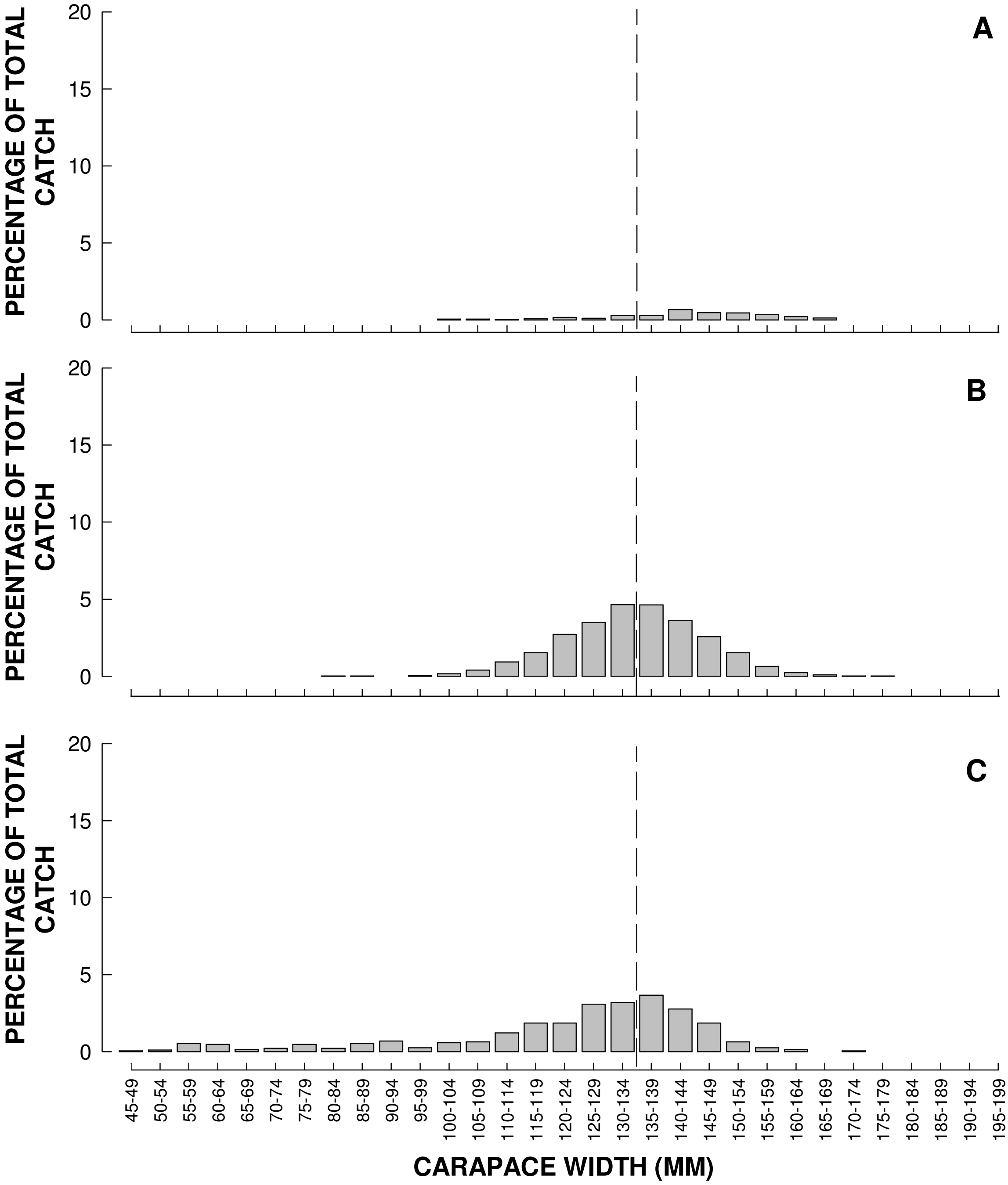

Figure 9.15 Length frequencies of female blue swimmer crabs measured during catch monitoring on commercial vessels in 2002. The dashed line indicates minimum legal size. (a) April (*n* = 126, 77% retained), (b) August (*n* = 2261, 49% retained), (c) November (*n* = 481, 37% retained).

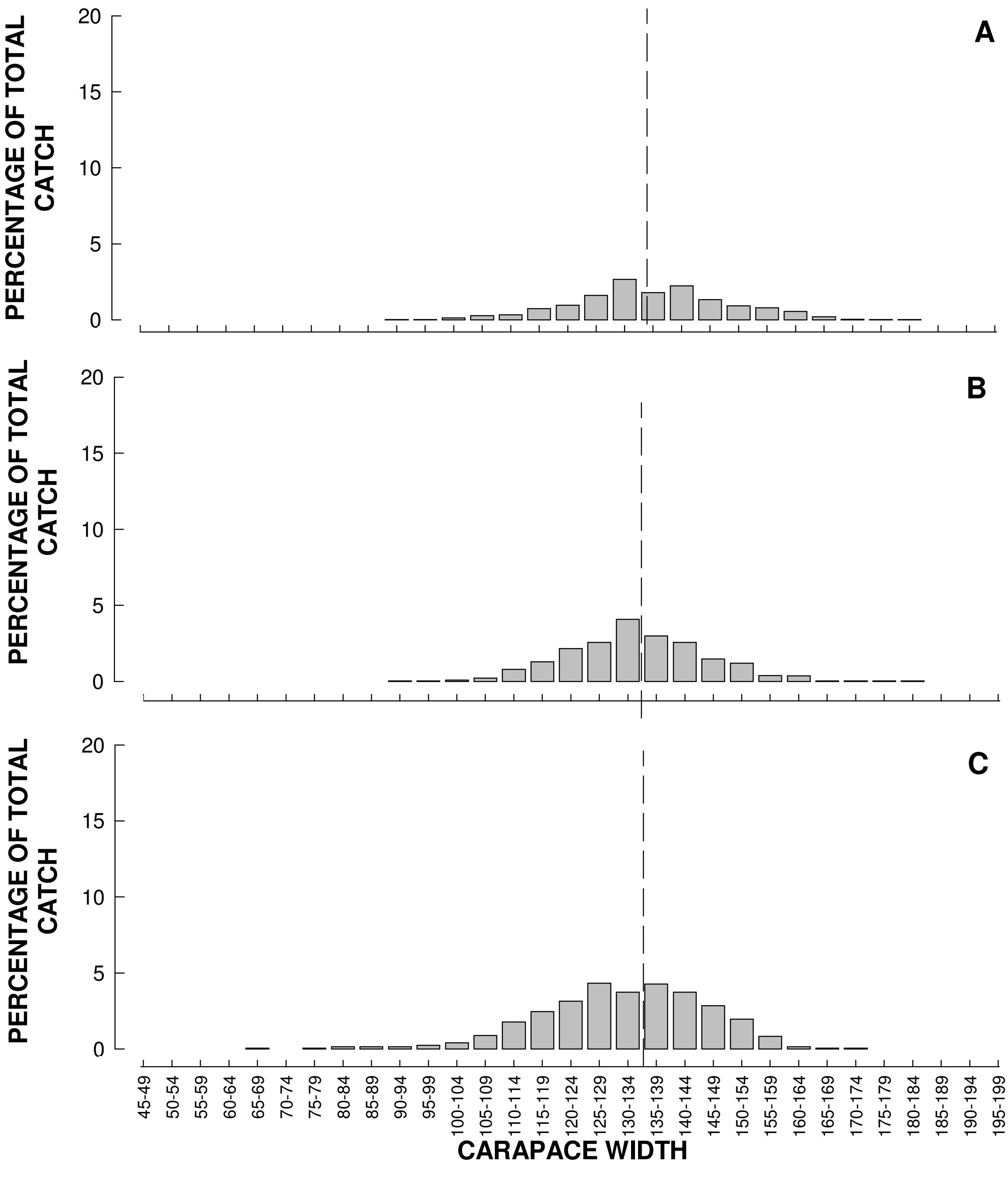

Figure 9.16 Length frequencies of female blue swimmer crabs measured during catch monitoring on commercial vessels in 2003. The dashed line indicates minimum legal size. (a) March (*n* = 837, 54% retained) (b) August (*n* = 1403, 45% retained), (c) November (*n* = 639, 44% retained).

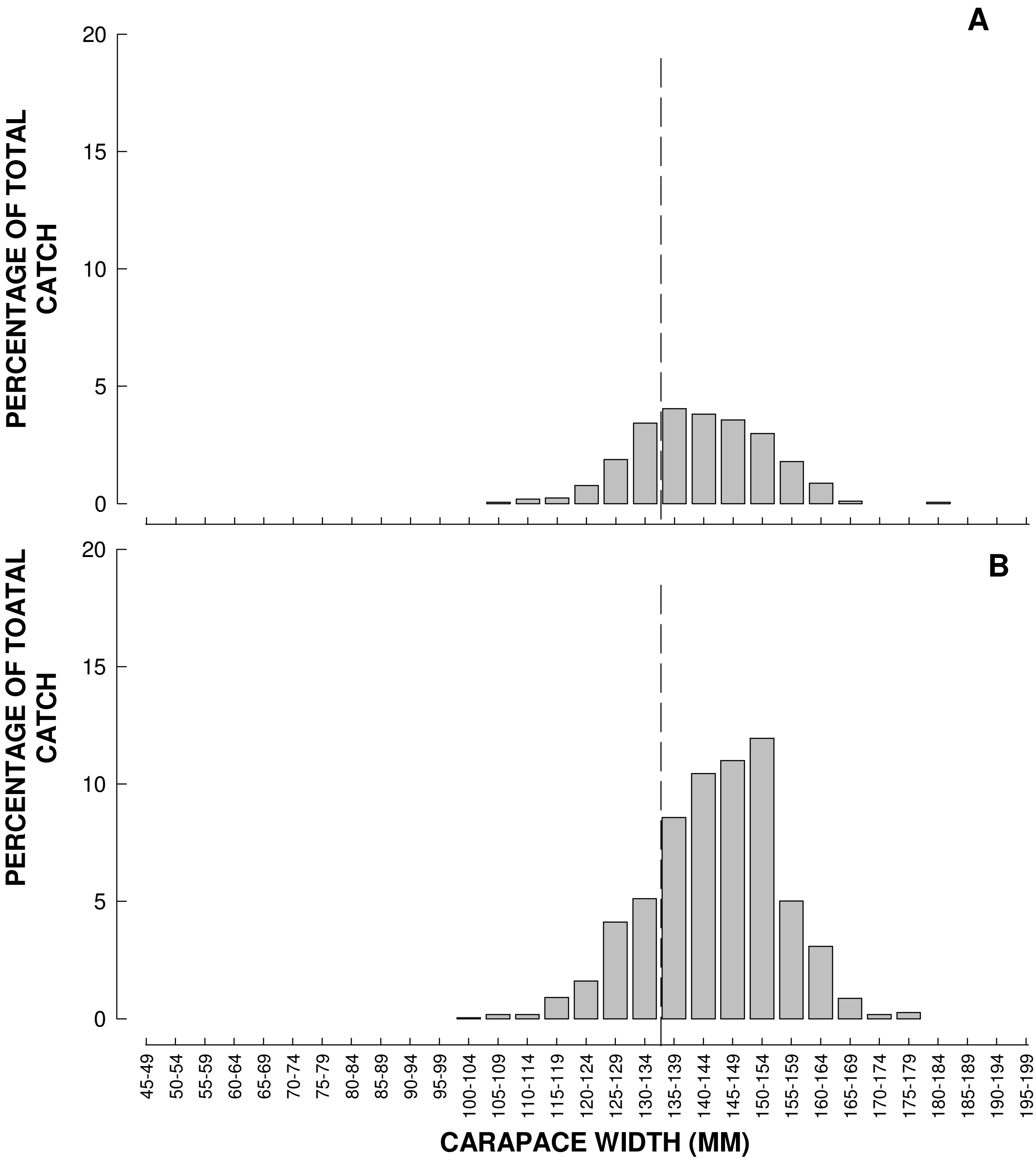

Figure 9.17 Length frequencies of male blue swimmer crabs measured during catch monitoring on commercial vessels in 1999. The dashed line indicates minimum legal size. a) May (*n* = 1571, 68% retained), (b) September (*n* = 591, 59% retained).

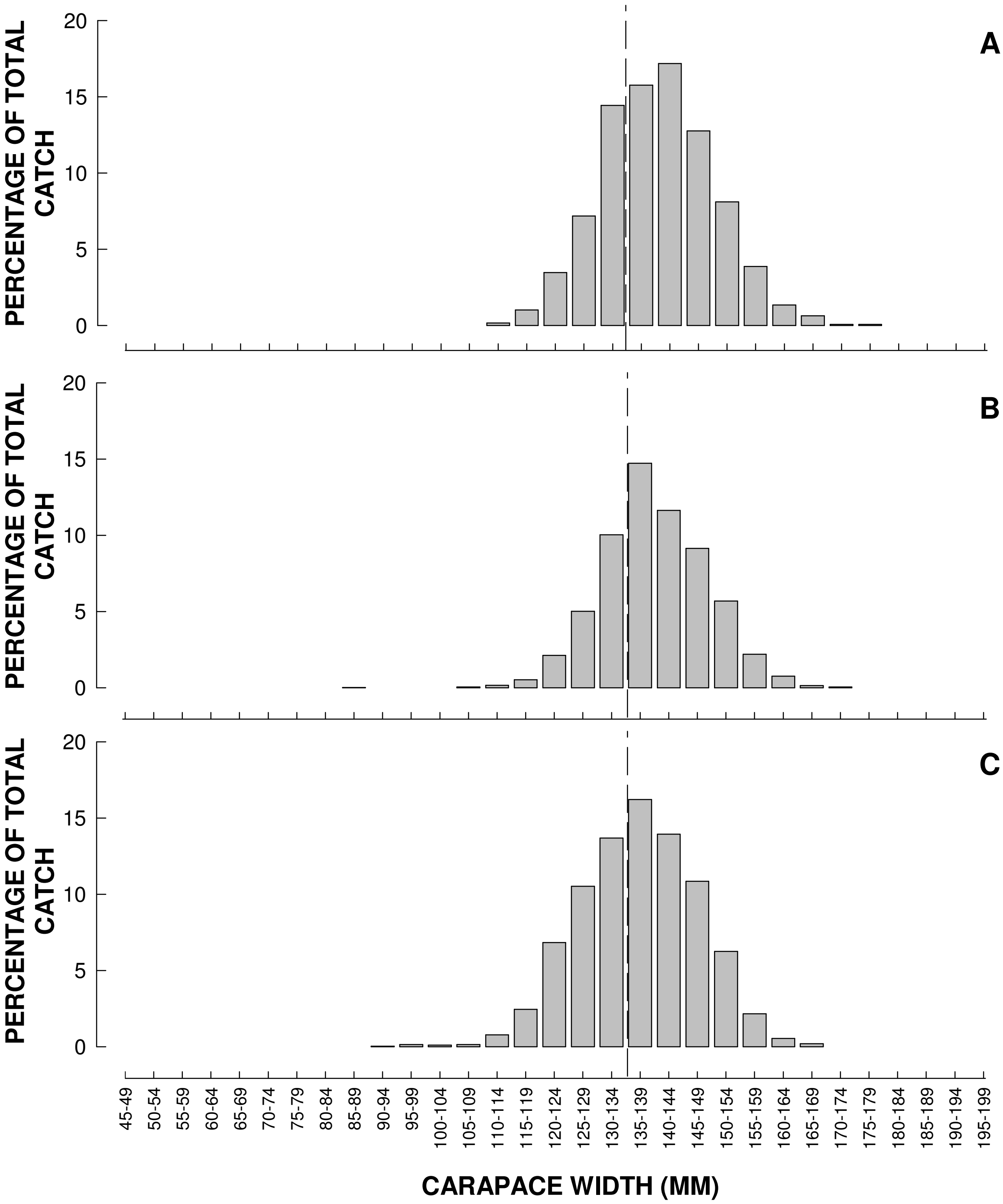

Figure 9.18 Length frequencies of male blue swimmer crabs measured during catch monitoring on commercial vessels in 2000. The dashed line indicates minimum legal size. (a) May (n = 1092, 70% retained), (b) August (n = 5996, 71% retained), (c) November (n = 2523, 59% retained).

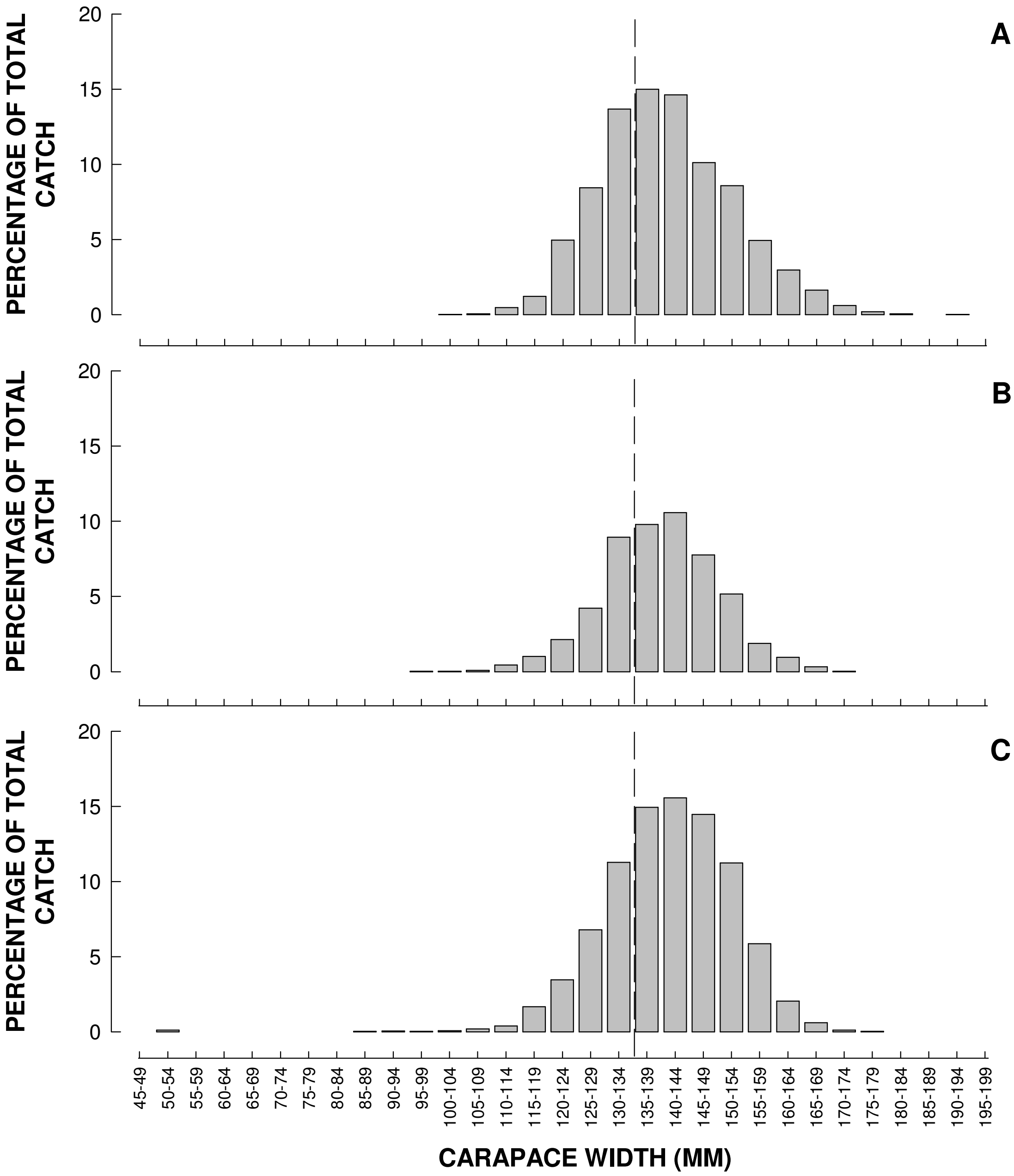

Figure 9.19 Length frequencies of male blue swimmer crabs measured during catch monitoring on commercial vessels in 2001. The dashed line indicates minimum legal size. (a) May (*n* = 6086, 67% retained), (b) August (*n* = 1972, 68% retained), (c) December (*n* = 4379, 73% retained).

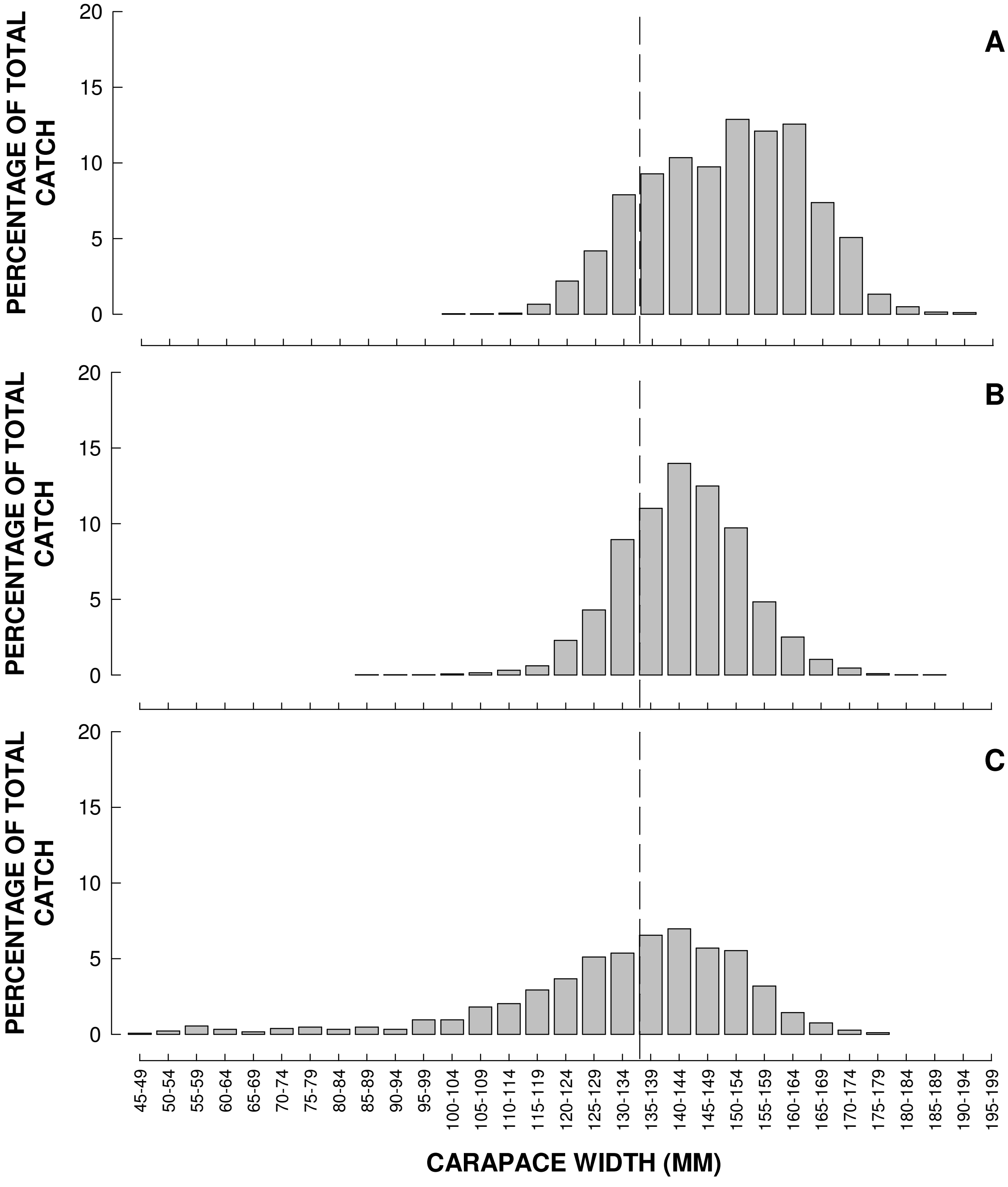

Figure 9.20 Length frequencies of male blue swimmer crabs measured during catch monitoring on commercial vessels in 2002. The dashed line indicates minimum legal size. (a) April (*n* = 3,577, 84% retained), (b) August (*n* = 6,067, 77% retained), (c) November (*n* = 1,063, 54% retained).

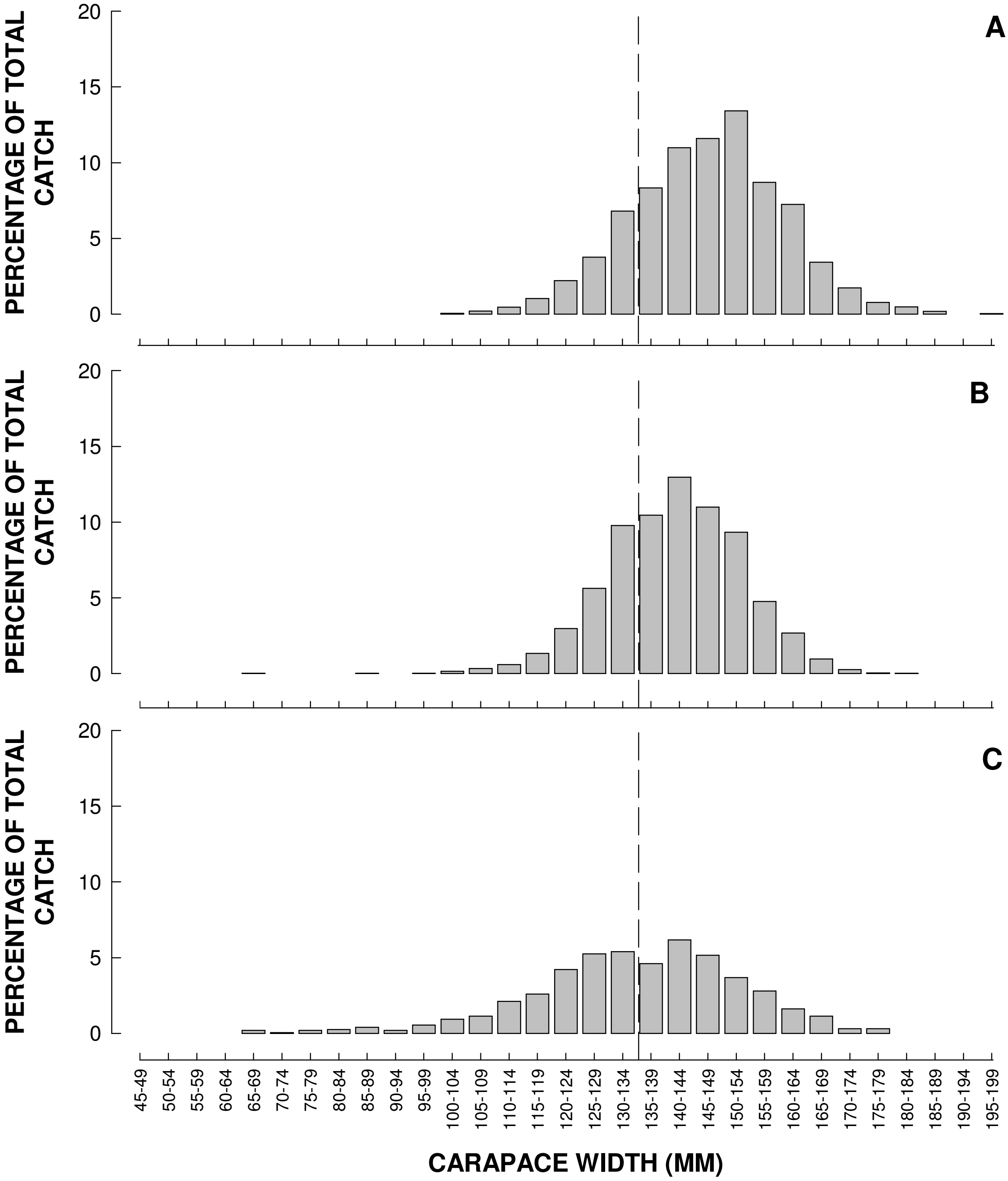

Figure 9.21 Length frequencies of male blue swimmer crabs measured during catch monitoring on commercial vessels in 2003. The dashed line indicates minimum legal size. (a) March (n = 4658, 67% retained), (b) August (n = 5099, 68% retained), (c) November (n = 1003, 73% retained).

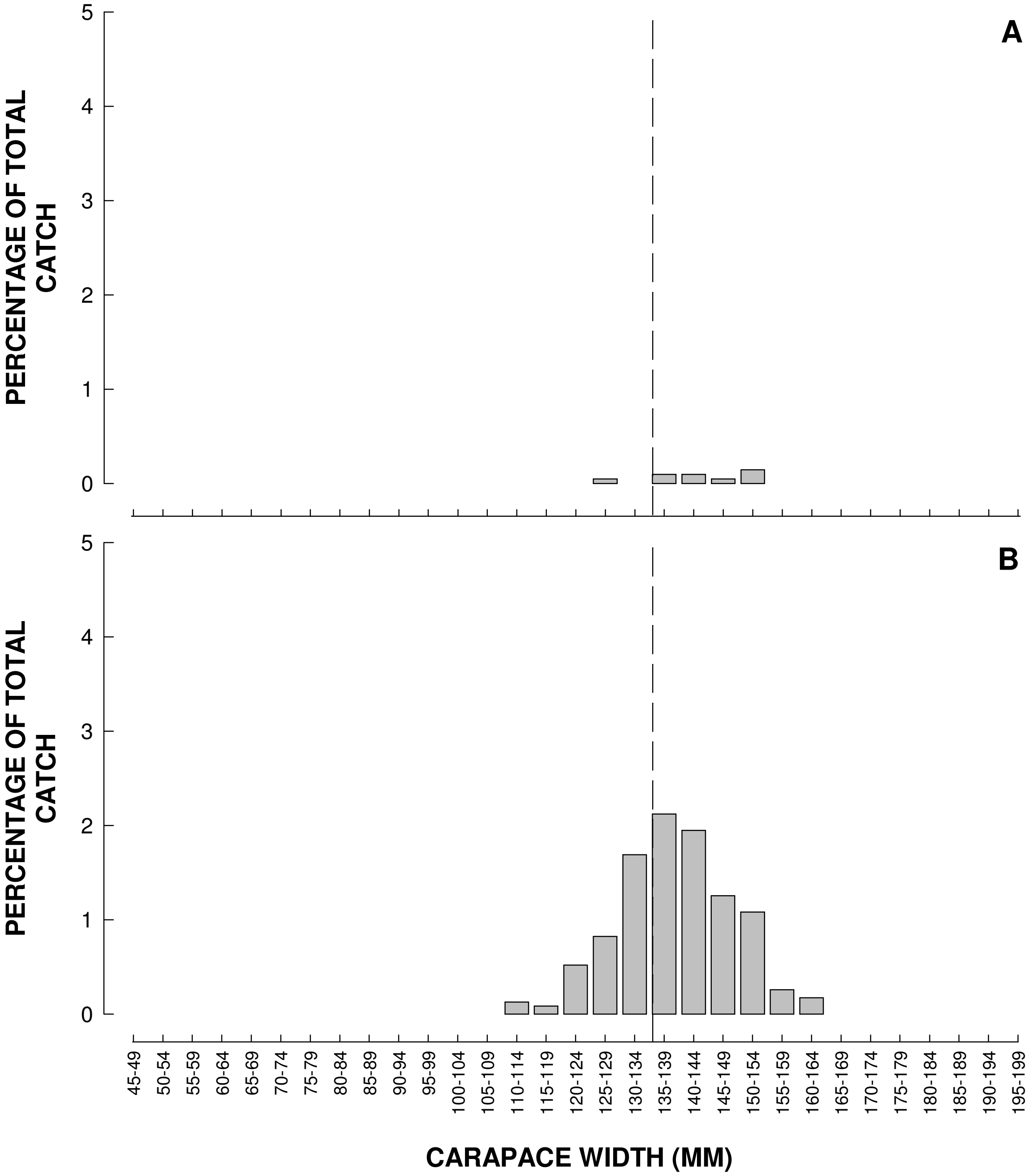

Figure 9.22 Length frequencies of berried female blue swimmer crabs measured during catch monitoring on commercial vessels in 1999. The dashed line indicates minimum legal size. (a) May (*n* = 9), (b) September (*n* = 233).

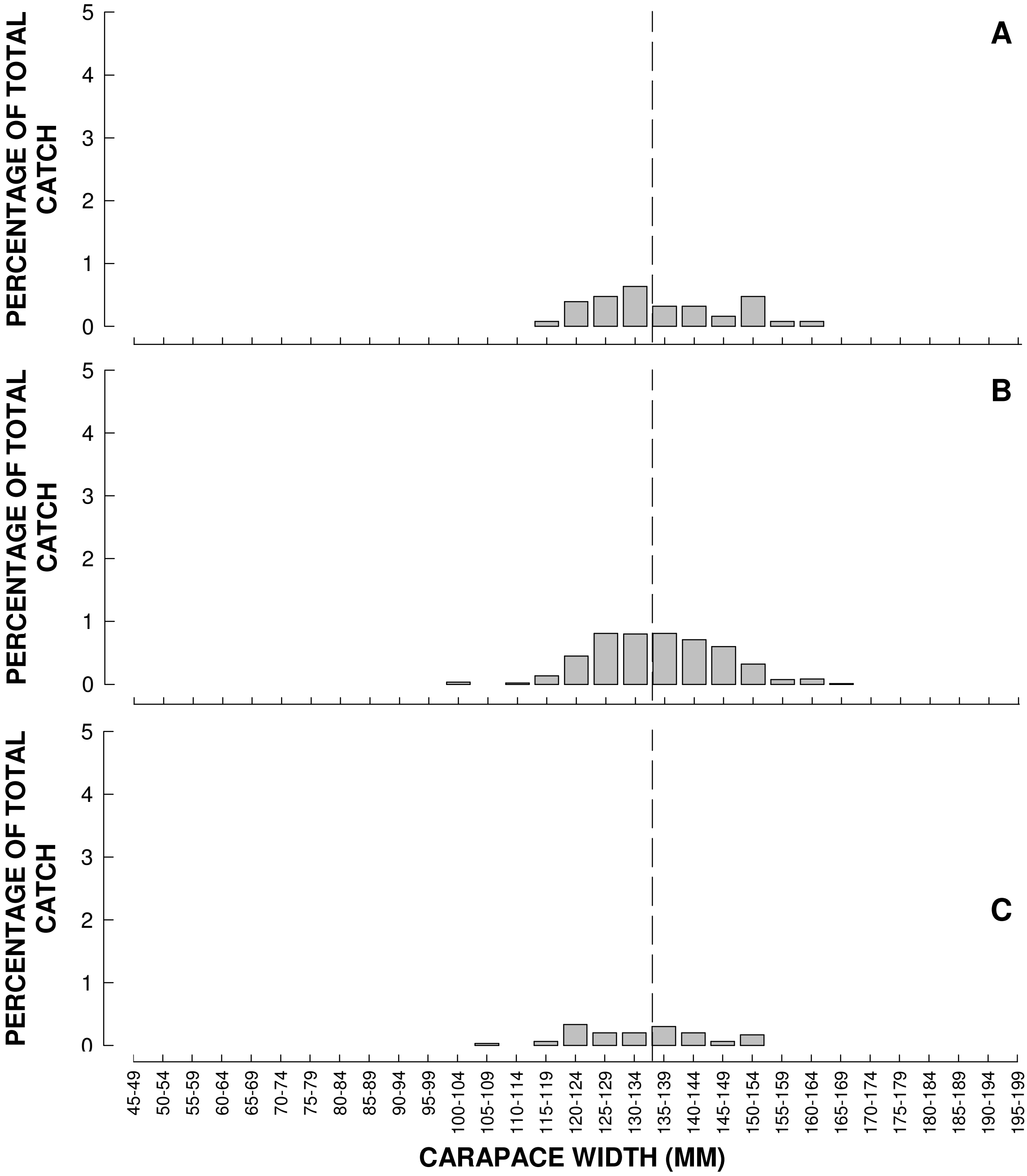

Figure 9.23 Length frequencies of berried female blue swimmer crabs measured during catch monitoring on commercial vessels in 2000. The dashed line indicates minimum legal size. (a) May (n = 38), (b) August (n = 467), (c) November (n = 47).

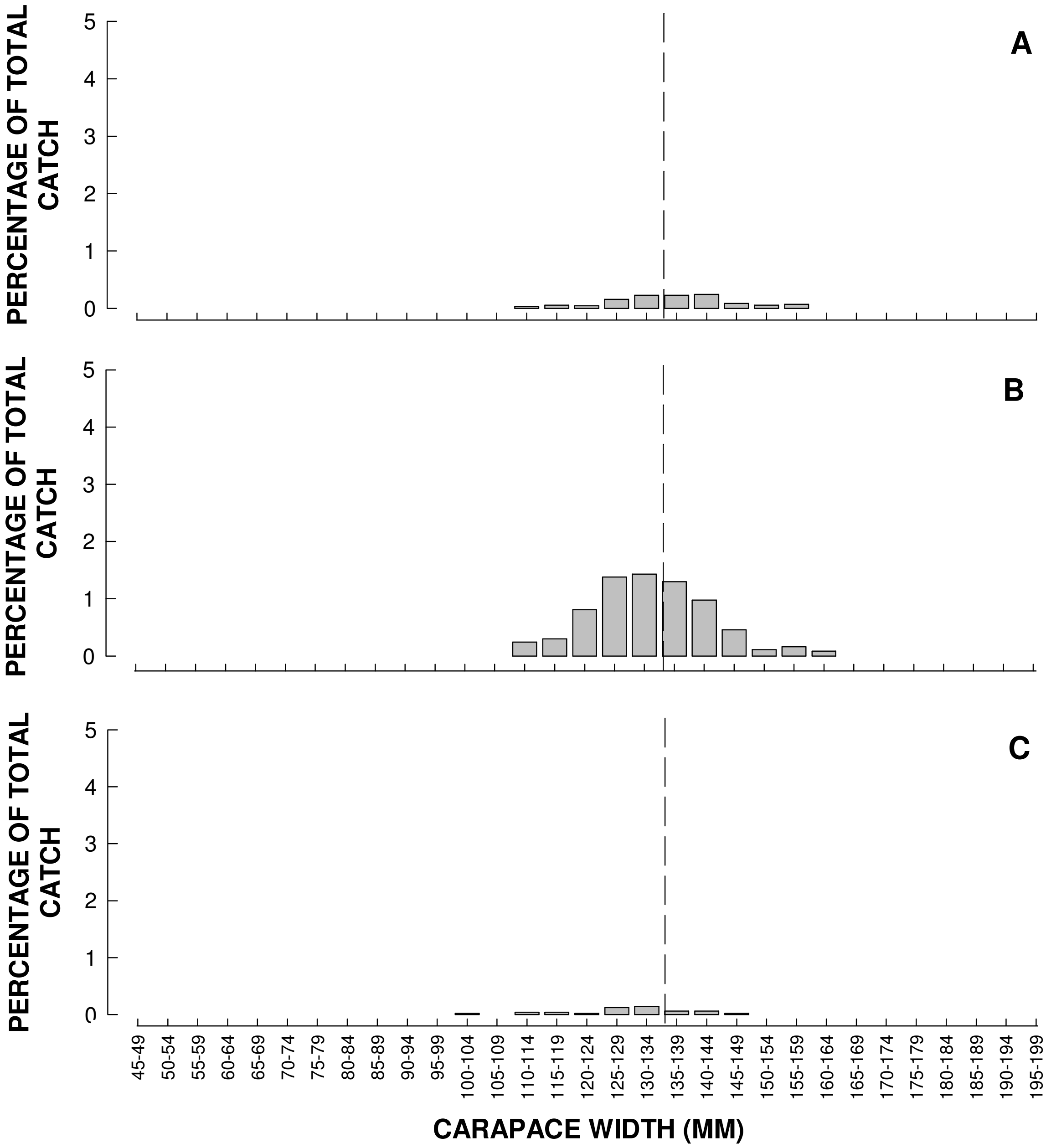

Figure 9.24 Length frequencies of berried female blue swimmer crabs measured during catch monitoring on commercial vessels in 2001. The dashed line indicates minimum legal size. (a) May (n = 84), (b) August (n = 268), (c) December (n = 26).

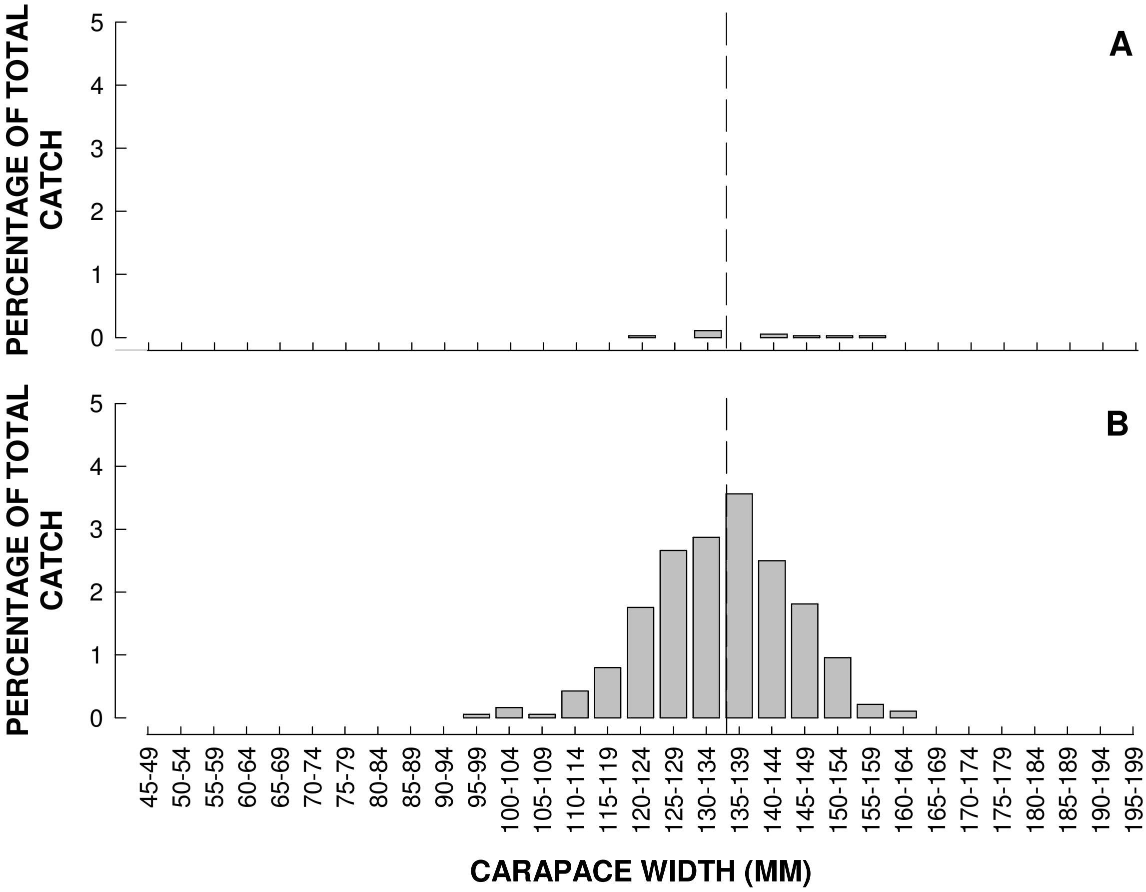

Figure 9.25 Length frequencies of berried female blue swimmer crabs measured during catch monitoring on commercial vessels in 2002. The dashed line indicates minimum legal size. (a) April (*n* = 10), (b) November (*n* = 337). Note: No ovigerous females were caught in August.

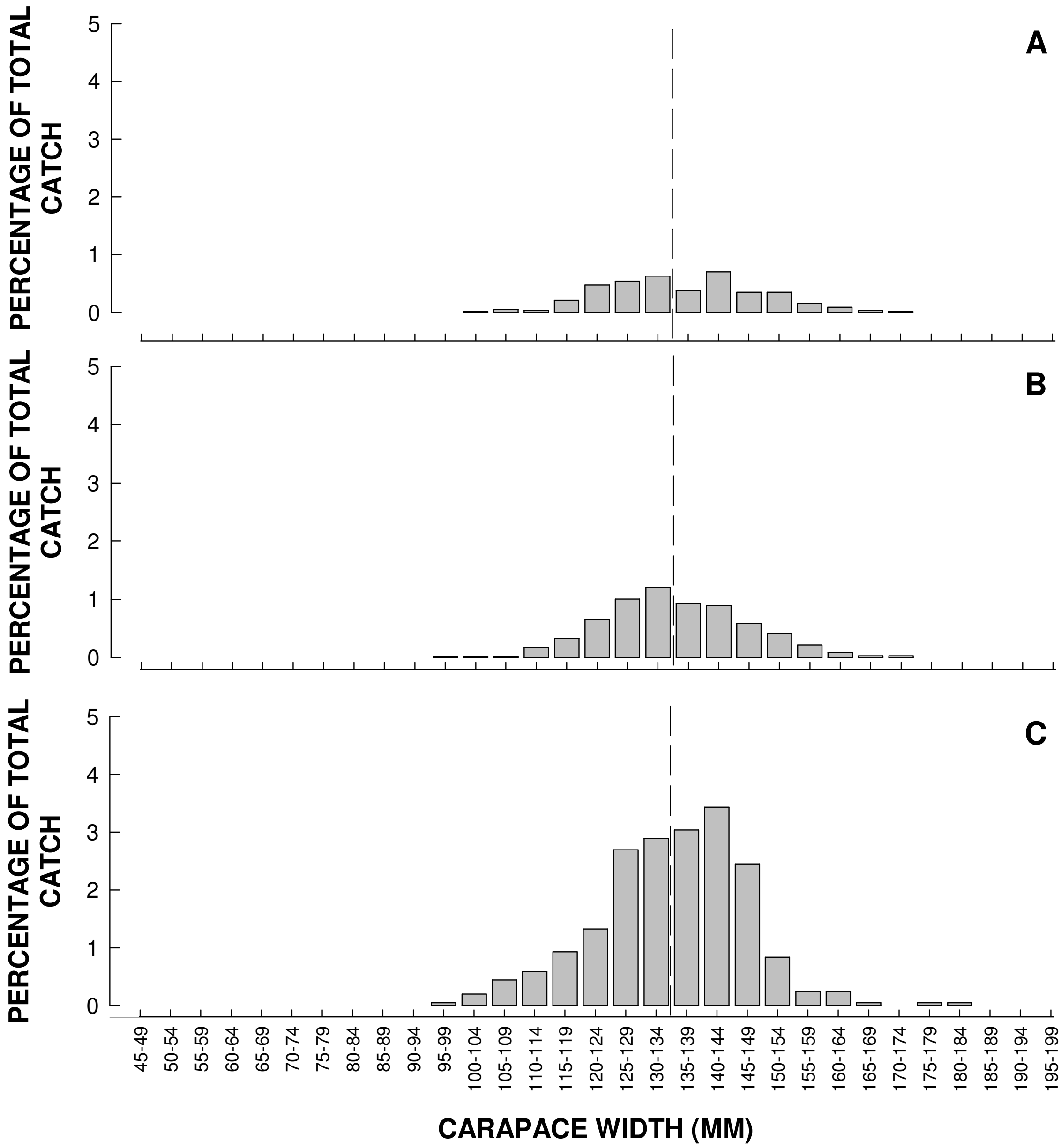

Figure 9.26 Length frequencies of berried female blue swimmer crabs measured during catch monitoring on commercial vessels in 2003. The dashed line indicates minimum legal size. (a) March (*n* = 231), (b) August (*n* = 459), (c) November (*n* = 398).

9.5 *TAGGING OF* PORTUNUS PELAGICUS *IN SHARK BAY*

9.5.1 *Introduction*

Tagging programs generally allow estimates of fishing mortality, individual growth and movement of the target species. For a tag to be useful in studies relying on commercial returns there are two main criteria: it needs to have a negligible effect on the animals at application, during the moulting process and during the intermoult period and it must also have good visibility at capture, while not compromising survival potential for recapture. Previous tagging programs with blue swimmer crabs have been largely unsuccessful due to the inability to find a tag that will successfully last through a moult cycle without either being shed in the moulting process or causing large-scale mortalities of tagged individuals (McPherson, 2002). Therefore in the absence of a long term tag this tagging program was conducted using individually numbered Hallprint® FPN glue-n tags applied to the carapace with cyno-acrylic glue. While the tags would not last through a moult and therefore would not provide growth data, information could be gained about movement and fishing mortality of crabs within Shark Bay.

9.5.2 *Methods*

Tagging of blue swimmer crabs in Shark Bay was conducted on commercial vessels on two separate occasions: 20 – 23 August 2001 and 27 – 29 August 2002. On the first occasion all the undersize blue swimmer crabs caught were tagged with a total 1,885 tagged. While on the final tagging occasion, in August 2002, a total of 3,000 crabs were tagged with all size classes tagged up to a total of 1,000 crabs per day. Crabs were sexed, individually tagged and returned to the water and their latitude and longitude at the release point recorded. The fishers recorded tag numbers and latitude and longitude of each recapture. The recaptured crabs were then returned to the water and their new latitude and longitude recorded.

9.5.3 Results and discussion

Of the 1,885 and 3,047 undersize crabs tagged in August 2001 and August 2002 respectively, 88 and 99 were recaptured respectively, resulting in at recapture rates of 4.7% and 3.2%. In comparison, recapture rates of blue swimmer crabs tagged in Moreton Bay ranged between 2 – 60% depending on the area with an overall average of approximately 15% of released crabs being recaptured (Sumpton *et al.*, 1999). However in the current study, an additional 14 recaptures could not be used in any subsequent analysis due to incomplete recording of the required details. The longest period at liberty was very similar between the years, 57 days in 2001 and 59 days in 2002. The fact that no tag recaptures were recorded after 60 days from release is likely to be due to the fact that tags are lost when crabs moult. The majority of the recaptures in both 2001 and 2002 were recorded within the first five days after release, 58% and 85% respectively, while only 7% and 6% respectively were recorded after 20+ days at liberty (Fig. 9.27).

In 2001 the shortest distance travelled by any of the recaptured crabs was 0.08km in seven days while the longest distance was 24.31km in 54 days. In 2002 these figures were 0.04 in two days and 43.60 km in 39 days respectively. The highest number of recaptured crabs in both periods travelled between 1.0 and 2.0km from release to recapture while only 9% and 15% of the recaptures travelled more than 5.0km from their point of release in 2001 and 2002 respectively (Fig. 9.28). Due to their ability to utilise strong tidal currents, which is evident in their ability to migrate into and out of estuaries, *P. pelagicus* are capable of moving substantial distances, with one crab recorded as having travelled 20km in one day in Moreton Bay, Queensland (Sumpton and Smith, 1991). Similar studies in Moreton Bay have showed fairly small scale movement of crab populations with 79% of the recaptures caught less than 2km from their release point and only 4% were recaptured more than > 10km from their release point (Potter *et al*., 1991). Potter *et al*. (2001) tagged 3,000 blue swimmer crabs in Cockburn Sound most of the crabs travelled < 2km from their release point, a few crabs travelled > 10km. In this study the majority of crabs travelled a relatively short distance from their release point and there did not appear to be any marked tendency for tagged crabs to move in any particular direction. A similar situation was evident in this study (Fig. 9.30).

The results of this study indicate that blue swimmer crabs in Shark Bay do not undergo large-scale movements. However, caution must been taken when using the results of these types of tagging studies to infer exploitation levels as the number of recaptures was dependent on; minimal tag loss, commercial fishers consistently fishing in the area which the tagged crabs were released, and consistent reporting of recaptures. Previous studies have also suggested that failure to see all the tags recaptured is dependent on size and sex of the crab and that poor return rates may be increased by fishers not examining the categories of crabs which are unmarketable such as undersize (Williams, 1986). For these reasons, the low recapture rates provide some limited evidence for the resource being lightly exploited.

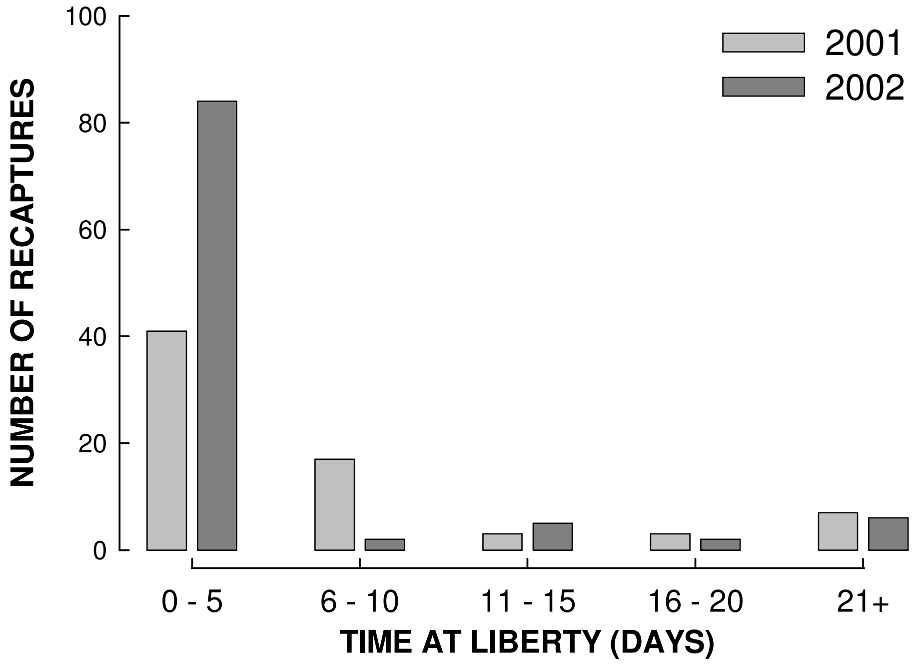

Figure 9.27 Number of recaptured blue swimmer crabs from 2001 and 2002 tagging *vs* time at liberty in days.

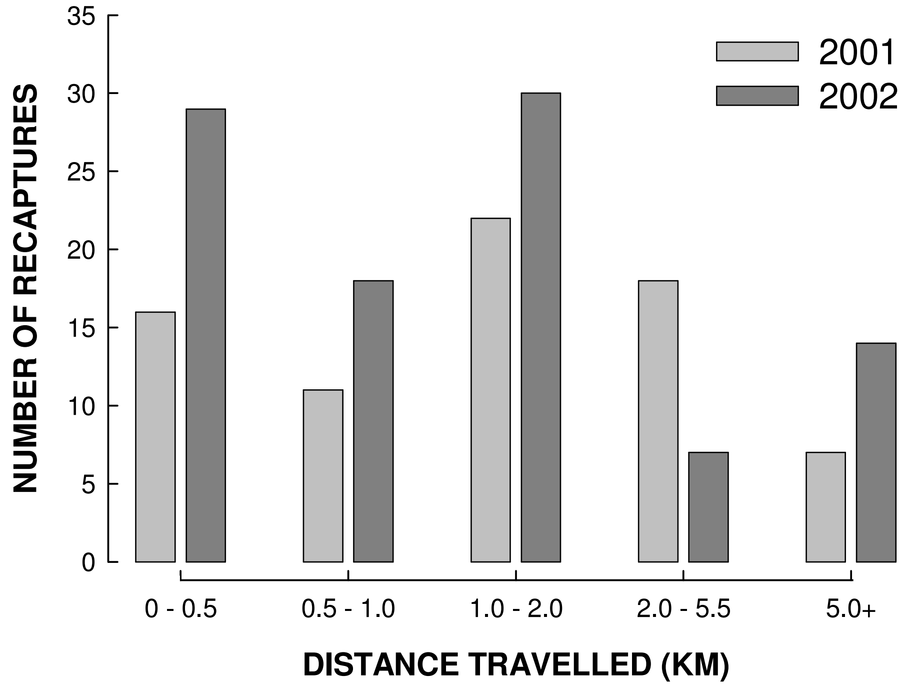

Figure 9.28 Distance travelled by recaptured blue swimmer crabs in Shark Bay from August 2001 and August 2002 tagging.

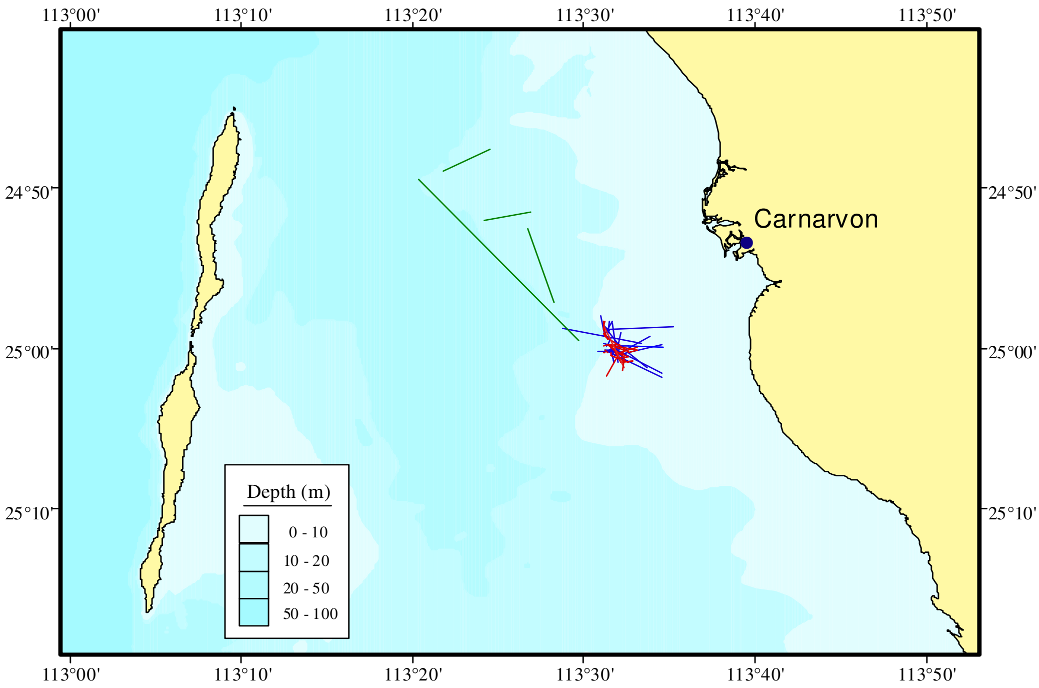

Figure 9.29 Movement of recaptured crabs retrieved by commercial vessels operating in the Experimental Carnarvon Crab Pot Fishery (*n* = 74).

9.5.4 Conclusions

Since implementation in 1998, total catch and catch rate (CPUE) in the Experimental Carnarvon Crab Trap Fishery have increased significantly, making it the largest blue swimmer crab fishery in Western Australia. These increases are a result of increased fishing efficiency and trap numbers in conjunction with an increased knowledge of blue swimmer crab stocks in Shark Bay. The second largest blue swimmer crab fishery in Western Australia is Cockburn Sound. Cockburn Sound has a total annual catch in the vicinity of 212 tonnes, eleven licenses holding a total of 880 traps and a total area of 100km^2. In comparison Shark Bay has a total annual catch in the vicinity of 255 tonnes, five license holders with a total of 1,500 traps and a total area of 13,000km^2. A small proportion of the total area of Shark Bay cannot be used due to conflicts with trawling operations. However, given the range of habitat types and depths inhabited by blue swimmer crabs the potential for exploitation of unfished or lightly fished areas in Shark Bay is significant. While research and data collection have occurred since the fishery's inception, due to the short time period over which the fishery has been operating and the small spatial area covered, it could be some time before dramatic changes in catch rates and in the structure of blue swimmer stocks become evident. Therefore, a planned approach for development of this fishery is required. Little is known about the recreational and indigenous sectors in the region and likelihood of future conflict with these user groups. Recreational fishing surveys conducted by the Fisheries Department, Western Australia, estimated the number of blue swimmer crabs caught by recreational fishers in Shark Bay to be 608 in 2004, which is down from the 2,941 (0.64 tonnes) landed at Monkey Mia, in 2002 (Fisheries Department Western Australia, unpublished data) an area not related to the current Carnarvon based fishery. Commercial participants in the fishery have set a legal size of 135mm CW, to ensure a premium market price and this maintains a portion of the resource for other users groups.

Patterns in catch composition are beginning to emerge. However, as the data contained in this report is collected from commercial vessels caution must be used when interpreting these results as differences in catch composition may be due to fishing area as well as the mode of fishing. Blue swimmer crabs aggregate on the basis of size and sex, which further complicates catch comparisons (Sumpton *et al*., 1999). As with many trap fisheries large males dominate the catches, due in part to behavioural differences between the sexes that make males more susceptible to capture in traps (Sumpton *et al.,* 1994). While this is also the case with blue swimmer crabs, market demands also mean that fishers target large males to obtain premium market prices. Research in Queensland, where there is a total ban on the taking of female crabs, has indicated that providing there are sufficient males to mate with all the females there is likely to be continued recruitment success from year to year (Sumpton *et al*., 1999).

While duration as well as peak fishing period has varied in different years, trends in seasonality are evident. Previous studies have indicated that in tropical regions portunids breed throughout the year with spawning peaks varying both annually and geographically (Batoy *et al.,* 1987). It would appear from the available data that *P. pelagicus* in Shark Bay follows this general pattern with spawning peaks evident in spring. The presence of ovigerous females in catches throughout the year indicates that despite the fact that males are heavily exploited in commercial catches, there are still sufficient numbers to mate with sexually mature females as males and females mature before reaching legal size. The presence of large numbers of undersize crabs in commercial catches in autumn also indicates that the fishery appears to be resilient to fishing, as recruits are continuously being added to the fishery, and at least at current levels of exploitation are unlikely to be overexploited.

Studies of populations on the lower west coast of Western Australia show that blue swimmer crabs display rapid growth and have a relatively short life cycle, reaching the current legal size of 135mm CW in approximately 18 months (Potter *et al*., 2001). Previous studies have indicated that in Shark Bay both males and females reach sexual maturity well below the legal minimum size, at 97.0mm CW and 92.0mm CW (50% maturity) respectively (de Lestang *et al*., 2003c), ensuring that crabs at the legal minimum size have had the opportunity to reproduce before being fished. In addition, the extended spawning season, high fecundity of females and short time to legal size means that the fishery is able to quickly recover from heavy exploitation.

It is important to note the limitations of the current research on blue swimmer crab stocks in Shark Bay. Given the vastness and variability of Shark Bay there are still large gaps in our knowledge of crab stocks particularly as the majority of research conducted was reliant on the commercial fishery for logistics and data collection. It is essential that research in the state's largest blue swimmer crab fishery does not cease. Currently, blue swimmer crab commercial fishers are taking an active role in the management of their fishery, especially in regards to assisting with research. The continued support of fishers and ongoing research and monitoring is essential to ensure that the transition to a managed fishery is based on a sound knowledge of the species and its fishery. Similarly continued research is essential if the fishery is to obtain and maintain approval from the DEH through the ESD process. Research also needs to be undertaken outside of the areas currently fished in order to prepare for future expansion of the fishery.

While blue swimmer crab stocks in Shark Bay are currently healthy and appear to be adequately coping with the current rates of exploitation, if this fishery is to avoid the pitfalls of other fisheries it is essential that future changes to exploitation levels are carefully considered, before implementation, and assessed throughout their duration. Given the vast area of Shark Bay and its potential crab stocks it is important that future management decisions seek to avoid the "gold rush" syndrome and actively encourage the commercial fishery and research to work co-operatively to collect accurate and comprehensive fisheries data to ensure biological and economic sustainability.

9.6 PRELIMINARY ASSESSMENT OF THE SUSTAINABILITY OF HARVEST LEVELS

9.6.1 Introduction and methods

The purpose of a stock assessment is to provide advice on the optimum sustainable exploitation of living resources (Sparre *et al.,* 1989). Developmental fisheries, such as the *Portunus pelagicus* (blue swimmer crab) fishery in Shark Bay, are characterised by increasing levels of fishing effort as stake holders become active in the fishery and more efficient. Some stock assessment techniques may not be appropriate for developing fisheries, largely because levels of fishing effort are not yet stable and new fishing areas are being discovered. However, provided with reliable catch and effort data from the earliest days the fishery, managers of developing fisheries can assess sustainable fishing levels by studying the response of what is essentially an unfished stock, to different levels of fishing effort. An assessment of this type can help to determine whether the fishery is capable of sustaining an increase in effort. The purpose of this analysis was to present an analysis for assessing if the blue swimmer crab fishery in Shark Bay has shown signs of stock depletion at past levels of fishing effort, and to predict the effect on catch of an increase in fishing effort. This information is critical if the fishery is to progress to a managed fishery, whereby effective management measures can be set in place to ensure a known exploitation level that will provide the maximum yield from the fishery.

Intra-annual trends in CPUE versus total catch

To examine how heavily the Experimental Carnarvon blue swimmer crab fishery is depleted annually, cumulative total catches in each calendar month were plotted against the standardised CPUE for each year since the inception of the fishery in 1999. In this and the subsequent analysis (inter-annual trends in standardised effort versus catch) CAES data were used to provide total catch estimates of blue swimmer crabs in Shark Bay. Since the accuracy of effort data recorded in logbooks is more highly regarded than the accuracy of that recorded in CAES (see FRDC report for project 2001/055 and FRDC report for project 98/121) the much more reliable effort data from logbooks was used to estimate CPUE for this fishery. Due to the spatial distribution of fishing effort in Shark Bay (refer to section 9.1.1), catch data from CAES and effort data from logbooks were restricted to CAES block 96021 (logbook blocks 246 – 253, Fig. 9.5). The lower gulfs were excluded as only two fishers are entitled to fish in this area and data is limited.

Inter-annual trends in standardised effort versus catch

The approach used was based on the technique of Hall and Penn (1979) who conducted a stock assessment to estimate the effective fishing effort and maximum sustainable yield of two species of penaeid prawns in Shark Bay.

Consideration is given to the spatial and temporal variations of fishing effort and to differences in fishing efficiency between licensees by standardising CPUE. CPUE was adjusted to remove the effects of month and block by calculating CPUE for each month and block (blocks comprising 96021/246 - 253) of each year. For each year, the average of these CPUE was taken to be the CPUE for that year for blocks "96021/246 - 253". When no logbook data existed for a particular block and month, this value was taken to be that of the next known CPUE for that block. (The catch and effort reported in logbooks for the different fishing blocks within the Carnarvon Experimental Trap Fishery are shown in Table 9.13). This analysis is similar to a GLM analysis with Year, Month and Block. Total effort was then calculated to be:

CAES catch / standardised logbook catch rate.

Table 9.13 Commercial catch and effort data for the Caranarvon Experimental Trap Fishery 1999 – 2004 by fishing block.

		LOGBOOK BLOCK NUMBER			
YEAR		**246**	**251**	**252**	**253**
1999	Catch	71	0.04		0.3
	Effort	47	0.3		0.6
2000	Catch	81	29		
	Effort	44	16		
2001	Catch	120	3	11	18
	Effort	81	0	8	11
2002	Catch	14	19	16	13
	Effort	18	18	11	8
2003	Catch	42	60	29	7
	Effort	24	40	13	5
2004	Catch	24	46	53	15
	Effort	18	27	31	8

Catch in kg x 1000
Effort in potlifts x 1000

9.6.2 Results and discussion

Intra-annual trends in CPUE versus total catch

Assuming that catch rate is an index of abundance, CPUE was high in the initial two months of 1999, i.e. May and June, however the area depleted rapidly (Fig. 9.30A). CPUE fell from between 3.00 and 3.18 in May – June to a low of 0.56 in October. Since 1999 was the first year of the fishery, the marked and rapid depletion may be due to the fact that fishers concentrated their efforts directly off Carnarvon in order to capitalise on high catch rates and minimal travelling distances (see Fig. 9.30 later) before expanding into the surrounding grounds in subsequent years. In 2000 the trend is indicative of some exploratory fishing whereby CPUE increased from 0.65 in February to a peak of 2.57 in May (Fig. 9.30B). From May 2000 onward, CPUE remained relatively constant, indicating that productive grounds had been identified and that the stocks were resistant to fishing pressure as little stock depletion is evident.

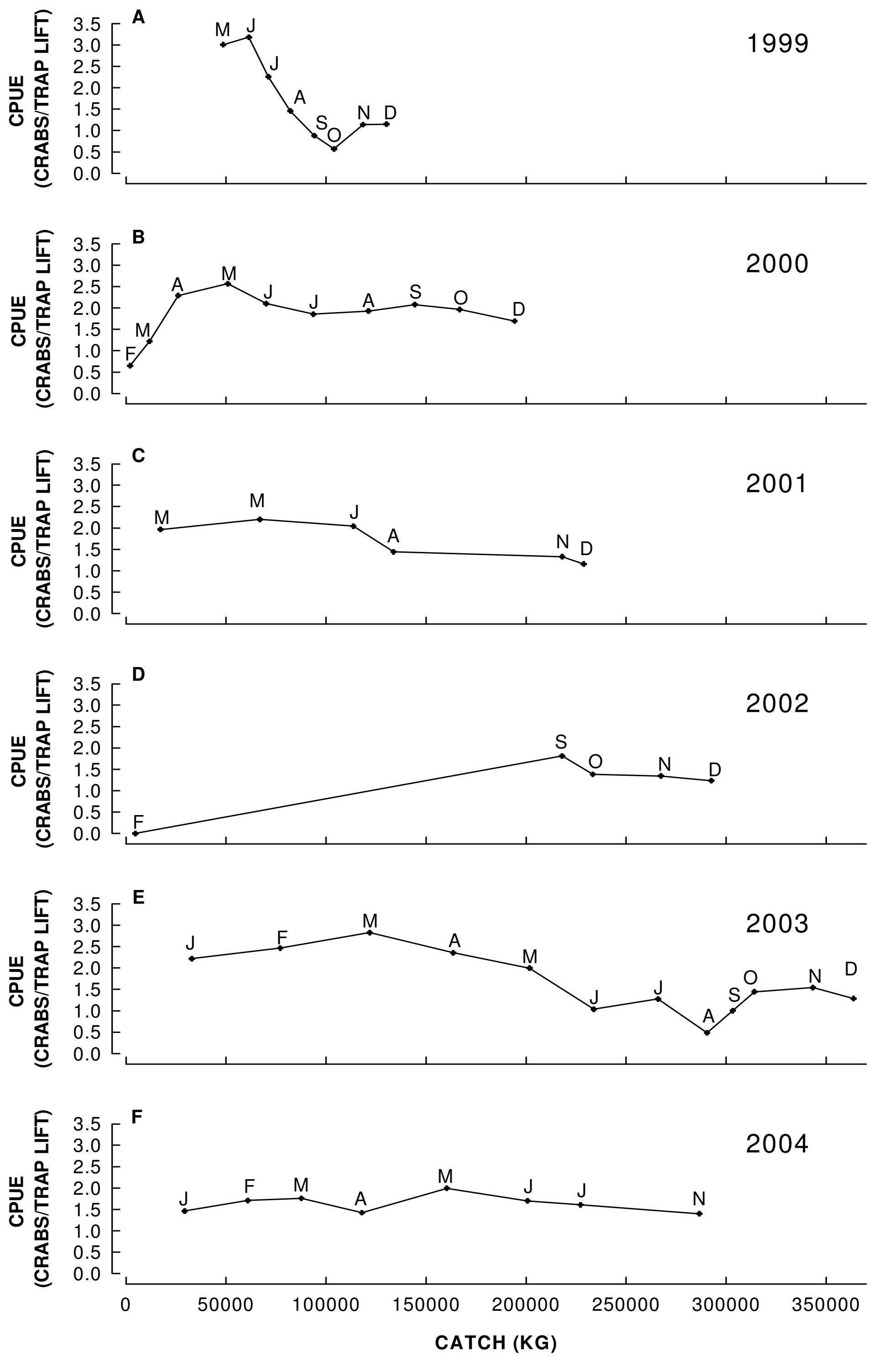

Figure 9.30 Total catch and CPUE for the Shark Bay blue swimmer crab fishery for each month.

The trend in 2001 is one of a sustained CPUE with only a small overall decline in CPUE over the year from 1.96 kg/trap lift in March to 1.16 kg/trap lift in December with little or no indication of depletion within the fishery. In 2002, effort was negligible until September and thereafter, any depletion was only slight as CPUE declined from 1.81 kg/trap lift to 1.24 kg/trap lift in December (Fig. 9.30D). In 2003, the stock appears to be resilient until March and subsequently CPUE declines markedly, although gradually, to a low of 0.48 kg/trap lift. Subsequently, CPUE recovers, possibly indicating that fishers moved on to new ground (Fig. 9.30E). In 2004, CPUE was constant throughout the year, ranging from 1.44 kg/trap lift in November to 1.99 kg/trap lift in May (Fig 9.30F). In general, there was an increase in CPUE to March – May with the peak catch rate occurring in may in most years. This was followed by a small decline in CPUE from May to November – December.

The Experimental Carnarvon trap fishery possesses a capacity for further expansion since the stock is not displaying a strong annual cycle of depletion. Blue swimmer crabs are a short lived and rapidly growing species that enter the fishery after their first reproductive season from about 12 months of age. If the fishery was fully exploited, an annual cycle of depletion would be evident whereby catch rates are initially high when new recruits are abundant at the beginning of the year, but then decline throughout the year. Neither of Figs. 9.30A to 9.30F show such a cycle and therefore, the Experimental Carnarvon trap fishery does not appear to be fished to full capacity, and has the capacity to support an increase in fishing effort.

Inter-annual trends in standardised effort versus catch

The plot of standardised logbook effort and CAES catch (Fig. 9.31) is consistent with the trend that would be expected in a developing fishery. The increase in catch is slow as fishers become familiar with the fishery i.e. fishing vessels and crews, fishing grounds and gear. However, since the relationship between catch and effort is linear, CPUE between years appears to be relatively constant. The linear relationship between catch and effort indicates that the fishery is not showing signs of depletion. Any increase in catch is entirely dependent on an increase in effort, therefore either the fishery is not fishing a single year class, or fishers are rotating fishing areas sufficiently so as not to deplete the fishing grounds as a whole.

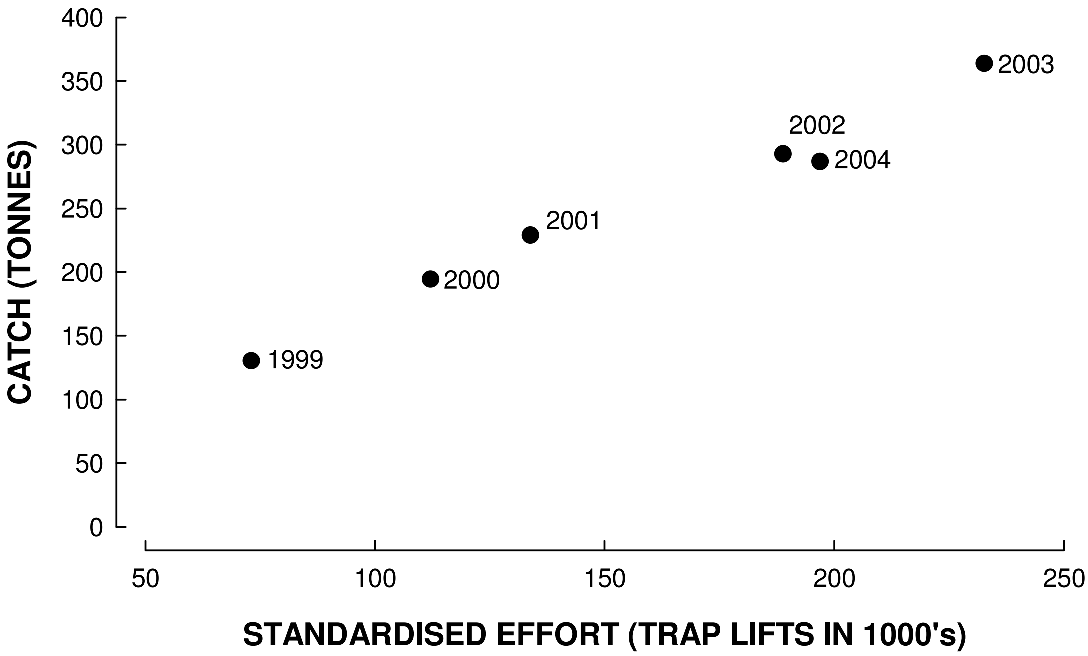

Figure 9.31 Plot of standardized effort (CAES catch /standardised logbook catch rate) versus CAES catch. Logbook catch rate was adjusted to remove month and block effects.

Using a t-test to test the significance of the coefficients in a linear fit of the data (Fig. 9.31; catch being the dependent variable and effort the explanatory), it is seen that the gradient is significant ($P < 0.01$) but the intercept is not ($P = 0.18$). (The optimal ratio between catch and effort was 1.6

(s.e. = 0.04) i.e. Catch (kg) = 1.6*Effort (trap lifts). This is similar to a Schaeffer curve with the quadratic component being zero. Fitting a linear equation (with no intercept) to the data, the mean predicted catches (and 95% confidence bounds) are 442.4 tonnes (393 tonnes, 492 tonnes) and 490.2 tonnes (424 tonnes, 556 tonnes) for 20% and 40% increases in effort respectively, on the highest level of effort experienced in this fishery in 2003.

This analysis shows that prior to 2004, total catch increased linearly with increases in effort, in consecutive years. In 2004, total catch declined to 214.6 tonnes in response to a decrease in effort. In 2004, the relationship between catch and effort remained the same as in earlier years. The decline in effort in 2004 was due to a combination of factors including one vessel undergoing the addition of a steamer for cooking crabs at sea, a license exchange that involved a new vessel that subsequently broke down, and the cumulative acquisition of knowledge that meant fishers didn't have to fish as much to maintain high catches. This analysis shows that CPUE has not changed since the earliest days of the Shark Bay blue swimmer crab fishery and therefore the fishery is not showing signs of depletion.

9.7 RECOMMENDATIONS

1. *Implementation of fishery independent assessment*

Currently all research and data collection relies on the participation of the commercial fishers, which gives a biased population sample due to the mode and area of fishing which is a subset of the total stock in Shark Bay. To assess the abundance of crabs in more remote areas not fished and to obtain a more accurate indication of crab stocks in Shark Bay a fishery independent method of assessment is required. This will give an overview of the stock in Shark Bay and the potential for further expansion of this fishery. This will also allow more detailed assessment of juvenile, undersize and ovigerous crabs which will give an indication of the resilience of crab stocks in the region.

2. *Encourage fishers to disperse fishing effort to utilise all areas available and provide addition information of stocks in the area*

Catch monitoring and logbook returns indicate that fishers use only a small portion of the available ground. Any future increases in effort in the fishery should be restricted to areas that are not currently used. This will effectively distribute the fishing effort while increasing our knowledge of crab stocks.

3. *Continued funding for research, monitoring and scientific input into future management decisions input*

With the conclusion of external funding (FRDC) for blue swimmer crab research it is essential to ensure that a level of research and monitoring is maintained so that future management needs are based on a sound knowledge of the species and its fishery. Future research needs to be cost-effective and given the willingness and enthusiasm of participants in this fishery, a portion of the research may best be conducted by the fishers themselves with some input from research staff.

4. *Improve the participation and accuracy of compulsory blue swimmer crab logbook returns*

Blue swimmer crab logbook returns provide essential information not only on total catches and CPUE but also on the undersize and ovigerous components of commercial catches. While the majority of fishers currently participate in the logbook program it is important that all the fishers participate to ensure that future management decisions are based on a true representation of the fishery. Furthermore, it is important that catch details are recorded thoroughly and accurately, i.e. that all data categories be completed particularly with respect to spatial information, and that these be completed for all of the traps in the fishery. By-catch should also be included to provide information required to fulfill ESD requirements.

5. *Continuation and extension of catch monitoring program*

Catch monitoring provides a snap shot not only of catch composition and seasonality but also gives an indication of fishing grounds. More frequent catch monitoring would provide invaluable data for future assessments or alternatively a portion of the daily catch could be sampled daily by the fishers themselves.

6. *Investigation of other user groups i.e. recreational and indigenous fishers*

It is important to assess the needs of all user groups and the impacts of various management strategies. Currently there is little information regarding the importance of blue swimmer crabs to these user groups, their needs must be assessed to enable future catch sharing issues to be assessed. Anecdotal evidence suggests that there is currently little spatial overlap in the effort distribution. This needs to be confirmed to ensure that effort expansion does not impact on recreational catch. This is imperative for Integrated Fisheries Management.

7. *Allow adequate assessment periods when introducing change*

The results of this report reinforce the importance of long-term datasets in the assessment of changes in stock structure due to variation in exploitation levels. In the future it is essential that all management changes be accompanied by compulsory data collection. Long-term change to management should be conditional on an interim assessment period of at least three years.

10.0 BENEFITS

The results of the research contained in this report will allow managers to;

1. Predict the commercial catch of blue swimmer crabs in Cockburn Sound, removing uncertainty and aiding in the management and marketing of this valuable species. One of the conditions of the Cockburn Sound Crab fishery agreed arrangements package is a catch share arrangement of 3/8ths recreational and 5/8ths commercial take. This study has produced a robust and cost-effective catch prediction index that, when used in combination with commercial CAES and recreational fishing surveys, will allow managers to closely monitor the share of the two sectors and to adjust catch limits. Catch prediction also reduces market instability caused by large inter-annual fluctuations in landed catch by providing some certainty of supply. The quantification of supply will enable seafood processors to establish markets for blue swimmer crabs in advance, which is in-turn likely to increase the price they can ask per kilogram for their product.

2. Quantify recreational fishing catch and effort through a proven low-cost recreational fishing survey. This will improve the ability of managers to assess relative catch shares of blue swimmer crabs between the recreational and commercial sectors. Recording the catch and effort of recreational fishers in Cockburn Sound is an important step toward monitoring trends in this popular recreational activity. Without the implementation of surveys such as this one, managers have little information to implement improved management strategies. These surveys can contribute to Integrated Fisheries

Management (IFM), as they are a direct means of estimating recreational catch on a regular basis and are a means of educating the public through fisheries liaison.

3. Further develop commercial fisheries for blue swimmer crabs away from recreational fishing "hot-spots" such as Cockburn Sound, Geographe Bay and Peel-Harvey. This would assist in reducing the conflict between the recreational and commercial sectors and reducing the overall fishing pressure on these heavily exploited stocks. Additional fisheries throughout the state will increase the supply of blue swimmer crabs and reduce the inconsistency of supply caused by the large inter-annual fluctuations in landed catch within existing fisheries such as Cockburn Sound. Monitoring these fisheries from the beginning will enable features such as catch rates to be compared with established fisheries and highlight any changes due to fishing, ensuring their sustainability and controlled expansion.

4. Utilise data provided for the Shark Bay fishery to develop methods for assessing the rapid development of new areas in light of the number of changes within this experimental fishery since its commencement in 1998. The continued sustainability and/or development of this fishery is advantageous given that this fishery is located away from the metropoliton area, therefore minimising conflict between commercial and recreational sectors.

11.0 FURTHER DEVELOPMENT

Trawling for juvenile blue swimmer crabs in Cockburn Sound needs to be continued to predict future commercial catches on an ongoing basis. The continuation of this program will increase the time series of data to improve the accuracy of catch estimates and allow for the possibility of adjusting the model. Changing the number of sites and duration of sampling may refine the current program. The results of the catch prediction model need to be disseminated to commercial fishers so that they are aware of the trends within their fishery and can adjust their fishing and marketing practices accordingly.

The continuation of cost-efficient recreational fishing surveys, in combination with commercial catch predictions, will allow the assessment of catch share agreements and implementation of Integrated Fisheries Management.

Monitoring of developmental fisheries (Northern and Shark Bay) should be ongoing with the aim to progress from developing fishery status to a formal management plan with allowances for ongoing research to ensure sustainable catch levels, an examination of the effects of fishing pressure and to address ESD issues raised by DEH (Department of Environment and Heritage).

12.0 PLANNED OUTCOMES

Our results will require managers to consider the following when reviewing management plans.

1. A robust catch prediction index has been developed which can be implemented with minimal cost on an ongoing basis. The index can forecast the following season's catch, and can be used for assessing the success of catch share agreements and aid with product marketing by reducing some of the uncertainty surrounding supply.
2. Commercial catch monitoring has resulted in estimates of catch per unit effort (CPUE) for the respective developing fisheries in their "virgin states", which can be used as reference points when determining threshold CPUE for ongoing management as measures of the potential impact of fishing pressure.
3. A rigorous stock assessment has been provided for the Experimental Carnarvon Crab Trap Fishery based upon a detailed description of the commercial catches and has provided recommendations for the potential expansion of the developing fishery.
4. The objective: to investigate the model for blue swimmer crabs which was to be developed in South Australia (FRDC 98/116) and to determine it's suitability for application to selected Western Australian blue swimmer crab fisheries, has been removed from the project.

13.0 CONCLUSION

The following summary highlights the objectives of the project and illustrates that the project has successfully achieved its objectives.

Objective 1. To determine if the abundance of juveniles can be used to predict the relative strength of the subsequent recruitment of the adults of this species into the fishery.

Commercial catches of *Portunus pelagicus* in Cockburn Sound, the second largest blue swimmer crab fishery in Western Australia, vary markedly between fishing seasons from 92 to 362 tonnes between 1989/90 and 2002/03. The prediction of each season's catch would remove uncertainty and aid management and marketing of this valuable species. This study has produced a robust and cost-effective catch-prediction index. The densities of seven age/sex categories of *Portunus pelagicus* in three regions of Cockburn Sound, derived by otter trawling between 1999 and 2004, were examined to determine which related best with the size of commercial blue swimmer crab landings in the following fishing season. The majority of age/sex categories correlated well with subsequent commercial catches, with the "all 0+ females and males" category producing the best index. This category was then split into individual regions and month combinations and re-analysed to determine if less sampling effort, and therefore a more efficient regime, would still produce a catch-prediction index of similar quality. The resulting index, which uses "all 0+ females and males" sampled in only the northern and middle regions of Cockburn Sound between May and August accurately predicts the subsequent commercial catch (r = 0.65) and has predicted a catch of 127 tonnes for the 2004/05 fishing season.

Objective 2. To develop low cost annual recreational catch monitoring methods for resource allocation adjustments.

The recreational fishing surveys conducted during the present study were designed specifically to quantify recreational catch and effort for blue swimmer crabs in Cockburn Sound and Geographe Bay during peak catch periods. By conducting the surveys within a restricted period when the majority of catch is taken, 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 (2004), and also reflect more recent trends within each fishery, particularly those associated with the implementation of catch share arrangements. A large component of both of these fisheries is caught by the recreational sector.

Objective 3. To assess the relative impacts of minimum size and fishing effort controls on the resource shares in Cockburn Sound and Geographe Bay.

Management measures were introduced in Cockburn Sound and Geographe Bay to address issues between recreational and commercial sectors. However, it is difficult to determine the precise effects of the new management measures as they are confounded with changes in fishing effort gear type and recruit success. In Cockburn Sound commercial effort reductions were successful in initially increasing the proportion of recreational catches from 8% to 15% between 1996/97 and 2001/02 but these still remain well below the target set by managers of 3/8's (37.5%). However, during the present study recreational fishing decreased to between 9 – 12% of the total catch. The surveys indicated that this decrease was due to a reduction in recreational effort that may indicate a shift from recreational crabbing to angling. This highlights the difficulty of maintaining a fixed catch ratio if the effort in the sectors, particularly in the recreational sector, is highly variable.

Throughout the survey period crabs >127mm and <130mm CW were the most abundant cohort in recreational catches, with 2-15 % of male and up to 16% of female crabs caught by recreational fishers in this category. Therefore, it appears that a change in the legal size to 130mm CW for the commercial fishers may be beneficial to recreational catches.

In Geographe Bay 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 in Geographe Bay has always been significantly greater than the commercial catch and it has continued to steadily increase throughout the survey period. The peak catch period of blue swimmer crabs in Geographe Bay is winter/autumn with few legal size crabs remaining by peak tourist season in summer and autumn. An increased commercial size limit (128mm CW) does appear to have some effect with approximately 6% of recreational catches comprised of crabs 127mm CW. The increase in recreational catches with such a small size discrepancy in the legal recreational and commercial sizes may be due to the spatial and temporal overlap in the effort of the two sectors.

Objective 4. To work with industry to collect baseline data on unfished stocks of blue swimmer crabs by developmental fishing, which is necessary to set initial catch limits, in selected areas along the coast of Western Australia.

The targeting of blue swimmer crabs in the coastal waters between Mandurah and Bunbury and the Pilbara region has proved largely successful. Commercially viable quantities of crabs were landed from both fisheries, although it is still unclear as to whether either could sustain fishing throughout the year. Furthermore, commercial operations appear to have had no discernible impact on the recreational catch and effort in these regions. It is expected that the viability of operations in both of these areas will continue to improve as the fishers consolidate their knowledge of local crab stocks and further refine their fishing and marketing operations. However, further exploratory work is required before the long-term suitability of both the Pilbara coast and the waters between Mandurah and Bunbury as commercial crab fisheries can be determined. It is important that the research monitoring that has been conducted onboard commercial vessels in each of these areas is ongoing. As there was little fishing undertaken by the exemption holders in Exmouth Gulf, it was not possible to provide an assessment on the viability of targeting blue swimmer crabs in this area. Several years of exploratory fishing are still required before the viability of commercial operations, and any impact on the recreational blue swimmer crab catch and effort, in the Gulf can be considered.

Objective 5. To provide an assessment for the Experimental Carnarvon Crab Trap Fishery, based on commercial fishing and tagging data, as a means of developing methods for rapid assessment of new areas.

An assessment for the Experimental Carnarvon Crab Trap Fishery has been completed and patterns in catch rate and composition are beginning to emerge. In the absence of historical or fishery independent data the methods used during this study have provided rapid means of fishery assessment which can be applied to developing fisheries in other areas of the state. However, given the vastness and variability of Shark Bay there are still large gaps in our knowledge particularly as the majority of research conducted was reliant on the commercial fishery for logistics and data collection. Blue swimmer crab stocks in Shark Bay are currently healthy and appear to be adequately coping with the currently rates of exploitation however, continued research particularly fishery independent monitoring in fished and unfished areas is essential to ensure the longevity of this fishery and its further expansion.

Objective 6. To investigate the model for blue swimmer crabs, which is currently being developed in South Australia (FRDC 98/116) and to determine its suitability for application to selected Western Australian blue swimmer crab fisheries.

The primary objective was to obtain a model being designed by South Australian scientists for blue swimmer crab fisheries in that state and modify it to suit Western Australian fisheries. However, South Australia was unsuccessful in producing the required model and therefore after extensive consultation the objective was removed from the project (see June 2003 milestone report).

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15.0 APPENDICES

APPENDIX I

Intellectual Property

The FRDC's share of project income, based on the relative value of contributiosn in Part C of the proposal for this project, will be 64.95%.

APPENDIX II

Staff

Principal Investigator: Dr Lynda Bellchambers
Research Scientist: Mr Kimberly Smith
Statistical Officer: Mr Adrian Thomson
Technical Officers: Mr David Harris
Mr Scott Evans

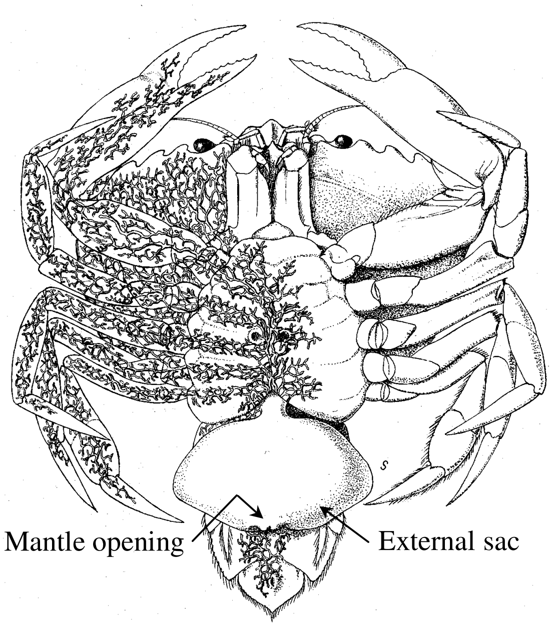
APPENDIX III

Parasitism of the blue swimmer crab **Portunis pelagicus** *by the Rhizocephalan barnacle,* **Sacculina granifera** *along the Pilbara Coast, Western Australia* **by David Harris**

Sacculina granifera Boschma is a parasitic barnacle that infects blue swimmer crabs, bringing about a number of major changes in the host crab (Hartnoll, 1967). Infestation is common in Australian waters, however, studies have generally been limited to the waters of Moreton Bay, Queensland (Bishop, 1975; Phillips and Cannon, 1978; Weng, 1987; Shields and Wood, 1993; Sumpton *et al*., 1994) with no mention of the barnacle in West Australian crab stocks.

The parasite consists of two parts: an internal root system and an external sac (Figure 1). The sac is a reproductive organ and occupies the space that is normally filled with developing eggs in a berried female. It is ovoid in shape, yellow in colour and grows about as wide as the abdomen of the host crab. The root system and sac are connected by a stalk, which is attached to the undersurface of the crab's abdomen (Bishop and Cannon, 1979).

The life cycle of the barnacle begins with a brief free-swimming larval stage, lasting about 10 days. The parasite then attaches to a hair on a host crab's abdomen and penetrates into the abdominal cavity. A mass of cells develops and rootlets gradually spread through the entire crab (Figure 1). This rootlet system is very difficult to detect, even after dissection.



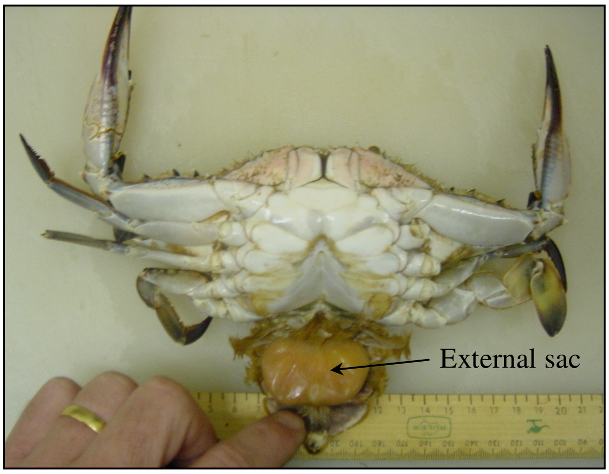


Figure 1. Rootlet system of *Sacculina* (original drawing by Boas, from The Biology of Crustacea, Bang) on the left, and an infected blue swimmer crab with external sac caught in the waters off Port Hedland.

After about nine months, the external sac emerges from below the apron of the host crab's abdomen (Figure 1). It is clearly visible and grows quickly. Two or more batches of parasite larvae are produced within the sac, which escape through a single mantle opening (Figure 1). Approaching winter, the sac bursts and dislodges leaving a visible scar on the abdomen of the crab (Shields and Wood, 1993). Reproductive development was seen to increase in female crabs with scarring compared to those still carrying the sac, suggesting that infected crabs can return to reproduction once the sac had gone (Sumpton *et al.*, 1994). The roots of the parasite remain alive long after the sac has dropped off the host crab.

Sacculina granifera is known to have a number of effects on its crab host, including degeneration of the sex organs in both sexes and modification of the male crab to a more female form (Hartnoll, 1967). Infection usually results in castration for both sexes, however, infected hosts are still capable of mating and some females are still able to produce a clutch of eggs (Sumpton *et al.*, 1994). Other than the appearance of the external sac in place of an egg clutch, there are no obvious body changes to infected female crabs. Parasitised male crabs, however, moult and grow with the abdomen developing a more 'female' shape as the infection progresses (Figure 2, 3). The mechanism locking the abdomen to the sternum is reduced, the claws of infected male crabs reduce in size to look more like female claws and the carapace colour changes from the mottled blue of males to the brown of females (Figure 3).

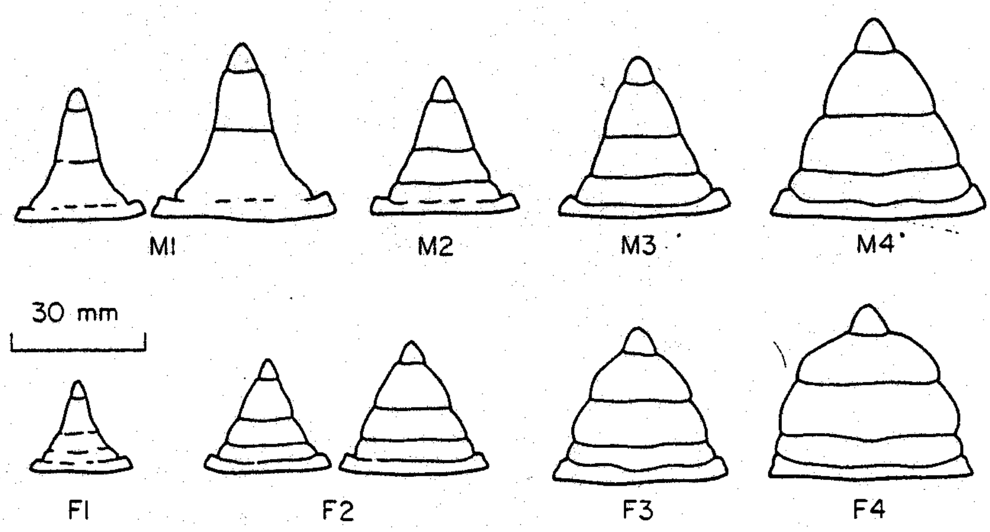


Figure 2. **A**bdominal shapes of blue swimmer crabs infected with *Sacculina granifera* at different stages of growth (adapted from Weng, 1987; pp. 222). M1: normal male condition, M2-M4: parasitised males, F1-F4: normal females.

Figure 3. Morphological comparison between a normal male blue swimmer crab (A) and a male with advanced *Sacculina granifera* infection (B).

Infected crabs behave as normal crabs when feeding, moving and reacting to danger. However, their stance, defecation and burrowing behaviour differs as they must accommodate the external sac. The sac is treated as a surrogate egg mass and looked after in the same way a berried female tends her egg clutch. The parasite also causes crabs to behave like berried females and move seaward as they grow (Bishop and Cannon, 1979).

The parasite also influences the growth rates of infected male and juvenile crabs. While infection appears to have no effect on the growth rates of female crabs, male and juvenile crabs have significantly lower moult increments than uninfected crabs (Shields and Wood, 1993).

Infection with *Sacculina* is most likely to occur in juvenile crabs, however, animals of any age/size are at risk (Shields and Wood, 1993). In Moreton Bay, *Sacculina* infection rates increase over the summer months. It has been suggested that the appearance of the external sac coincides with the host's spawning season so the parasite can make use of nutrients normally used for reproduction (Bishop and Cannon, 1979).

Various theories have been put forward to explain the effects the parasite has on blue swimmer crabs, with most focused on the parasite altering the host crab's genetic and hormonal determination. Failure to develop male characteristics and moult inhibition has been attributed to the parasite's influence on organs producing the relevant hormones. The parasite may also be capable of producing hormones that mimic those normally released by the crab's ovary.

METHODS AND RESULTS

As the focus of the survey was to monitor the general crab population, the presence of crabs with visible sacs was only noted as a secondary event and no internal examination of crabs was carried out. Consequently, the proportion of crabs infected with the parasite was probably higher than actually recorded. Previous surveys carried out in Moreton Bay recorded between 5-30% of crabs infected with *Sacculina* (Phillips and Cannon, 1978), compared to just 1.2% in the Gulf of Carpentaria in Queensland (Weng, 1987).

Port Hedland

During the three days of catch monitoring carried out in the waters off Port Hedland during July 2002, a total of 719 crabs were measured, with approximately 2% (n=15) displaying external sacs (Table 1).

All 15 infected crabs caught were recorded as female, with 11 coming from just two of 31 potlines sampled (Figure 5). It should be noted that some of these crabs were possibly male crabs incorrectly recorded as female at the time because of their external 'female' appearance.

Nickol Bay

A total of 6344 crabs were caught over the three days of catch monitoring in Nickol Bay from 23rd – 25th July 2003. Approximately 3% (*n*=166) of these displayed external sacs (Table 1).

Monitoring of the commercial blue swimmer crab catch in Nickol Bay was also conducted on the 9th and 10th July 2004. A total of 3025 crabs were sampled of which 54 were identified with external sacs (Table 1).

Onslow

Catch monitoring aboard a commercial blue swimmer crab vessel was carried out in the waters off Onslow on the 6th and 7th July 2004. A total of 1195 crabs were sampled, with only 2 crabs seen to display external sacs (Table 1).

Table 1: Numbers of blue swimmer crabs caught in the waters off the Pilbara coastline during catch monitoring surveys aboard commercial vessels.

Location	Month	Potlifts	No visible parasite NUMBER	Visible parasite NUMBER	PROP'N (%)
Port Hedland	Jul 02	480	704	15	2
Nickol Bay	Aug 03	557	6178	166	3
	Jul 04	300	3025	54	2
Onslow	Jul 04	390	1193	2	0.2

Conclusion

With infestation rates of less than 3 per cent from each of the catch monitoring trips to date, the parasitic barnacle *Sacculina granifera* does not appear to pose any major problem to the blue swimmer crab stocks of the Pilbara coast. Given the low infection rate and the promiscuous nature of male crabs, the effects of parasitic castration on the spawning stock is likely to be minimal. Neither does the presence of the parasite appear to affect the marketability of infected crabs, once the externae has been physically removed.

It must be noted, however, that the monitoring of blue swimmer crab stocks in the region has been limited to one four-day trip a year and is also restricted to the locations where the fishermen were working at the time. Therefore, we must be careful in assuming the results represent all blue swimmer crab stocks in the region. We expect to monitor the Pilbara crabs in the future to develop a more thorough understanding of the parasite and its effects on the blue swimmer crab populations of the Pilbara coast.

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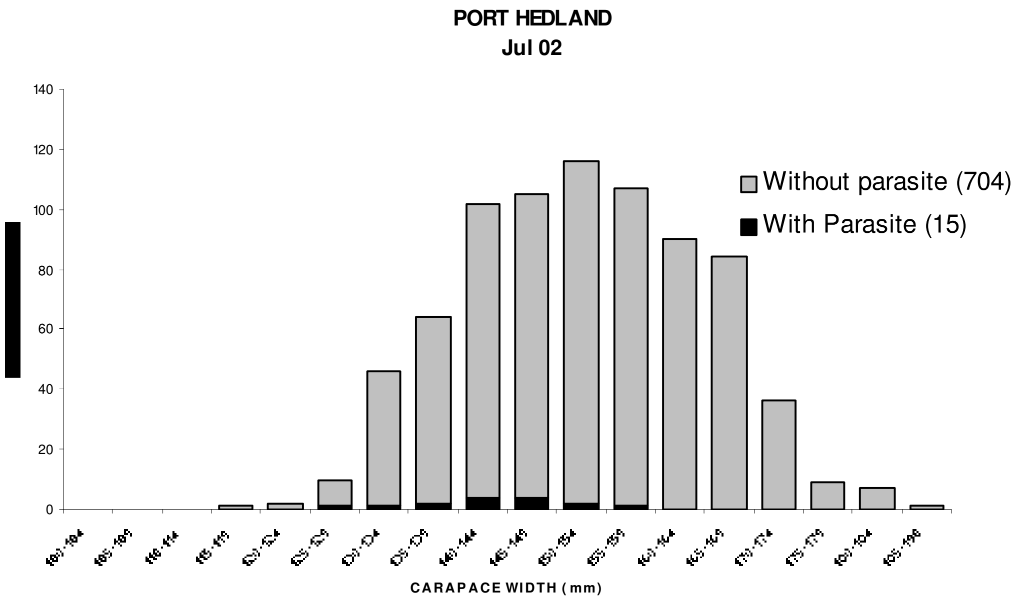


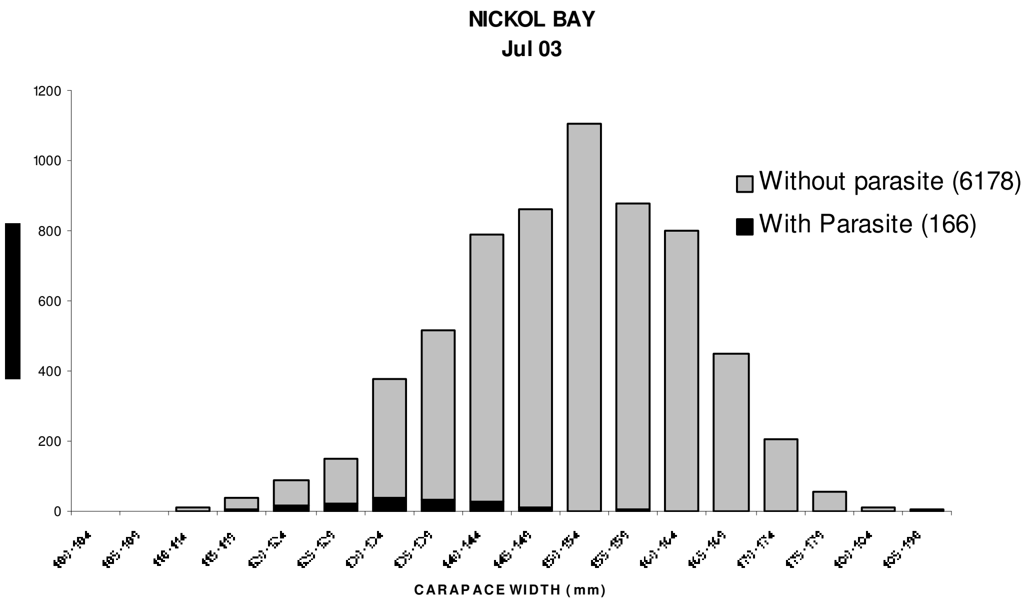
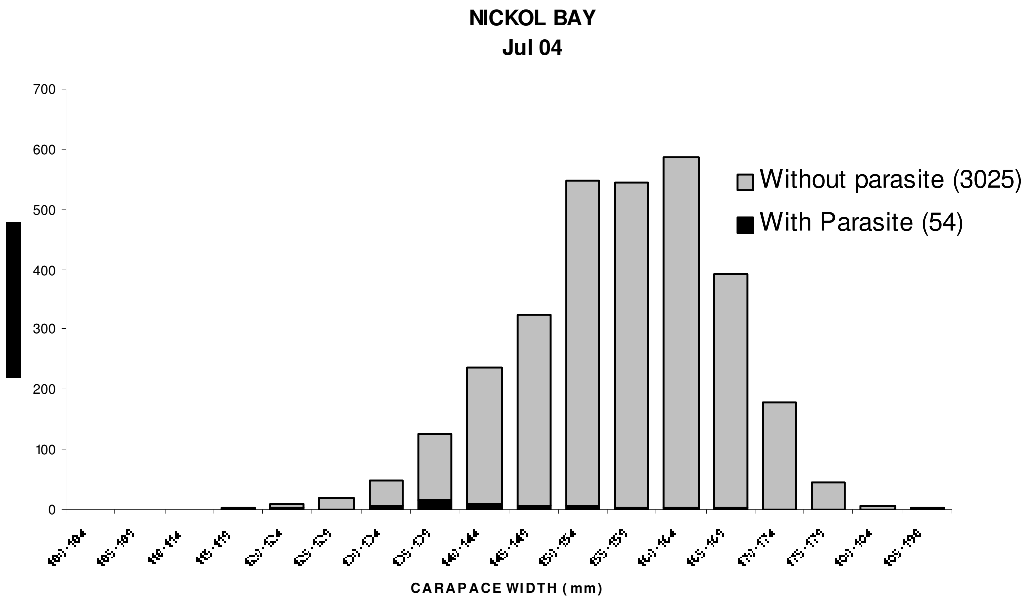


Figure 4: Length frequency of blue swimmer crabs with externally visible *Sacculina granifera* caught during catch monitoring in Port Hedland, Western Australia.



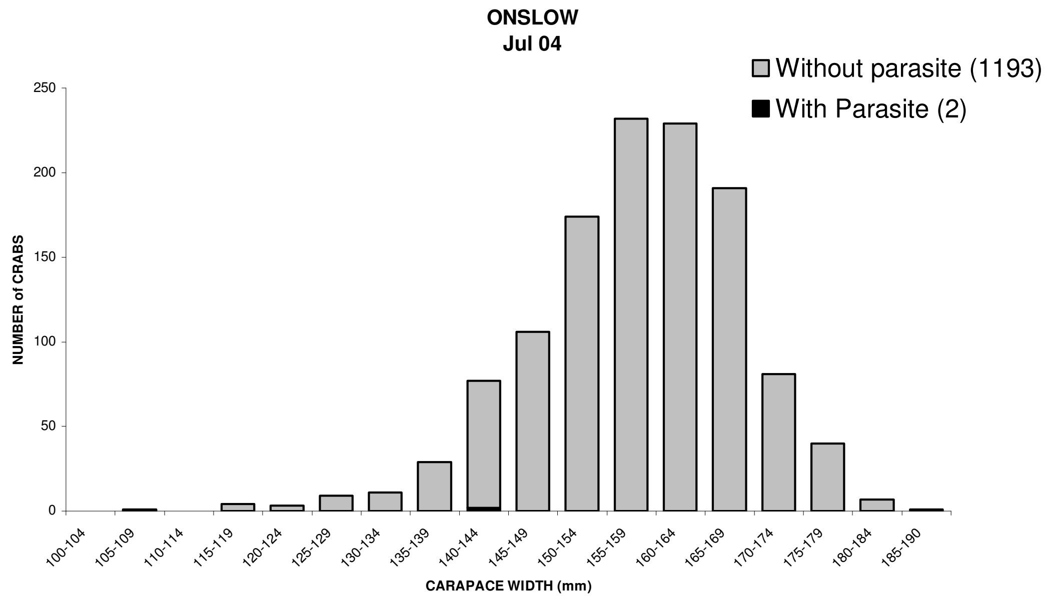


Figure 5: Length frequency of blue swimmer crabs with externally visible *Sacculina granifera* caught during catch monitoring in Port Hedland, Western Australia.

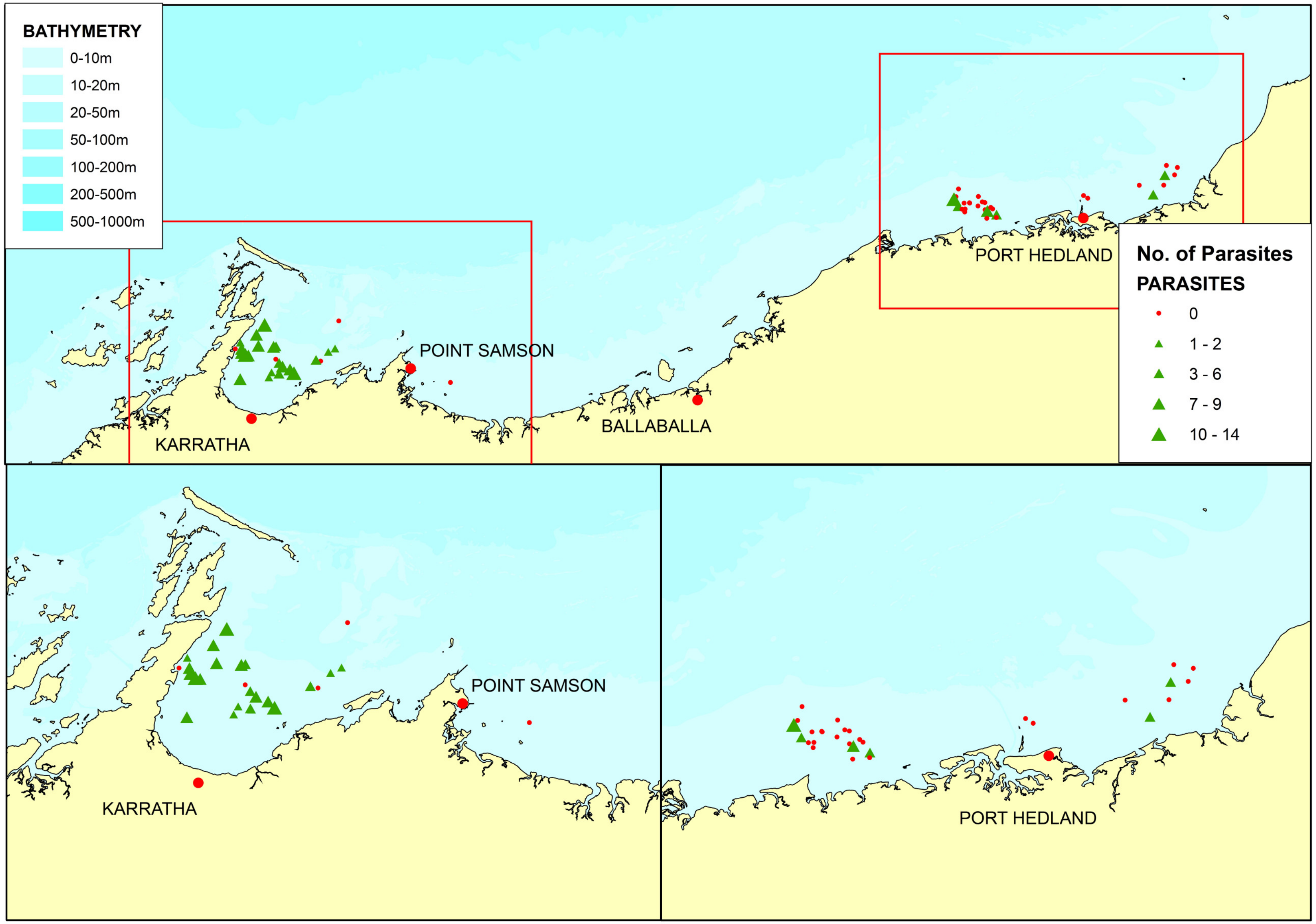


Figure 6. Spatial distribution of blue swimmer crabs bearing visible *Sacculina granifera* externae, caught during catch monitoring surveys aboard commercial vessels in the waters of the Pilbara coast between 2002-2004.

APPENDIX IV

Catches in the Northern and Exmouth Blue Swimmer Crab Fisheries

Table 1 Annual catch (kg) of commercial fishers operating in the Northern Blue Swimmer Crab Fishery from 1991-2004.

		CAES BLOCK									
YEAR	**METHOD**	**1918**	**1919**	**2015**	**2016**	**2017**	**2018**	**2019**	**2115**	**2116**	**TOTAL**
1991	**TW**			0.3	1.0	0.2			0.6		2.0
1992	**TW**	0.2			0.4	1.6	0.2		0.3		2.7
1993	**TW**		0.04	1.0	0.6	3.4	0.1	0.1	0.01		5.2
1994	**TW**			0.6	0.2	1.7	0.03	0.03			2.6
1995	**TW**		0.2	2.5	0.8	1.9	0.1		0.3		5.9
1996	**TW**	0.05	0.0	0.4	0.1	0.3					0.9
1997	**TW**		0.0	0.2	0.2	0.7			0.1		1.3
1998	**TW**	0.1		0.3	0.6	0.7	0.2		1.8		3.7
1999	**TW**	0.1		0.0	0.8	0.4	0.1		0.1		1.6
2000	**TW**		0.1	0.0	0.4	1.1	0.2		0.5		2.4
2001	**PT**				0.6	1.0	8.3				9.9
	TW			0.1	0.1	0.1			1.2		1.4
2002	**PT**	0.9	1.6		4.1	10.2	31.3				48.1
	TW			0.2	1.4	1.0			0.9		3.6
2003	**PT**			4.2	18.0	22.8			19.2		64.2
	TW			0.1	0.2	0.1			1.3		1.7
2004	**PT**				12.8	12.8			22.3	1.2	49.1
	TW				1.8	0.8	0.2		1.4		4.1

Table 2 Annual catch (tonnes) and effort of commercial fishers operating in Exmouth Gulf from 1991-2004.

		CAES BLOCK 2114				2214				TOTAL			
YEAR	METHOD	CATCH (t)	No of VESSELS	FISHER DAYS	TRAP LIFTS	CATCH (t)	No of VESSELS	FISHER DAYS	TRAP LIFTS	CATCH (t)	No of VESSELS	FISHER DAYS	TRAP LIFTS
1991	**PT**	0.2	1	15	900	0.2	1	16	960	0.5	2	31	1860
	TW	3.8	15	1723		7.8	12	639		11.6	27	2362	
1992	**PT**					0.6	1	12	360	0.6	1	12	360
	TW	4.3	16	1630		6.9	14	1052		11.2	30	2682	
1993	**TW**	4.1	15	884		3.7	13	1527		7.8	28	2411	
1994	**GN**					0.1	1	27		0.1	1	27	
	TW	36.8	17	2808						36.8	17	2808	
1995	**GN**					0.02	1	10		0.02	1	10	
	PT					0.2	2	49	445	0.2	2	49	445
	TW	21.1	17	2861		0.7	1	138		21.9	18	2999	
1996	**FT**	0.3	1	25	1375					0.3	1	25	1375
	GN					0.5	1	58		0.5	1	58	
	PT	0.2	1	2	80	0.2	1	3	120	0.5	2	5	200
	TW	14.9	18	2542		3.9	16	224		18.8	34	2766	
1997	**PT**	2.3	1	6	480	4.6	1	20	1680	6.9	2	26	2160
	TW	20.9	18	3132		0.3	1	60		21.2	19	3192	
1998	**PT**	1.8	1	7	350	6.7	1	24	2630	8.5	2	31	2980
	TW	32.6	17	2982		0.5	1	75		33.1	18	3057	
1999	**PT**					3.2	1	18	2370	3.2	1	18	2370
	TW	43.2	17	2869		0.2	1	23		43.4	18	2892	
2000	**PT**	0.9	1	4	600	2.9	1	20	2150	3.9	2	24	2750
	TW	6.1	14	2364						6.1	14	2364	
2002	**TW**	17.2	14	2247						17.2	14	2247	
2003	**TW**	2.7	10	305		18.6	12	2097		21.3	22	2402	
2004	**PT**	0.5	1	6	600	1.5	1	18	1400	2.0	2	24	2000
	TW	15.1	13	830		0.5	1	27		15.6	14	857	

APPENDIX V

GLM analysis of Shark Bay catch rates

This section contains the standardised catches from CAES, logbook and monitoring data in Shark Bay. It shows the least square means (LSM) output from the ANOVA on the standardized catch rates for Shark Bay.

Table 1 LSMs for the effects of month upon catch rate of blue swimmer crabs recorded in CAES in Shark Bay.

Month	Value	s.e.
Jan	1.17	0.07
Feb	1.50	0.07
Mar	1.71	0.07
Apr	1.49	0.07
May	1.95	0.06
Jun	1.58	0.06
Jul	1.39	0.07
Aug	1.15	0.06
Sep	1.16	0.06
Oct	1.21	0.06
Nov	1.21	0.06
Dec	1.09	0.06

Table 2 LSMs for the effects of year upon catch rate recorded in CAES of blue swimmer crabs in Shark Bay.

Month	Value	s.e.
1998	0.87	0.07
1999	1.04	0.06
2000	1.54	0.07
2001	1.33	0.05
2002	1.85	0.06
2003	1.60	0.06
2004	1.52	0.08

Table 3 LSMs for the effect of different water depths upon the catch rate of log-transformed legal size blue swimmer crabs in Shark Bay and recorded in logbooks.

Depth (m)	**Value**	s.e.
0-5	1.49	0.02
5-10	1.49	0.02
10-15	1.66	0.02
15-20	1.53	0.02
20+	1.36	0.03

Table 4 LSMs (and standard error) for each month of the logbook program of log-transformed catch rate of legal-size crabs in Shark Bay.

Month / Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1999	-	-	-	-	2.2(0.06)	2.8(0.06)	2.25(0.0 6)	1.4(0.05)	0.9(0.04)	0.7(0.05)	1.2(0.04)	1.25(0.0 5)
2000	-	0.7(0.17)	1.6(0.06)	2.3(0.07)	2.6(0.06)	1..3(0.12	1.9(0.06)	2.0(0.06)	-	0.9(0.3)	1.8(0.06)	1.9(0.08)
2001	-	-	1.9(0.05)	1.7(0.04)	2.7(0.04)	2.2(0.04)	1.5(0.04)	0.9(0.03)	0.7(0.03)	1.1(0.03)	1.5(0.04)	1.2(0.05)
2002	-	-	-	-	-	-	0.3(0.05)	1.7(0.04)	1.8(0.05)	1.5(0.19)	0.4(0.04)	1.3(0.05)
2003	2.5(0.04)	2.9(0.04)	3.1(0.04)	2.3(0.05)	2.0(0.05)	1.0(0.04)	1.4(0.03)	0.8(0.05)	0.8(0.05)	0.6(0.06)	1.6(0.03)	1.5(0.04)

Table 5 LSMs of the catch rate of berried crabs for each month of the logbook program in Shark Bay.

Month / Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1999	-	-	-	-	0.8(0.1)	0.6(0.09)	1.0(0.08)	0.8(0.08)	0.9(0.07)	0.4(0.07)	0.3(0.07)	0.3(0.07)
2000	-	0.0(0.16)	0.4(0.08)	0.4(0.09)	0.6(0.09)	0.2(0.12)	0.2(0.08)	-	-	0.1(0.27)	-	-
2001	-	-	0.0(0.09)	-	-	-	-	1.0(0.16)	0.8(0.19)	-	-	-
2002	-	-	-	-	-	-	1.1(0.19)	1.0(0.16)	1.0(0.16)	-	-	-
2003	-	-	-	-	-	0.0(0.16)	0.0(0.09)	0.2(0.1)	0.1(0.11)	0(0.11)	0.1(0.10)	0.1(0.10)

Table 6 LSMs of the log-transformed catch rate of undersize crabs in Shark Bay for each month of the logbook program.

Month / Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1999	-	-	-	-	2.2(0.09)	2.9(0.08)	2.0(0.08)	1.1(0.08)	0.9(0.07)	0.4(0.07)	0.6(0.07)	0.7(0.08)
2000	-	0.3(0.16)	1.2(0.07)	3.3(0.08)	4.4(0.08)	0.7(0.12)	1.1(0.08)	-	-	0.8(0.27)	-	-
2001	-	-	0.9(0.08)	-	-	-	-	1.6(0.19)	1.5(0.31)	-	-	-
2002	-	-	-	-	-	-	-	-	-	-	-	-
2003	-	0.7(0.09)	-	-	-	0.4(0.12)	1.1(0.09)	1.4(0.1)	0.8(0.11)	1.0(0.11)	0.7(0.09)	0.5(0.01)

Table 7 LSMs for the effect of different water depths upon the log-transformed catch rate of undersize blue swimmer crabs as recorded in commercial logbooks in Shark Bay.

Depth (m)	**Value**	s.e.
0-5	1.41	0.03
5-10	1.29	0.03
10-15	1.00	0.03
15-20	1.14	0.04
20+	0.84	0.06

Table 8 Year LSMs for legal size male crabs in the commercial length monitoring program from Shark Bay.

Year	Value	s.e.
1999	2.04	0.17
2000	4.48	0.13
2001	4.41	0.10
2002	3.58	0.07
2003	3.03	0.07
2004	2.11	0.12

Table 9 Contrasts for season, latitude and depth for the catch rates of legal sized male crabs (commercial catch monitoring) in Shark Bay.

Season	Depth\Lat	[24º50',25º)	[25º,25º10')	[25º10',25º20')	[25º20',25º30')
Autumn	0-5	-	-	-	-
	5-10	3.98(0.31)	9.96(0.28)	-	-
	10-15	5.62(0.11)	6.37(0.21)	7.65(0.2)	-
	15+	6.28(0.16)	7.07 (0.4)	-	-
Spring	0-5	4.72(0.2)	5.33(0.12)	4.28(0.24)	-
	5-10	1.92(0.26)	3.46(0.16)	-	0.69(0.57)
	10-15	2.28(0.31)	-	4.91(0.17)	2.61(0.19)
	15+	1.79(0.19)	3.37(0.25)	5.73(0.39)	-
Summer	0-5	-	1.71(0.25)	3(0.25)	-
	5-10	-	-	-	-
	10-15	-	-	3.54(0.18)	3.28(0.24)
	15+	0.32(0.15)	0.62(0.14)	1.09(0.13)	0.69(0.2)

Table 10 Year LSMs for legal size (non-berried) female crabs in the commercial length monitoring program in Shark Bay.

Year	Value	s.e.
1999	0.29	0.13
2000	0.50	0.10
2001	0.66	0.08
2002	0.48	0.06
2003	0.39	0.06
2004	0.83	0.09

Table 11 Contrasts for season, latitude and depth for the catch rates of legal sized (non-berried) female crabs (commercial catch monitoring) in Shark Bay.

Season	Depth\Lat	[24º50',25º)	[25º,25º10')	[25º10',25º20')	[25º20',25º30')
Autumn	0-5	-	-	-	-
	5-10	0.24(0.24)	-0.01(0.22)	-	-
	10-15	0.44(0.08)	0.35(0.16)	0.12(0.15)	-
	15+	0.81(0.12)	0.58(0.3)	-	-
Spring	0-5	0.83(0.16)	0.46(0.09)	0.75(0.18)	-
	5-10	1.08(0.2)	0.68(0.12)	-	0.42(0.43)
	10-15	0.64(0.24)	-	0.81(0.13)	0.91(0.15)
	15+	0.9(0.15)	1.18(0.2)	1.24(0.3)	-
Summer	0-5	-	0.24(0.19)	0.37(0.19)	-
	5-10	-	-	-	-
	10-15	-	-	0.12(0.14)	0.24(0.19)
	15+	0.3(0.12)	0.4(0.11)	0.3(0.11)	0.4(0.16)

Table 12 Year contrasts for sexually mature female crabs (commercial catch monitoring) in Shark Bay.

Year	Value	s.e.
1999	0.48	0.14
2000	0.89	0.11
2001	1.5	0.08
2002	0.90	0.06
2003	0.87	0.06

Table 13 Contrasts for season, latitude and depth for the catch rates of sexually mature female crabs (commercial catch monitoring) in Shark Bay.

Season	Depth\Lat	[24º50',25º)	[25º,25º10')	[25º10',25º20')	[25º20',25º30')
Autumn	0-5	-	-	-	-
	5-10	0.51(0.22)	0.08(0.2)	-	-
	10-15	0.64(0.07)	0.48(0.15)	0.25(0.14)	-
	15+	1.44(0.11)	0.86(0.27)	-	-
Spring	0-5	1.29(0.14)	0.92(0.08)	1.42(0.17)	-
	5-10	2.25(0.18)	1.28(0.11)	-	0.75(0.38)
	10-15	1.13(0.22)	-	2.23(0.12)	2.18(0.14)
	15+	2.09(0.13)	2.28(0.18)	3.13(0.27)	-
Summer	0-5	-	10.95(0.17)	1.03(0.17)	-
	5-10	-	-	-	-
	10-15	-	-	0.23(0.13)	0.42 (0.17)
	15+	0.35(0.11)	0.64(0.1)	0.87(0.09)	0.72(0.14)

Table 14 Year contrasts for sexually mature male crabs (commercial catch monitoring) in Shark Bay.

Year	Value	s.e.
1999	2.38	0.13
2000	6.04	0.10
2001	6.26	0.08
2002	4.44	0.06
2003	4.04	0.06

Table 15 Contrasts for season, latitude and depth for the catch rates of sexually mature male crabs (commercial catch monitoring) in Shark Bay.

Season	Depth\Lat	[24º50',25º)	[25º,25º10')	[25º10',25º20')	[25º20',25º30')
Autumn	0-5	-	-	-	-
	5-10	5.87(0.2)	13.51(0.18)	-	-
	10-15	7.35(0.07)	8.20(0.14)	8.45(0.13)	-
	15+	7.66(0.1)	8.97(0.25)	-	-
Spring	0-5	5.99(0.13)	7.40(0.08)	5.97(0.15)	-
	5-10	2.67 (0.17)	4.76(0.1)	-	0.74(0.35)
	10-15	3.04(0.2)	-	6.54(0.11)	3.42(0.13)
	15+	2.4(0.12)	4.41(0.16)	7.75(0.25)	-
Summer	0-5	-	3.12(0.16)	4.18(0.16)	-
	5-10	-	-	-	-
	10-15	-	-	4.41(0.12)	3.69 (0.16)
	15+	0.36(0.1)	0.86(0.09)	1.85(0.09)	1.12(0.13)

Table 16 LSMs for year for the catch rate of berried females (commercial catch monitoring) in Shark Bay.

Year	Value	s.e.
1999	0.16	0.08
2000	0.40	0.06
2001	0.08	0.04
2002	0.39	0.04
2003	0.19	0.04

Table 17 LSMs for Season for the catch rate of berried females (commercial catch monitoring) in Shark Bay.

Season	Value	s.e.
Autumn	0.08	0.04
Spring	0.51	0.03
Summer	0.12	0.03

Table 18 LSMs for depth for the catch rate of berried females (commercial catch monitoring) in Shark Bay.

Depth (m)	Value	s.e.
0-5	-0.01	0.05
5-10	0.32	0.03
10-15	0.50	0.04
15+	0.15	0.05

Table 19 Year contrasts for undersize crabs (commercial catch monitoring) in Shark Bay.

Year	Value	s.e.
1999	0.55	0.15
2000	2.63	0.12
2001	3.41	0.09
2002	1.65	0.06
2003	1.79	0.06
2004	1.69	0.11

Table 20 Contrasts for season, latitude and depth for the catch rates of undersize crabs (commercial catch monitoring) in Shark Bay.

Season	Depth\Lat	[24º50',25º)	[25º,25º10')	[25º10',25º20')	[25º20',25º30')
Autumn	0-5	-	-	-	-
	5-10	2.12(0.23)	3.34(0.21)	-	-
	10-15	1.94(0.08)	2.06(0.16)	1.16(0.15)	-
	15+	2.36(0.12)	2.4(0.29)	-	-
Spring	0-5	1.92(0.15)	2.72(0.09)	2.52(0.18)	-
	5-10	3.15 (0.19)	2.11(0.12)	-	0.44(0.41)
	10-15	1.36(0.23)	-	3.72(0.12)	2.68(0.14)
	15+	1.76(0.14)	2.37(0.19)	4.66(0.28)	-
Summer	0-5	-	1.96(0.18)	1.68(0.18)	-
	5-10	-	-	-	-
	10-15	-	-	0.95(0.14)	0.56 (0.18)
	15+	0.16(0.11)	0.82(0.11)	1.78(0.1)	0.99 (0.15)