FRDC PROJECT 98/121

The collection of fisheries data for the management of the blue swimmer crab fishery in central and lower west coasts of Australia.

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NON TECHNICAL SUMMARY

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OBJECTIVES:

1. To establish a logbook and catch monitoring program for the fishery.
2. To establish the effect of trap selectivity/efficiency on the size composition, sex ratio and moult stage of the catch in the two major regions.
3. To establish discard mortality for recreational and commercial fishing methods. Gear methods will include recreational drop netting, commercial trap fishing, tangle netting and trawling.
4. To establish conversion factors for relating the effort for traps to that of the historical tangle nets.
5. To assess the status of the various Western Australian fisheries for blue swimmer crabs, integrating information derived from this and other concurrent FRDC projects.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED

From a management point of view several important outcomes were achieved by this project. Firstly, a detailed logbook and catch monitoring program, in addition to the compulsory catch returns system, were established to ensure the collection of more detailed catch information.

Analysis of three gear types, (traps, seine, net and otter trawl) indicated that there was a significant difference in the catch rate and catch composition i.e. sex and size, according to the sampling method used.

Trials demonstrated that the duration of air exposure and fishing method (potting, gill netting, trawling and recreational dabbing) had a significant effect on the survival of undersize crabs returned to the water.

Yield per recruit models for blue swimmer crabs, in Cockburn sound, indicated that lowering the legal minimum size to approximately 87 mm CW could substantially increase yield. Similarly, egg per recruit analysis indicated that even high fishing mortalities had a minimal effect on fecundity of crabs between 69-81 mm CW. Therefore, yield per recruit in Cockburn Sound is below its maximum at the current legal minimum size of 130 mm CW. However due to market demands altering the current legal minimum size may not be a viable option.

The results of this study in conjunction with parallel studies (FRDC 97/137), on *P. pelagicus,* has provided fisheries managers with detailed biological and fisheries data with which to assess the blue swimmer crab fishery and develop appropriate management strategies.

A voluntary logbook was implemented based on the western rock lobster logbook and distributed to blue swimmer crab fishers in various regions throughout the state. The logbook records date, fishing location, fishing method, number of pots, fishing depth, catch in kg, soak time, numbers of undersize, dead and ovigerous crabs and well as voluntary information on by-catch and weather conditions. Databases for recording and validating the information have been established and summaries have been provided to the participating fishers on a regular basis. A catch monitoring programme, whereby Department of Fisheries research staff board commercial vessels to measure the catch, has also been established to record seasonal size composition, sex ratio and breeding states of blue swimmer crabs in the major areas in the south west. Both the logbook and catch monitoring programmes are ongoing.

The effect of trap selectivity on catch composition, sex ratio and moult stage, was investigated by comparing trap catches of blue swimmer crabs with trawl and beach seine catches. In 1997 several types of gear were trialed for their effectiveness in sampling blue swimmer crabs. The gear trialed included two types of traps with different mesh sizes, 12 mm and 72 mm stretch mesh, a seine net and an otter trawl. There was a significant difference in the catch rate of the two mesh traps, with 72mm traps displaying higher catch rates, catch composition of the two pot types also varied by month. A comparison of seine net and 72 mm mesh trap catches indicated that the total catch of each gear type varied depending on the sampling period. Analysis of the three gear types (72 mm trap, seine net and otter trawl) indicated that there was a significant difference in the catch rate between methods ($p<0.01$) with the seine net having the highest catch rate, catch composition i.e. sex and size also varied according to the sampling method used.

Trials were conducted to determine the survival of undersize crabs after being caught by different fishing methods four different fishing methods: potting, gill netting and trawling and recreational dabbing and returned to the water. For pot trials, the treatment was duration in ice slurry, treatment times of 0, 5, 10, 15 and 20 minutes in slurry were used. Keeping crabs in iced seawater for more than 15 minutes caused mortality rates of 5-20%. In gill net trials, the treatment effect was length of soak time and air exposure for one hour. Nets were left in the water for 24 and 48 hours and survival of the crabs were checked at 24, 48 and 72 hours. A higher level of predation was observed in nets soaked for 48-hours. Subsequent mortality was relatively low from handling and air exposure of up to one hour. Higher levels of damage were observed in trawled crabs compared to other fishing methods. Damaged crabs which had minimal exposure to air (0-19 minutes) had 95-100% survival over 72 hours when returned to the water. The recreational fishing method of scooping caused significant mortality (33-53%) when crabs were exposed to air for 1.5 to 2 hours.

A comparison of catches was made per net length and per trap-day by two commercial fishers in Cockburn Sound, each fishing with a different gear-type in March 1994, it was estimated 112 traps would be required to take a trap catch equivalent to 1,200 m of gill net in Cockburn Sound. A similar comparison using the results of two net and five trap fishers between January and March 1996 in the Peel-Harvey Estuary, showed the net to trap conversion ratio for January to be 40 traps/1,000 m of net. Conversion ratios were also calculated for Cockburn Sound and Peel-Harvey Estuary using monthly compulsory catch and effort returns supplied by commercial trap fishers. Examination has shown in both Peel-Harvey Estuary and Cockburn Sound, that when fishers change their gear from nets to traps that they fish substantially more days (in both areas approximately double) per year. Trap fishers utilise all their gear each day more often than net fishers, who occasionally choose through convenience to work with less than their allowable net allocation.

The fisheries for blue swimmer crab in Western Australia are managed using a minimum legal size that is sufficient to ensure that females reach maturity and spawn prior to reaching legal minimum size. The success of the minimum size regulations in ensuring the maintenance of spawning success was assessed. Information on growth and variability in growth as well as information on fecundity and size at maturity of blue swimmer crabs were derived from biological studies (FRDC project 97/137) and assessed using yield and egg per recruit models. The results indicate that blue swimmer crabs display rapid growth, are highly fecund, and have relatively short life cycle, reaching the current legal size of 130 mm CW within 18 months. The results also indicate that yield per recruit for blue swimmer crabs, in Cockburn Sound, is below its maximum at the current minimum legal size of 130 mm.

KEYWORDS: Blue swimmer crab, gear selectivity, trap, air exposure, survival, yield per recruit.

Acknowledgments

We acknowledge the help and cooperation of commercial blue swimmer crab fishers around the state. We would also like to thanks the numerous friends, colleagues and volunteers who helped collect blue swimmer crabs, assisted with commercial sampling and edited earlier versions of this report. Thanks to Norm Hall and Peter Stephenson for their assistance in developing and modifying the models used in yield and egg per recruit component of this study. We thank FRDC for the funding resources provided.

Background

Blue Swimmer Crab Commercial Fishery

The blue swimmer crab, *Portunus pelagicus* Linnaeus, is abundant in many coastal marine and estuarine waters throughout the Indo-West Pacific (Stephenson, 1962; Kailola *et al.*, 1995). They inhabit a wide range of inshore and continental shelf areas, from the intertidal zone to at least 50 m in depth. The blue swimmer crab supports substantial commercial fisheries and is an important component of many recreational fisheries in Australia and other parts of the world. In Australia, the commercial catches of blue swimmer crabs have been growing rapidly and recent annual catches were in the order of 1800 tonnes (Kumar, 1998), with increased commercial fishing pressure, this figure is likely to increase substantially in the future. In Western Australia, blue swimmer crabs inhabit coastal waters from Albany to the Northern Territory border, with the majority of commercially fished stock concentrated in the coastal embayments between Peel-Harvey in the south and Shark Bay in the north.

In Western Australia, the blue swimmer crab is the basis of an expanding commercial and a key recreational fishery. Commercial catches in this state have risen from 215 tonnes in 1991/1992 to 673 tonnes in 1999/2000, and the industry is currently worth around $2.9 million. During this time, the main commercial fishing methods have been gill-nets, drop nets and pots. Crabs are also taken as a by-catch component of the commercial prawn and scallop trawl activities in the Shark Bay Prawn, Shark Bay Scallop and Exmouth Gulf Prawn Managed Fisheries. There are six key commercial fishing areas for blue swimmer crabs in waters between Exmouth Gulf in the northwest and Albany in the south. Two managed crab fisheries are adjacent to the Perth metropolitan area: Cockburn Sound Managed Crab Fishery and Warnbro Sound Managed Crab Fishery. Other main commercial fishing areas are Shark Bay, Geographe Bay and the south-west estuaries (Swan-Canning, Peel-Harvey and Leschenault) (Figure 1). A small amount of fishing also takes place in the south coast estuaries. Commercial catches of blue swimmer crabs peaked at 740 tonnes in 1997/98 (Figure 2), and have subsequently been reduced through resource sharing initiatives implemented in 1999/2000 to reallocate catches back to the recreational sector.

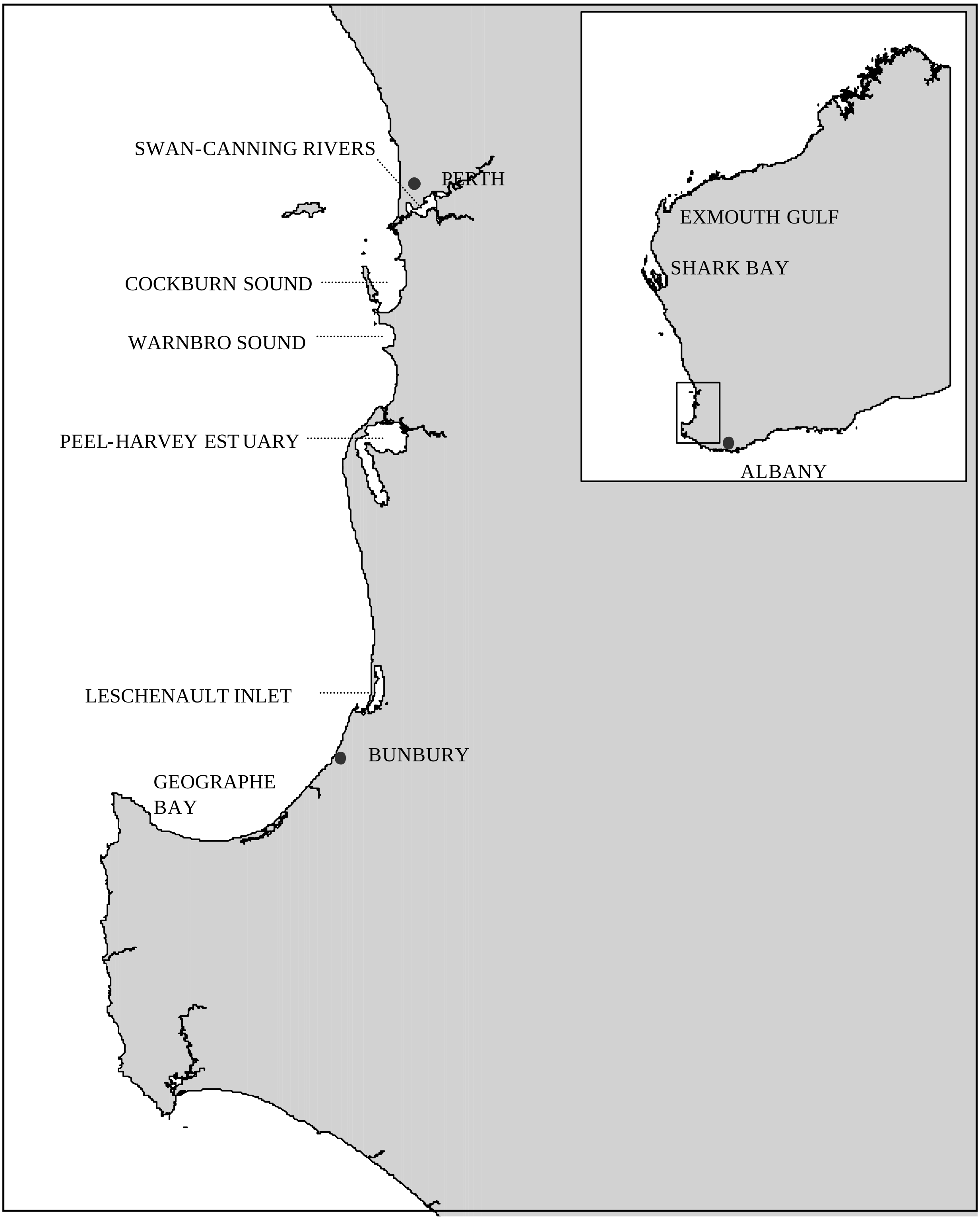

Figure 1: Map of Western Australia displaying major commercial blue swimmer crab fisheries.

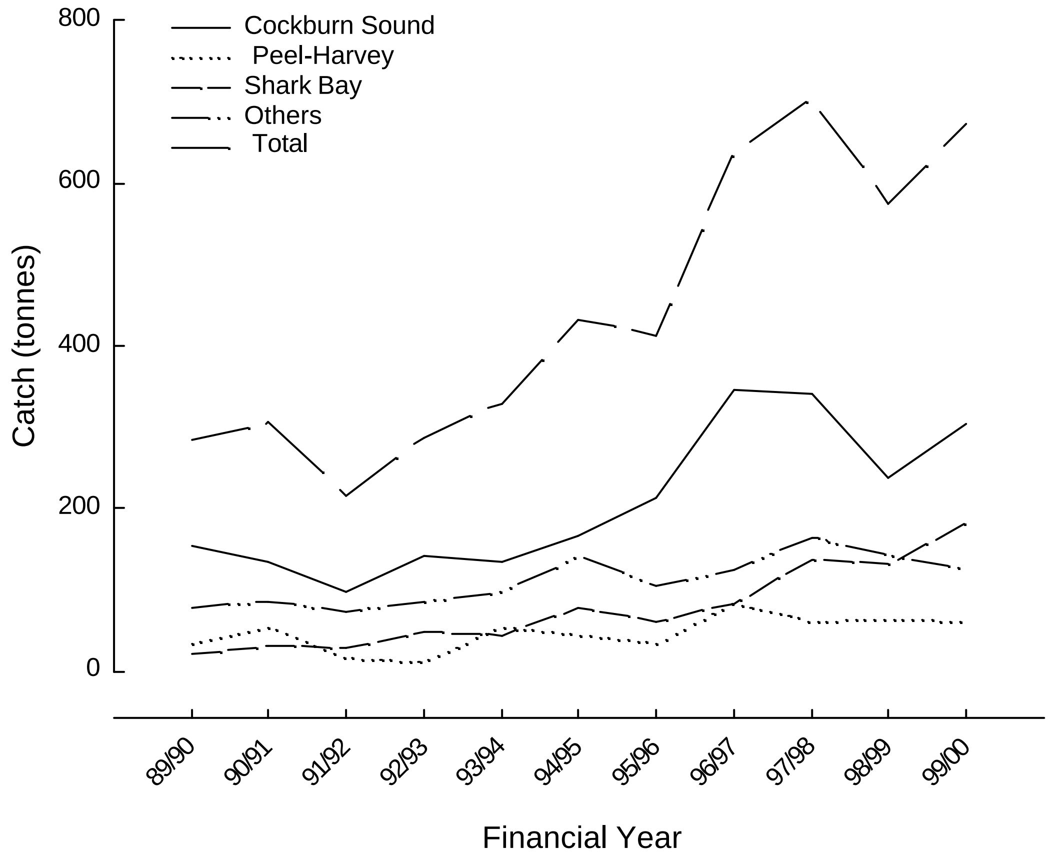

Figure 2: Commercial catch history for the blue swimmer crab (*Portunus pelagicus*) in Western Australia between 1989/90 and 1999/00, indicating main regions of commercial catches.

In Western Australia, high densities of crabs in the more populated south west of the State, south of Perth, have made them a particularly important recreational fishing species (Ayvazian *et al.*, 1997; Sumner *et al.*, 2000), with an estimated 76,000 people participating in the fishery in 1986/87 (Anon., 1989). Recreational fishing for blue swimmer crabs in the southwest of W.A. 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 (Sunmer and Williamson, 1999) and the second most important for shore based fishing (Ayvazian *et al*., 1997). In some areas of the state recreational fishing is more important than commercial. A survey on the recreational take in the Leschenault Estuary conducted in 1998 showed catches of 289 tonnes while the commercial catch for the area was 64 tonnes (Sumner *et al*., 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.

Management strategies currently in place for the commercial blue swimmer crab fishery in WA include; gear restrictions, a minimum carapace width (CW) (the distance between the tips of the two lateral spines of the carapace) of 127 mm (with special limits of 128 mm CW for Geographe Bay, 130 mm for Cockburn Sound and 135 mm for Carnarvon) and a requirement to return all berried females to the water. Recreational restrictions include all of the above (with a size limit of 127 mm CW for all areas) in addition to bag limits of 24 crabs per day per individual and 48 crabs per day per boat. These measures are in place to ensure a sustainable fishery. The minimum legal size is above the size at which 50% of females attain sexual maturity (Potter and de Lestang, 2000) and therefore allows females to spawn at least once.

Blue Swimmer Crab Biology

To date the biological knowledge of blue swimmer crabs has been generally limited to small regions of the coastline, particularly estuaries, and may not be representative of all regions now exploited or under consideration for future exploitation. In WA most research has been carried out in estuaries (Meagher, 1970; 1971; Potter *et al.*, 1983; Potter *et al.*, 1988; Potter and de Lestang, 2000) with only two studies in the marine embayments of Cockburn Sound (Penn, 1977) and Koombana Bay (Meagher, 1971) and one dietary study in the more open waters at Cliff Head (Edgar, 1990).

Given the lack of biological information available, the rapid increase in commercial catches and the high participation in the fishery by recreational fishers, in W.A., a number of research programs were instigated in 1998 under the umbrella of the National collaborative Blue Swimmer Crab Research Programme to address key biological parameters and collect fishery dynamics information required for stock assessments in the future.

1. Genetic (microsatellite) determination of stock structure of the blue swimmer crab in Australia (FRDC 98/118)

2. The collection of biological data required for management of the blue swimmer crab fishery in the central and lower west coasts of Australia (FRDC 97/137)

3. Estimating the recreational catch of blue swimmer crab in the south west of western Australia (FRDC 98/119)

4. The collection of fisheries data required for management of the blue swimmer crab fishery in the central and lower west coasts of Australia (FRDC 98/121)

Need

The rapid expansion of the commercial fishery and increased recreational effort focused on blue swimmer crab stocks have heightened the need to obtain more detailed information on the biology and exploitation of *P. pelagicus* in WA. While a number of studies have been undertaken on *P. pelagicus* both in southwestern WA and nationally, research on blue swimmer crab fisheries in Australia has to date been limited. This is primarily due to the relatively low size and value of commercial crab fisheries compared to other fisheries such as prawns, rock lobster and abalone. Due to increased interest, exploitation and likelihood of further development of blue swimmer crab fisheries in Western Australia this project was essential for the provision of fisheries data for the effective management of blue swimmer crab stocks.

Objectives

1. To establish a logbook and catch monitoring programme for the fishery.

2. To establish the effect of trap selectivity/efficiency on the size composition, sex ratio and moult stage of the catch in the two major regions.

3. To establish discard mortality for recreational and commercial fishing methods. Gear methods will include recreational drop netting, commercial trap fishing, tangle netting and trawling.

4. To establish conversion factors for relating the effort for traps to that of the historical tangle nets.

5. To assess the status of the various Western Australian fisheries for blue swimmer crabs, integrating information derived from this and other concurrent FRDC projects.

Development of a logbook and catch monitoring program for the *P. pelagicus* commercial fishery on the south west coast of Western Australia.

Bellchambers, L. M.

Introduction

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. However, while this is useful information for managing fisheries, it has limited use for scientific research, as monthly returns do not allow a detailed analysis of smaller scale trends. 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 a more detailed and accurate information for research purposes. The research logbook gives more detail on daily catches, discards (undersize, egg bearing, other), any by-catch and average size of crabs (male and females) caught per week. Participation in the logbook program was voluntary and preliminary logbooks were issued to blue swimmer crab fishers during late 1998 and early 1999 to assess its suitability and ease of use. Comments from fishers were incorporated and revised logbooks were issued to volunteer fishers in April - May 1999.

The volunteer logbook was supplemented by a commercial catch monitoring system, where Department of Fisheries research staff boarded commercial fishing vessels at various frequencies, depending on the area (Table 1), to record monthly or seasonal size composition, sex ratio, breeding condition of animals and various environmental factors, such as salinity and water temperature, in the major areas of the fishery. Catch monitoring commenced in December 1998 in Peel-Harvey and the Swan River and in January 1999 in Cockburn Sound and is ongoing.

Table 1: Sampling frequency of catch monitoring in bodies on lower south and central coast.

Location	Sampling Frequency
Cockburn Sound	3 times per month
Peel-Harvey	2 times per month
Swan River	Every 4 months
Comet Bay	Every 6 months
Carnarvon	Every 3 months
Geographe Bay	Every 4 months

Methods

Preliminary analysis of logbook data

All data collected from both the voluntary logbook and the catch-monitoring program are stored electronically in purpose-designed databases. The databases were developed in Microsoft® Access 2000.

To eliminate discrepancies, which may have occurred, logbook data was validated with the relevant CAES (Catch and Effort Statistics) data, where significant discrepancies occurred between the two data sets that would not be corrected by checking the originals of both the logbook and CAES the corresponding data was omitted from the analysis. The data was then analysed using Microsoft® S-Plus 2000. Normality was assumed for each variable and a linear model was fitted, using month and region as factors. Year was not considered as a factor due to insufficient data.

The model was as follows:

$$y_{ij} = a + \alpha_i + \beta_j + \varepsilon_{ij}$$

Where;

- y_{ij} is the variable being considered, for region i in month j,
- a is a constant to be determined,
- α_i is the effect due to region (i= Carnarvon, Peel-Harvey and Geographe Bay),
- β_j is the effect due to month (j=Jan,…,Dec) and
- $\varepsilon_{ij} \sim N(0,\sigma^2)$

Preliminary analysis of commercial length monitoring data

Analysis of the length monitoring data tested the effects of a number of factors, vessel, year, month, soak time, temperature and salinity, on the proportion of the catch to obey a particular property (i.e. legal size). Region has not been considered in the analysis as each vessel fished in only one region.

The properties of the catch being considered have been modeled on the factors using a generalized linear model (glm) with a logit link function. The probability of a particular crab having the characteristic under consideration (i.e. legal size) was assumed to follow a binomial distribution. That is, the

$$\log it(p_{ijtk}) = a + b^*\omega_{ijt} + \alpha_i + \beta_j + \theta_t + \tau_k + \alpha\theta_{it} + \varepsilon_{ijkt}$$

where

- p_{ijkt} is the proportion of the catch, that meets a particular characteristic (i.e. legal size), for region i, year j and soak time k;
- ω_{ijt} is the average water temperature, in degrees, for region i in year j and month t;
- b is some constant coefficent, indicating the effect of temperature on $\log it(p_{ijkt})$, to be determined;
- a is some constant to be determined;
- α_i is the effect of region i= Carnarvon, Cockburn Sound, Comet Bay, Geographe Bay and Peel Harvey ;
- β_j is the effect of year j=1999,2000, and 2001;
- θ_t is the effect of month t=January,…,December;
- τ_k is effect of soak time k=10,12,15,24,48;
- $\alpha\theta_{it}$ is the effect of the interaction between region i and month t;
- $\log it(p_{ijkt}) = \frac{p_{ijkt}}{1 - p_{ijkt}}$; and
- $\varepsilon_{ijkt} \sim N(0, \sigma^2)$

The interaction between region and month was the only level of interaction considered due to sample size (n=105).

Results and Discussion

Voluntary Logbook

Blue swimmer crabs caught using hourglass pots contributed the majority of the catch recorded in logbooks (hourglass pots = 300.4 tonnes, rectangular pots = 3.9 tonnes, set nets = 10.5 tonnes), therefore the preliminary statistical analysis of the logbook data has focused on this method of capture. Similarly, the regions analysed in this component of the study were restricted to Carnarvon, Geographe Bay and Peel Harvey, due to limited logbook returns in other regions. The analysis of the catches from hourglass pots (total catch, total effort and catch rates, by month and region) is presented for each year of the logbook program to date (Figure 3). As the daily catch rates, by month and region, are normally distributed a linear model was used to model the monthly catch rates.

Logbook data indicates that Carnarvon catches, in tonnes, are consistently higher than catches in other regions, although large fluctuations in catch occur throughout the year. Similarly effort (expressed as 1000 of potlits) is also highest in the Carnarvon fishery, with periods of high catch corresponding to periods of high effort. The differences in catch and effort between the two regions can in part be explained by the number of pots operated by the fishers, Carnarvon fishers operate 200 pots each while fishers in Peel Harvey have 42 pots. However, when the data is examined in terms of catch rate (kg/potlift) the values for Carnarvon (1.41 kg/pot) and Peel Harvey (1.23 kg/pot) were not dissimilar (Figure 4). It also appears that periods of high catch rates in Carnarvon are mirrored by periods of low catch rates in Peel Harvey and vice versa.

The linear model suggests that logbook catch rate is independent of both region ($p=0.40$) and month ($p=0.33$). A Kolmogorov-Smirnov test on the residuals of this model concluded that there is sufficient information to suggest that the residuals are not normally distributed ($p=0.5$). However, there was insufficient data to test for the interaction of factors. The small number of data points may have caused a significant factor to be falsely accepted as non-significant. As there are substantial logbook returns for Carnarvon a linear model, with month as a factor, was constructed for this region.

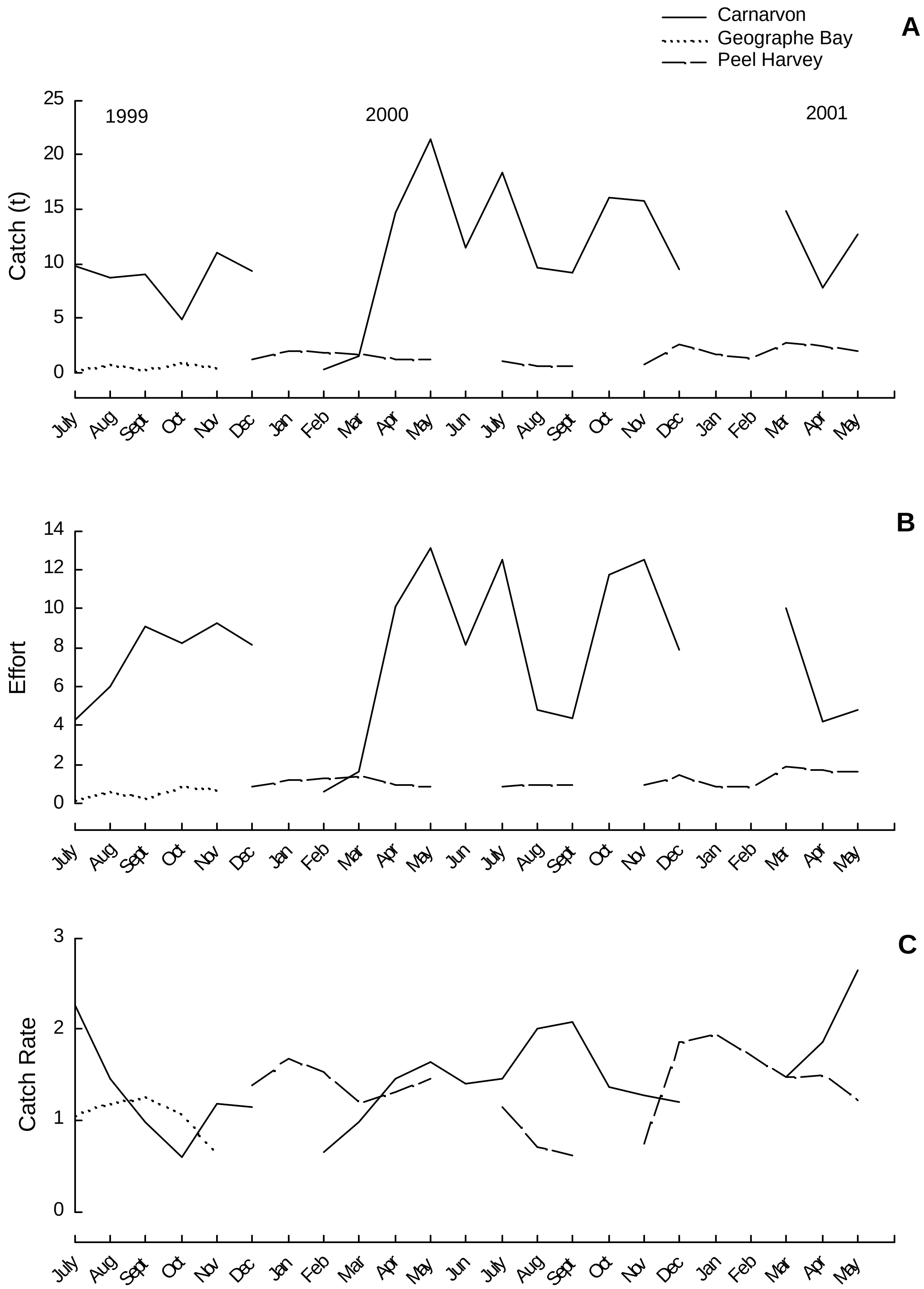

Figure 3: A) Total catch (tonnes), B) Effort (1000 of pot lifts) and C) Catch rate (kg/pot lift) for each region.

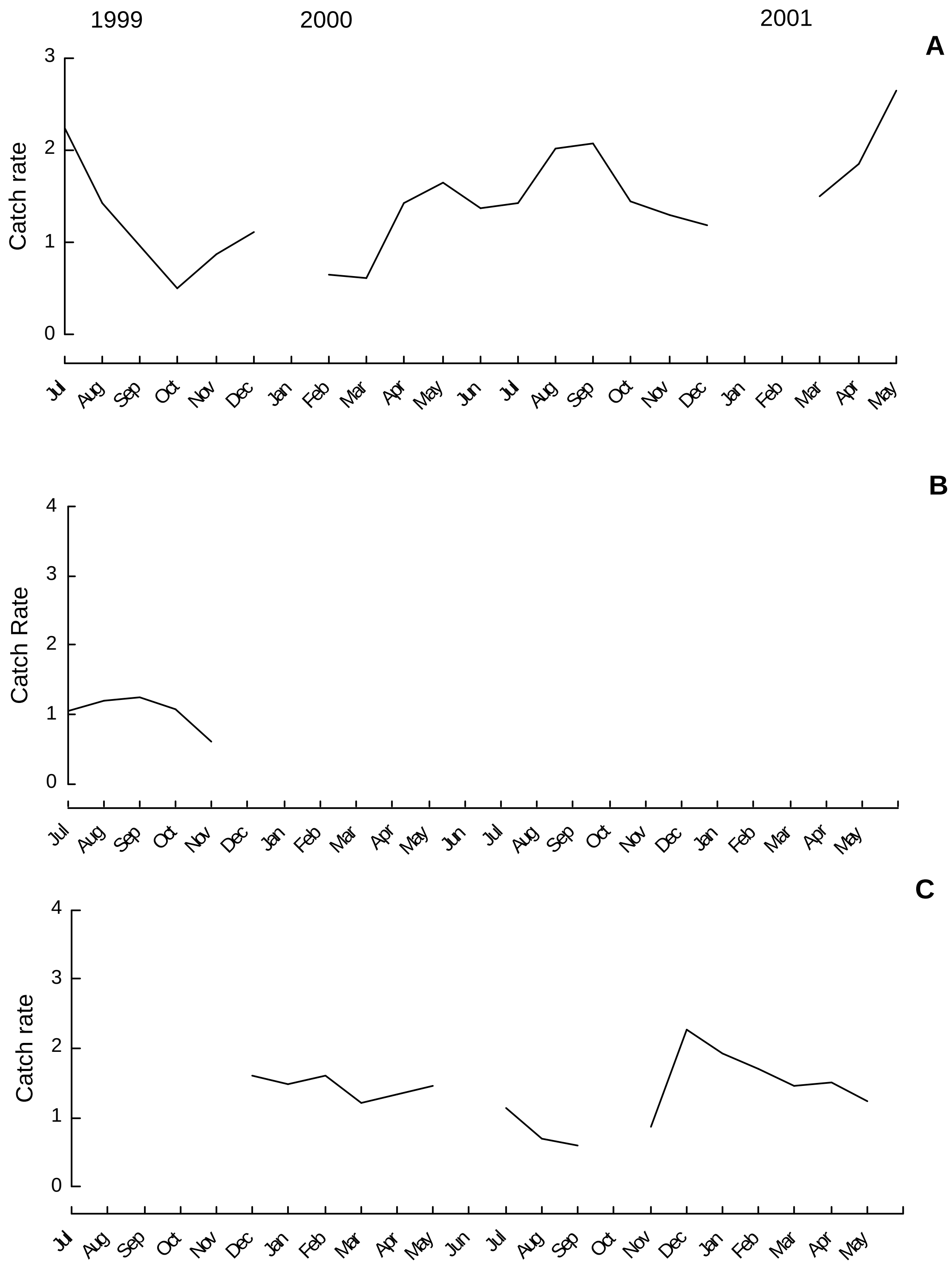

Figure 4: Plot of the mean daily catch rate (kg/potlift)from logbook data for 1999-2001, by region. A) Carnarvon B) Geographe Bay C) Peel Harvey

The model suggests that there is no interaction between month and region (p=0.35). However, it must be noted that fitting the same model to the data for Peel Harvey, concluded that there is an interaction between month and region. (p=0.02).

As the most comprehensive logbook records are available for Carnarvon, a quality control chart was applied to the data (Figure 5). A quality control chart with upper and lower limits allows fisheries managers to detect an unusual catch rate, based on the fisheries history, thereby allowing reassessment of the fishery. The maximum and minimum chart (Figure 5) indicates that while never dropping below the lower limit the catch rates in the Carnarvon fishery have exceeded the upper limit in the months of April to May 2001. However, due to the short history of the fishery such charts must be used with caution.

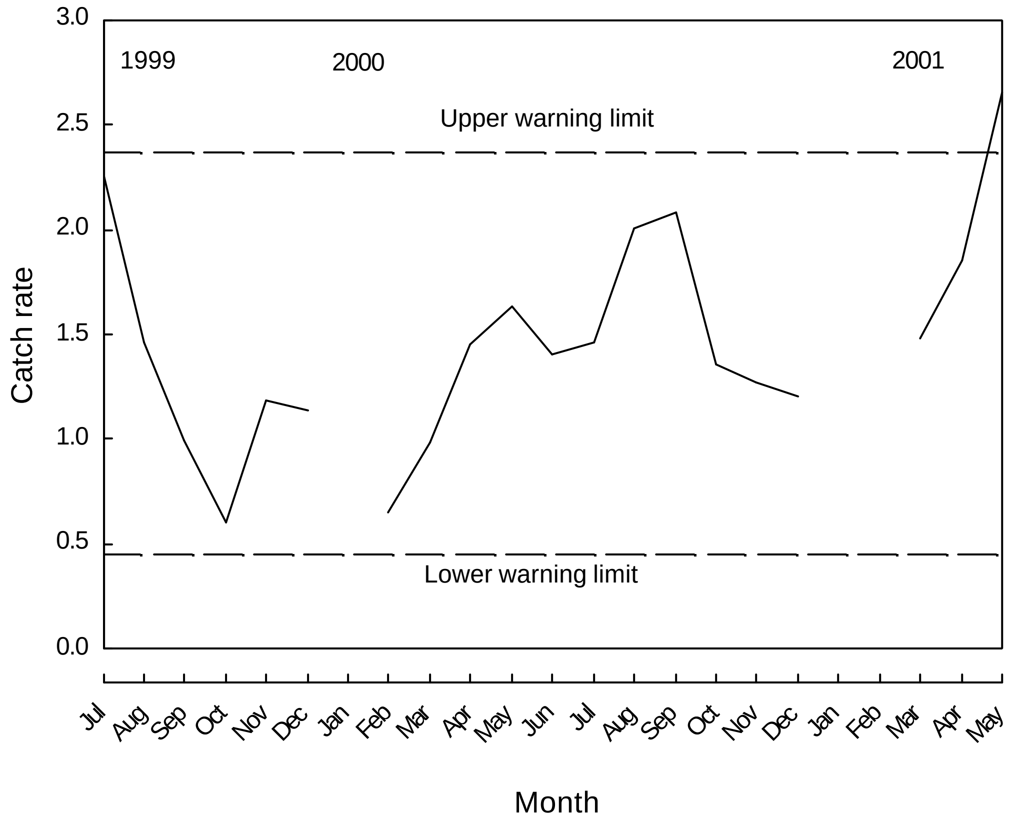

Figure 5: Catch rate (kg/potlift) of blue swimmer crabs in Carnarvon from logbook data for 1999 - 2001, with upper and lower warning limit.

Commercial vessel catch monitoring

Catch monitoring data indicates that in comparison to the other regions sampled catches in Carnarvon displayed the highest proportion of legal size crabs (79%) (Table 2), while Geographe Bay catches displayed the lowest proportion of legal size crabs (37%). In fact, Geographe Bay was the only region sampled in which the legal size component of the catch was less than 50 % of the total catch.

Table 2 Summary of the proportion of the daily catch that is legal sized.

Region	Min	Max	Mean	S.E.
Carnarvon	0.65	0.84	0.79	0.06
Cockburn Sound	0.37	0.94	0.67	0.14
Comet Bay	0.64	0.64	0.64	NA
Geographe Bay	0.32	0.40	0.37	0.05
Peel Harvey	0.35	0.97	0.69	0.17

A stepwise ANOVA indicated that all of the factors tested had a significant effect on the proportion of legal size crabs in the catch (region $p<0.01$, month $p<0.01$, year $p<0.01$ soak time $p<0.01$, temperature $p<0.01$ and month*region $p<0.01$).

The summary of the male proportion of the daily catch, given that the catch is legal sized (Table 3), indicates that Peel Harvey has the highest proportion of legal size males in the catch while Geographe Bay has the lowest proportion. The majority of the catch in both Peel Harvey and Carnarvon was composed of legal size males (89 and 80% respectively). The sex distribution of the catch in Cockburn Sound was closer to parity than the other two regions (67%) however, legal size catches in both Comet Bay and Geographe Bay were heavily dominated by females.

Similarly a step wise ANOVA indicated that all of the factors tested had a significant effect on the proportion of the catch that were legal size males (month $p<0.01$, region $p<0.01$, year $p<0.01$, temperature $p<0.01$, month*region $p<0.01$).

Table 3 Summary of the proportion of the daily catch that is male, given that the catch is legal size.

Region	Min	Max	Mean	s.e.
Carnarvon	0.62	0.95	0.80	0.11
Cockburn Sound	0.13	0.99	0.66	0.25
Comet Bay	0.34	0.34	0.34	NA
Geographe Bay	0.08	0.14	0.11	0.03
Peel Harvey	0.47	1.00	0.89	0.15

The summary of the proportion of the catch that is berried indicates that catches of berried females are highest in Comet Bay and lowest in Geographe Bay. However caution must be used interpreting these results as the regions that were sampled infrequently (Comet Bay, Geographe Bay) may display biases due to seasonal effects on the composition of catches

Table 4 Summary of the proportion of the daily catch that is berried, given that the catch is female.

Region	Min	Max	Mean	s.e.
Carnarvon	0.01	0.37	0.13	0.10
Cockburn Sound	0.00	0.59	0.11	0.14
Comet Bay	0.64	0.64	0.64	NA
Geographe Bay	0.00	0.01	0.01	0.01
Peel Harvey	0.00	1.00	0.09	0.20

Similarly stepwise ANOVA indicated that all the factors tested had a significant effect on the proportion of the daily catch that is berried, given that the catch are female (month $p<0.01$, region $p<0.01$, year $p<0.01$ temperature $p=0.03$, soak time $p<0.01$, month*region $p<0.01$)

The summary of the proportion of the daily catch that is berried, given that the catch is legal sized female (Table 5), indicates that the highest proportion of berried legal size females was evident in Comet Bay catches. In contrast, Geographe Bay catches had few legal size, berried females although the majority of the catch in this region is females (Table 2). Cockburn Sound displayed the largest difference between the minimum and maximum proportions of legal size berried females this may be largely due to the fact that this region has a distinct breeding season (October-February) and berried females are absent from catches the remainder of the year.

Table 5 Summary of the proportion of the daily catch that is berried, given that the catch is legal sized female.

Region	Min	Max	Mean	s.e.
Carnarvon	0.01	0.41	0.14	0.11
Cockburn Sound	0.00	0.52	0.10	0.14
Comet Bay	0.58	0.58	0.58	NA
Geographe Bay	0.00	0.01	0.01	0.01
Peel Harvey	0.00	1.00	0.12	0.30

Similarly stepwise ANOVA indicated that all the factors tested had a significant effect on the proportion of the daily catch that is berried, given that the catch is legal sized female. (month $p<0.01$, region $p<0.01$, year $p<0.01$ temperature $p<0.01$, soak time $p=0.04$ month*region $p<0.01$)

Conclusion

Both the logbook and catch monitoring program have been established for blue swimmer crab fisheries in the major areas on the south west coast.

The value of the logbook data in determining trends in the catches of blue swimmer crabs is at this stage limited due primarily to the length of the dataset. Furthermore the variable number of fishers willing to participate in the program makes determining regional trends difficult. However, those fishers participating in the program regularly return accurate and comprehensive logbook information that will prove invaluable in determining trends once a longer and more comprehensive dataset has been obtained. To improve the value of this data for future monitoring and management of the fishery greater liaison between fisheries and industry is required to encourage a higher rate of participation in areas which until now have been reluctant to participate i.e. Cockburn Sound. There are also plans to incorporate participation in the logbook program as a licensing condition for all new licenses issued.

Data from the catch monitoring program is valuable in determining year-to-year variation in the catch composition. However, for any real comparisons to be made a long term dataset is required to minimize the impact of abnormal trends due to unusual weather patterns or ‘one off events’. The catch monitoring program is ongoing it is expected that trends in catch composition will become more evident as the data set expands.

Sampling selectivity of different gear types on the blue swimmer crab, *Portunus pelagicus*.

Bellchambers, L. M., de Lestang, S. and Thomson, A. W.

Introduction

Various methods are used to target crabs; until the early 1990s the majority of the commercial catch was taken with 152 mm stretch mesh gill nets (Melville-Smith *et al*., 1999). However, over the past few years commercial fishers have moved to replace existing gill nets with crab traps, which are now the main commercial gear type used in WA. Other methods used are, haul nets, beam tide trawling and dabbing. Blue swimmer crabs are also a by-catch component of the commercial prawn and scallop trawl activities in the Shark Bay Prawn, Shark Bay Scallop and Exmouth Gulf Prawn Managed Fisheries.

Traps are among the most versatile and efficient methods for fishing as they fish unattended are suitable for most bottom types and depth ranges and are inexpensive and robust (Krouse, 1989; Miller, 1990). Furthermore, the species and the size range can be targeted through the choice of trap design and bait to accommodate market demands. These are desirable qualities for a fishing method as by-catch is minimal, undersized animals can be returned to the water undamaged, the retained catch is a high quality, and the cost of fishing is low (Miller, 1990).

Given the versatility and cost effectiveness of traps and the potential of this industry to increase, in terms of catch and value, managers and researchers are concerned about the stocks capacity to withstand future increases in both commercial and recreational pressure. To ensure the maintenance of blue swimmer crab stocks, it is essential that researchers not only devise an effective method for sampling blue swimmer crab populations but also to relate commercial catches to accurate assessments of breeding stock and recruitment to the fishery, undersize individuals and sex distribution of the stocks.

Methods

Field Work

The Peel Harvey Estuary in southwestern Australia covers an area of approximately 136 km^2 (Latitude 32°32'S, Longitude 115°47'E). The natural entrance channel at Mandurah is ca 5 km long and opens into the northwestern corner of the circular Peel Inlet, which occupies an area of ca 75 km^2. The southwestern corner of the Peel Inlet in turn opens into the elongate Harvey Estuary, which has an area of ca 56 km^2. The Harvey Estuary is also connected to the ocean via the Dawesville Channel at the north-western corner of this estuary. The Serpentine and Murray rivers discharge into the southern end of the Harvey Estuary.

Portunus pelagicus were collected from sites throughout the Peel-Harvey Estuary between January 1996 and June 1998 using traps covered in two mesh sizes (72 & 12 mm mesh), two seine nets (10.5 and 21.5 m long) and an otter trawl net (5 m wide). Sampling was conducted once every new moon cycle, with three replicate samples being taken at each site on each sampling occasion, irrespective of the type of sampling method employed.

Crab traps used were constructed of either 72 or 12 mm mesh and were 630 mm high and 1000 mm in diameter. These traps are typical of what is used by commercial fishers in Peel-Harvey Estuary and therefore provided a sample of crabs similar to that obtained by commercial fishers. Traps were joined together in groups of four, each trap located 15 m apart and alternating between 72 and 12 mm mesh traps, baited with fish and left for 24 h before being retrieved and emptied. The 10.5 m seine net consisted of two 4.5 m long wings, each comprising 6 mm mesh and a 1.5 m long pocket made of 3 mm mesh. On each sampling occasion, the seine net was trawled by hand along shallow banks at each site for a period of 5 mins. The distance covered by each trawl ranged between 75 to 130 m, the precise distance covered depending on the strength of tidal water flow and the composition of the substrate. The otter trawl net had a 2.6 m wide mouth and was 0.5 m high and 5 m deep. The warp and bridle lengths were 50 and 13 m, respectively. The wings consisted of 51 mm mesh, while the bunt was made of 25 mm mesh. The net was towed for a distance of ca 250 m at a speed of ca 3 - 4 kmh^{-1}, during which time the trawl covered an area of ca 650 m^2.

Crabs caught by the various gear types were sexed and the carapace width (CW), *i.e.* the distance between the tips of the two lateral spines of the carapace, caught in the various gear types were measured to the nearest 1mm with vernier callipers

Analysis

Sampling selectivity of the different gear types was compared in terms of number of crabs caught, size distribution of catches, legal minimum size (127 mm CW) and sexual maturity of both females (95.5 mm CW) and males (85 mm CW). Seasonal differences in the sex ratio of the catch were also analysed. Seasons were taken as summer (December 1 - February 28), autumn (March 1 - May 31), winter (June 1 - August 31) and spring (September 1 - November 30).

It was necessary to restrict the comparison of gear types to methods that were used in the same months and year, since the analysis compared the total number of crabs caught by each sampling method standardising catch rates across gear types was essential. The catch rate of traps is defined as the number of crabs per pot lift while the catch rate of the seine nets and otter trawl is defined as the number of crabs caught per m^2.

A repeated measures experiment, using catch rates as the response variable was used to collect the data. Therefore a split plot analysis, analysed using ANOVA, was used to partition the various components of variation likely to exist in this type of experimental design. In a split-plot framework, there are two sources of error: between sites and within sites. The observations within a site are correlated, the p-values estimated in the within stratum will underestimate the true values if the data does not satisfy the circularity property (S-PLUS, 1999). To avoid this a more conservative test whereby the F-value for the test was calculated by dividing the degrees of freedom by the number of repeated measures minus 1 (S-PLUS, 1999) was used.

After comparing the effect of sampling methods on catch rate, contingency tables were constructed for each month by pooling all observations by method for a month and dividing these into categories of satisfying or not satisfying the required condition. These contingency tables were constructed to test for equality of the proportion of the pooled catch that satisfied the given condition of each sampling method, for each month. If one of the cells had an expected frequency less than 5, then the Fisher exact test was used; otherwise the chi-square method was used. This was done to reduce the effect of expected low frequency bias in the test results (Zar, 1999).

A binomial test was use to compare the proportion of crabs in each length class to 0.5. While a Kolmogorov-Smirnov test was used to compare the length distribution of males and females.

Results

Comparison between 72 and 12 mm mesh traps

The catch size and composition of the 72 and 12 mm mesh traps were analysed for the months of January to May 1997. During this period there was a significant difference in the number of crabs caught by the two trap types ($p < 0.01$) and between months ($p < 0.14$), with catches in the 72 mm mesh trap (1.44, se=0.41) being consistently higher than the 12 mm (0.84, se=0.39) (Fig. 1).

The catch composition of the two methods was similar in terms of sex ratio for all months; January (p=0.83), February (p=0.93), March (p=1.00), April (p=0.91) and May (p=0.64). Except for January (p=0.03) all months; February (p=0.90), March (p=0.91), April (p=0.88) and May (p=0.89) had the same proportion of legal sized crabs comprising the catch of the 12 mm and 72 mm trap. In January, the 12 mm trap (0.68, n=60) caught significantly more legal sized crabs than the 72 mm (0.48, n=79).

Size classes represented in both trap types were similar (p=0.54) with crabs present in all size classes between 97-106 and 157-166 mm CW, while the majority of the catch was present in the classes between 117-126 and 137-146 mm CW (Fig. 2).

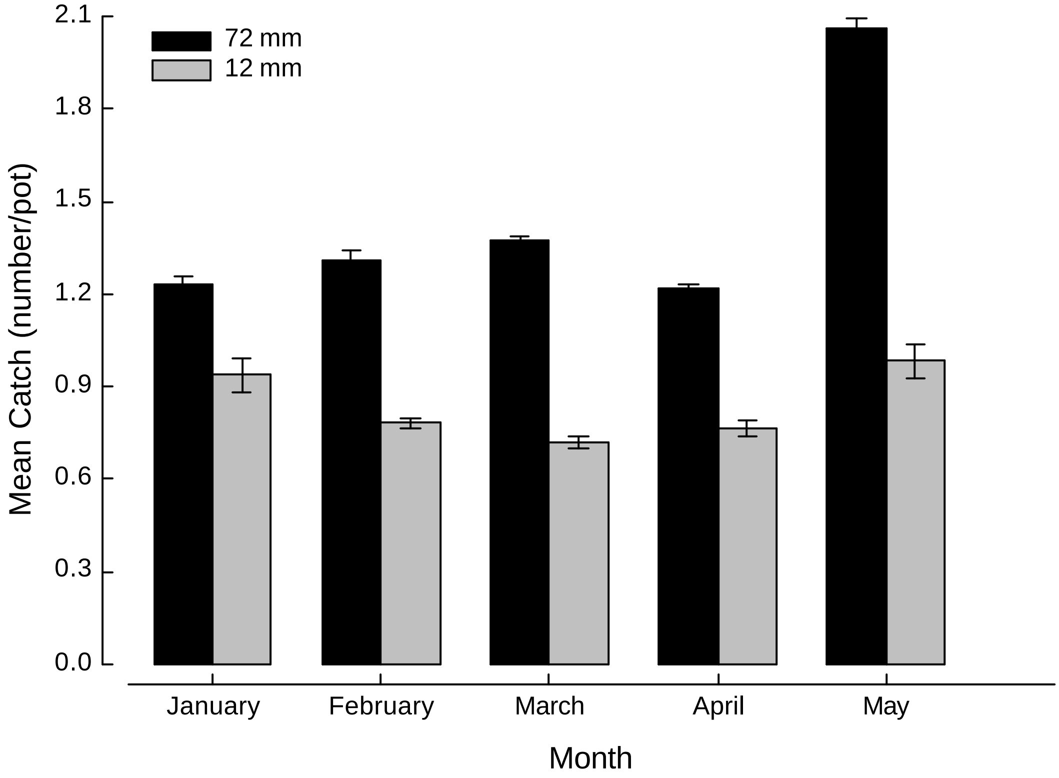

Figure 1: Comparison of the catch rates from 72 mm mesh and 12 mm mesh traps between January and May 1997.

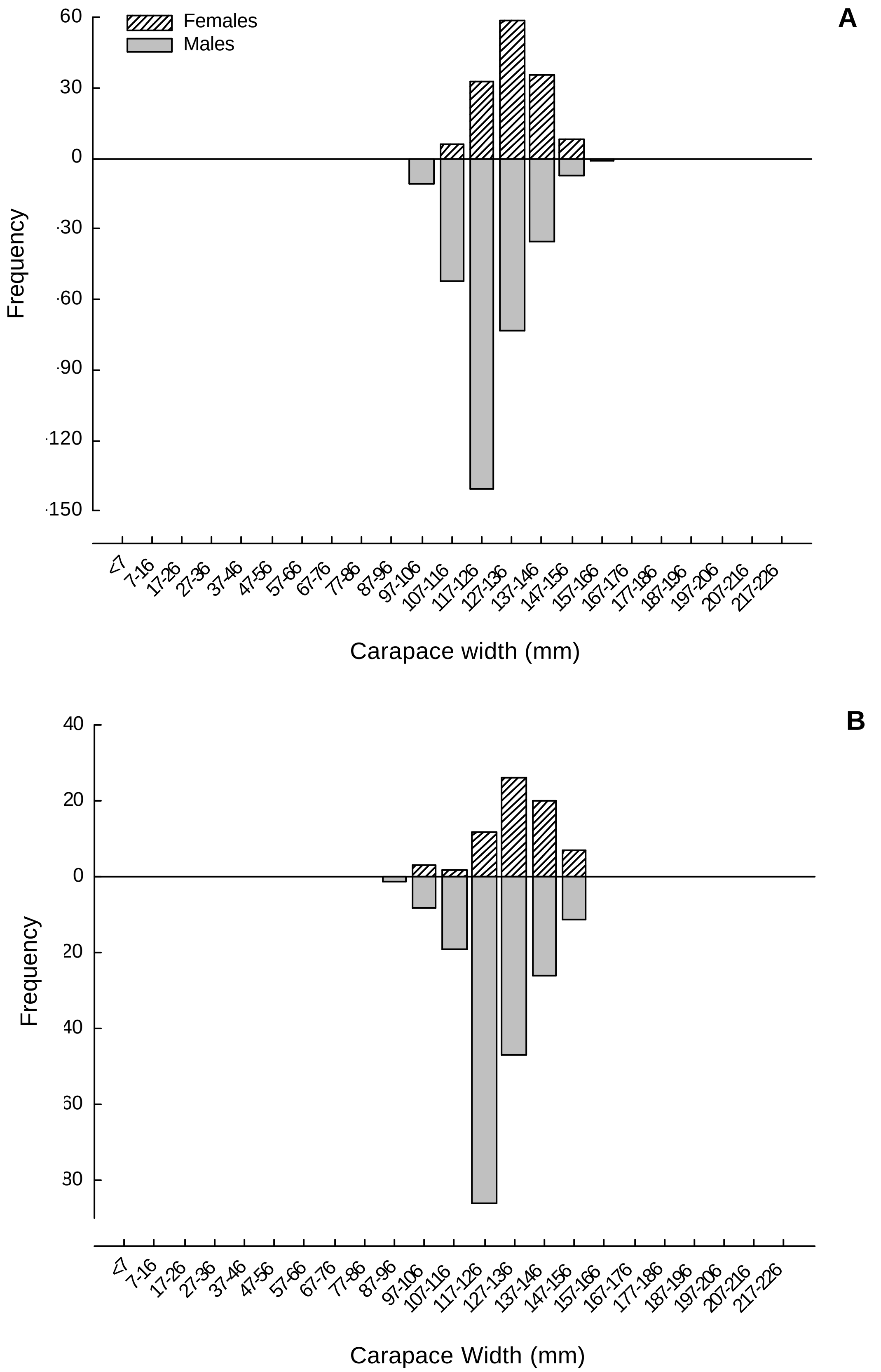

Figure 2: Length classes and sex composition of catches from A) 72 mm mesh trap and B) 12 mm mesh trap between January and May.

Comparison between 72 mm mesh traps and 10.5 m seine net

To compare the sampling efficiency of traps with seine netting, data obtained from 72 mm mesh traps and the 10.5 m seine net were used. Since the 72 mm mesh traps (2.33, se =1.49) had larger catches than the 10.5 m seine net (0.55, se=0.65) for the months January to July and the opposite was true for the remaining months (September to October - Fig. 3), with a mean catch rate in these months of 0.89 (se=0.39) and 1.53 (se=1.40) respectively, the data was divided into two sets, January to July and September to October, and analysed separately. There was a significant difference ($p < 0.01$) between the two methods for the first period, *i.e.* January to July, but not for the second period, *i.e.* September and October ($p=0.35$).

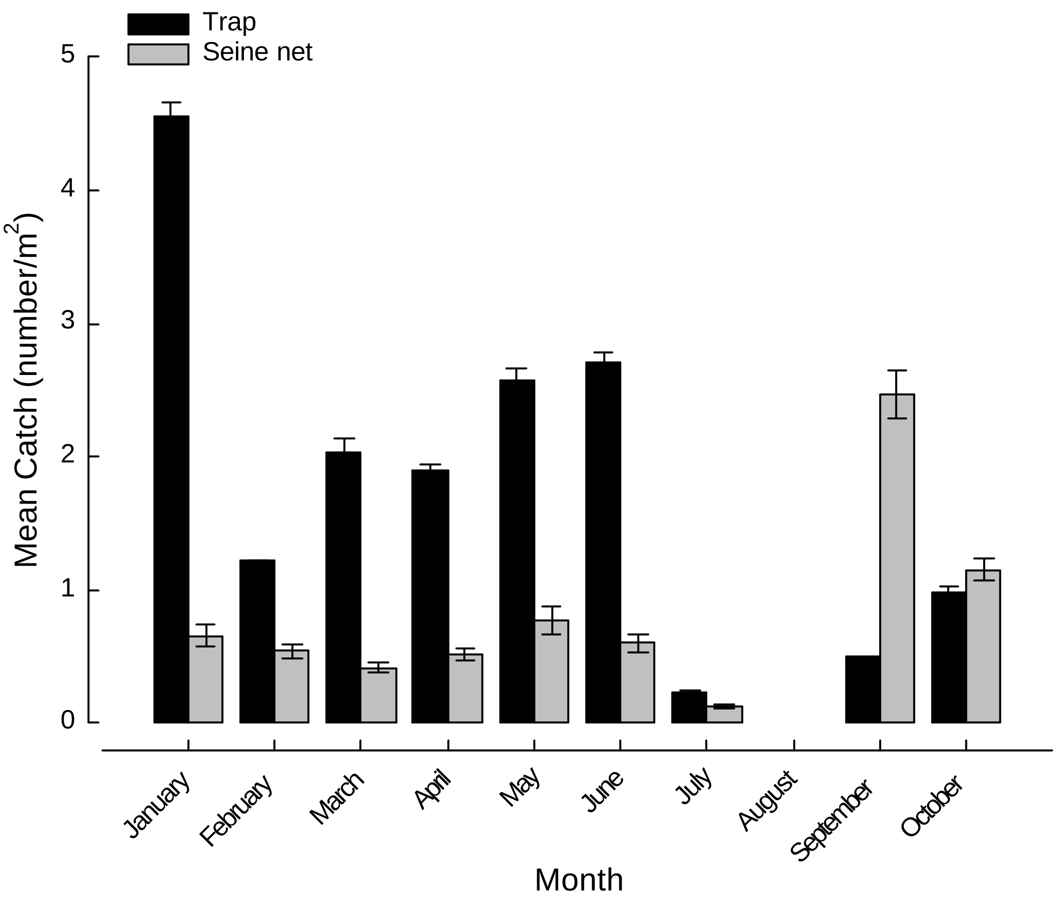

Figure 3: Comparison of mean catch rates from 72 mm mesh trap and seine net between January and October.

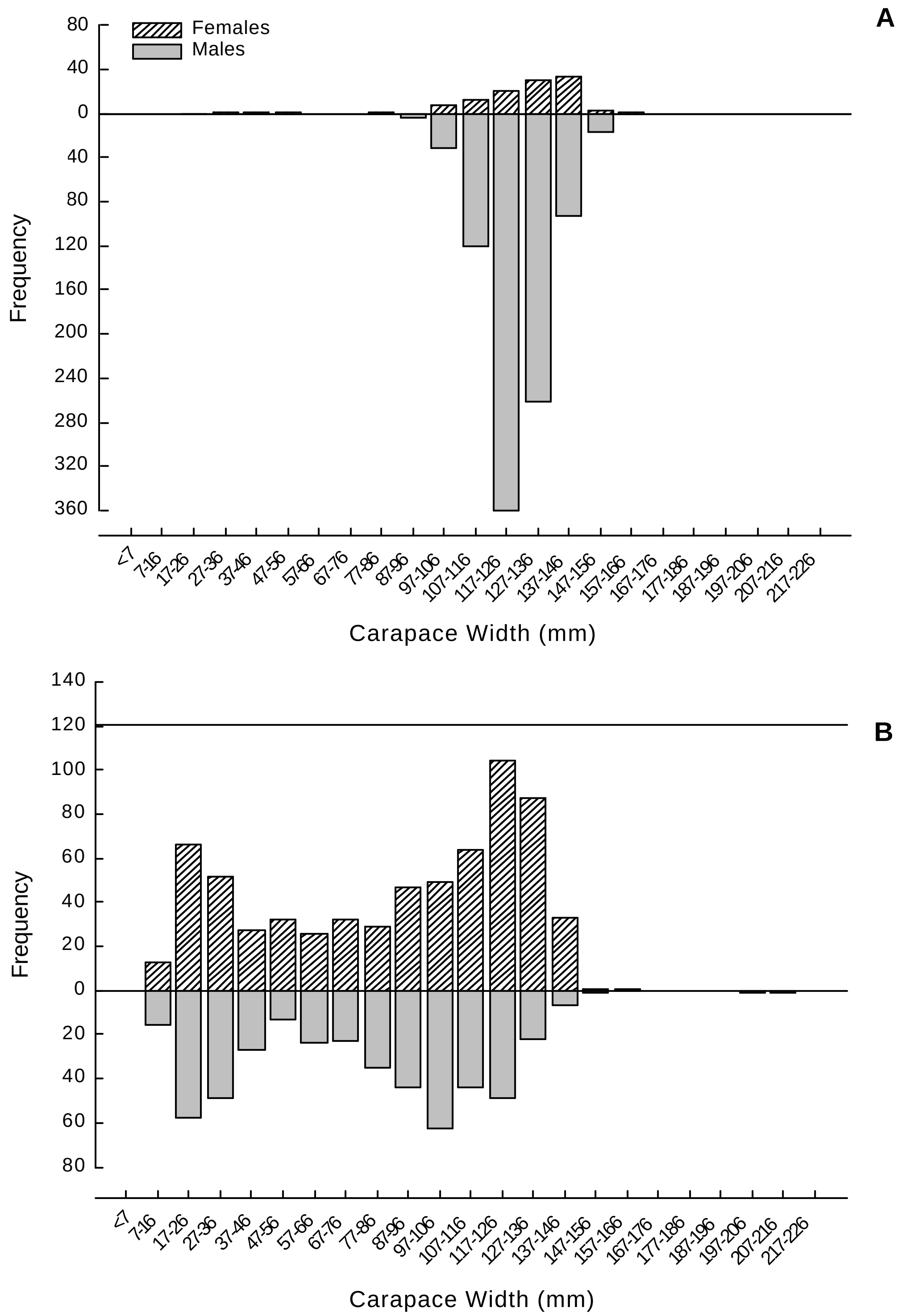

Figure 4: Length classes and sex composition of catches from A) 72 mm mesh trap and B) seine net, between January and October.

The two methods had significantly different ratios of male crabs for all months (p<0.01) except July (p=0.70) and Sept (p=0.14). The 72 mm trap (0.89, n=1002) invariably attracted a higher proportion of male crabs than did the 10.5 m net (0.42, n=1157). In terms of legal sized, all months (p<0.02) were significantly different for the two methods except for February (p=0.27), July (p=1.00) and September (p=1.00). Again, the 72mm trap (0.44, n=1002) caught a higher proportion of legal sized crabs than did the 10.5 m seine net (0.13, n=1157). Considering the proportion of sexually mature crabs, both male and female, all months (p<0.01) produced a difference between the two methods with the 72 mm trap (0.99, n=1002) capturing a higher proportion than the 10.5 m net (0.51, n=1157).

In terms of length classes the two methods differed (p<0.01), with traps represented in the classes between 107-116 and 137-146 mm CW, while the seine net produced a more diverse catch, with all size classes from 7-16 to 157-166 mm CW being represented (Fig. 4). Furthermore, although female crabs were represented in all size classes obtained in trap catches, sex ratios were far from parity (p<0.01), whereas those in the size classes obtained by seine netting were closer to parity (p=0.10) when animals > 126 mm CW are not considered (Fig. 4).

Comparison of 72 mm mesh traps, 10.5 m seine net and 5 m otter trawl

To compare the sampling efficiency of traps with seine netting and otter trawling, data obtained between September and December 1997 from the 72 mm mesh traps, the 10.5 m seine net and the 5 m otter trawl were used. There was a significant difference in the catch sizes obtained by each of the three (p < 0.03). There was also a significant difference between the traps and seine net (p=0.03), however there was no significant difference in the catch rate between traps and otter trawl (p=0.16) and seine net and otter trawl (p=0.15) (Fig. 5). Catch rates were highest in the seine net three months sampled, while traps consistently caught the lowest number of crabs (2.47, se=1.42) (Fig. 5).

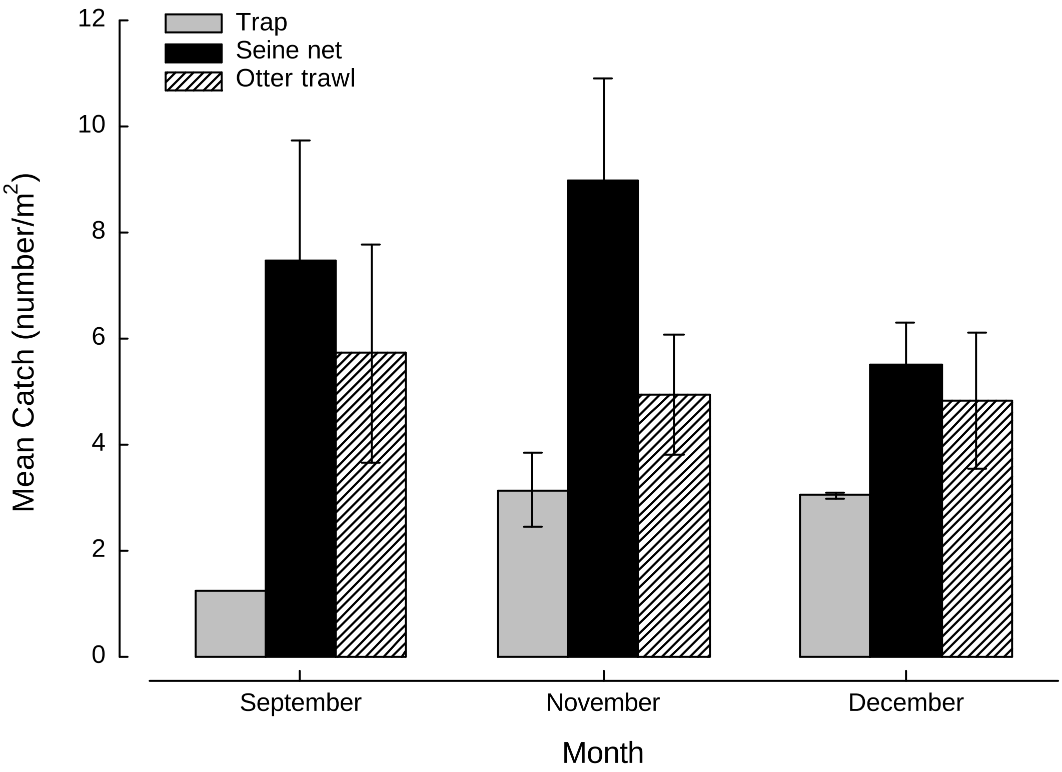

Figure 5: Comparison of the catch rates from 72 mm mesh trap, seine net and otter trawl for the months of September and November.

The three methods were significantly different for each month, September ($p<0.01$), November ($p<0.01$) and December ($p<0.01$), in terms of the proportion of catch that was male. Trap catches displayed a higher ratio of males (0.91,n=475) than the seine net (0.46, n=297) and otter trawl (0.56, n=626). In terms of legal sized crabs, the three methods were again significantly different for each month, September ($p<0.01$), November ($p<0.01$) and December ($p<0.01$) with the trap (0.34, n=475) outperforming the seine net (0.06, n=297) and otter trawl (0.05,n=626). In terms of sexually mature females and males, the three methods were significantly different for September ($p<0.01$,), November ($p<0.01$, Bin) and December ($p<0.01$) with the trap (0.99, n=475) again outperforming the seine net (0.84,n=297) and otter trawl (0.54, n=626). However, catches from both the seine net and otter trawl displayed a more diverse range of size classes, especially in terms size classes < 127 mm (Fig 6).

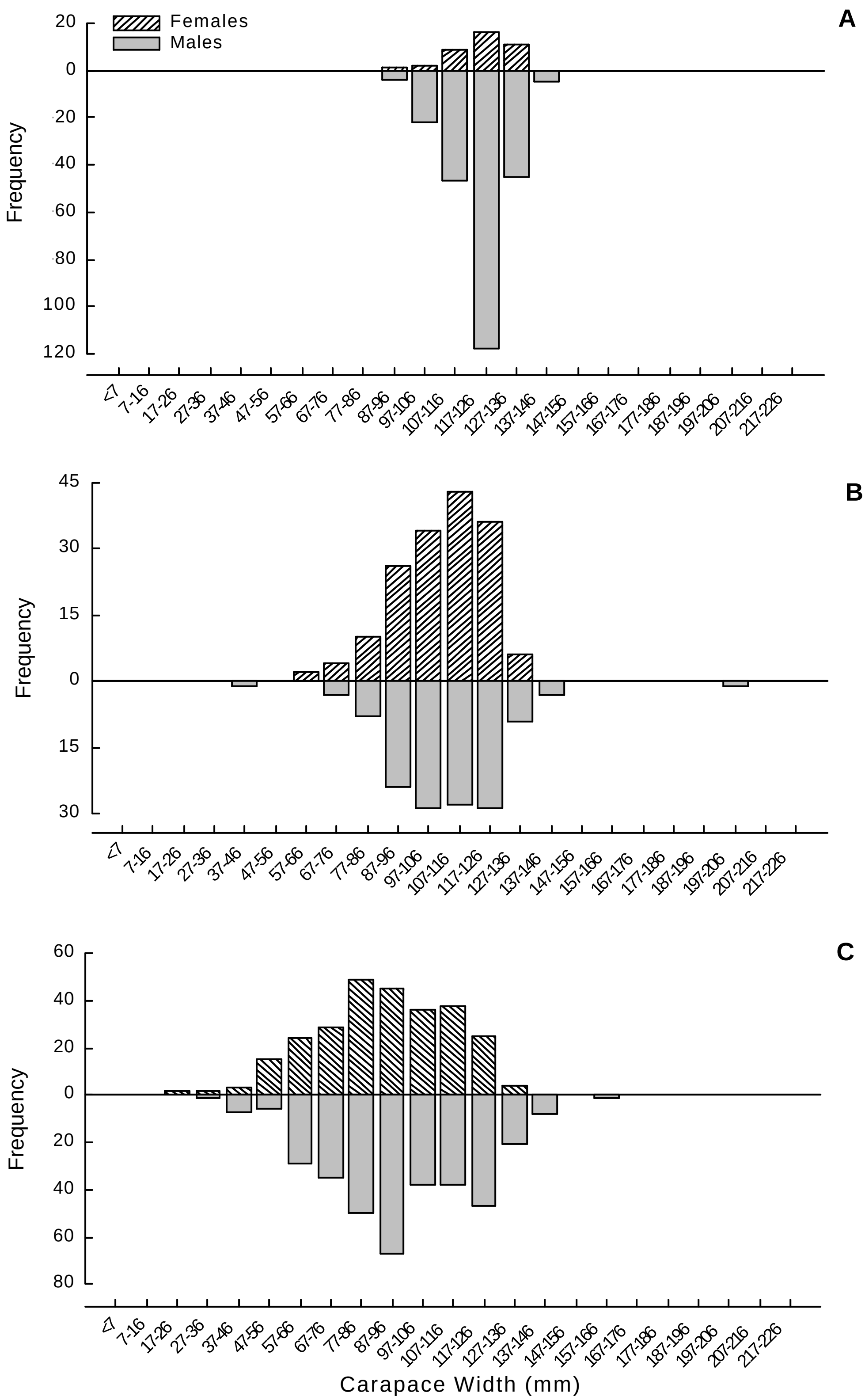

Figure 6: Length classes and sex composition of catches from A) 72 mm mesh trap, B) seine net and C) otter trawl, for the months of September and November and December.

Discussion

Comparison between 72 mm and 12 mm Traps

Previous studies have reported significant differences in the catch rates of traps with different mesh sizes (Guillory and Prejean, 1997; Montano, 1997; Guillory, 1998). Similarly, in this study there was a significant difference in the catch size of the two trap types. With the exception of one sampling period, the 72 mm mesh trap produced larger catch sizes than the 12 mm mesh trap. This may in part be due to the finer mesh, of the 12 mm mesh traps, becoming clogged with weed, reducing the effectiveness of the bait and blocking the trap entrances which allow the escape of small fish.

Numerous studies have suggested that mesh size selection is crucial as it determines the size composition of the catch and consequently the sublegal to legal ratio of the catch (Guillory and Prejean, 1997; Guillory, 1998; Jeong *et al*., 2000). However, crabs from pot catches during this study were represented in the two size classes either side of legal size (127 mm) regardless of mesh size. Both types of mesh trap were highly selective in terms of the size classes of crabs captured (97 mm < CW < 156 mm). Similarly, Montano (1997) working on *Callinectes sapidus* in Lake Maracaibo, Venezuela, states that size structure of catches from two pot types, 2 inch mesh and 1 inch mesh, were similar.

It appears that vulnerability to trap capture increases dramatically at sizes greater than 97 mm CW, especially in males. Similarly, previous authors have suggested that other crustacean species also display differential vulnerability to capture, with sub-adults less vulnerable to capture in traps than adults, *i.e. Cherax tenuimanus*, (Morrissy and Caputi, 1981) and *Scylla serrata* (Williams and Hill, 1982). The reason for size dependant catchability is unknown, however antagonistic social interactions may be responsible (Potter *et al*., 1991).

A size dependent social hierarchy has been demonstrated for blue swimmer crabs, with larger males being dominant over smaller males (Eales, 1972; Smith and Sumpton, 1989). The presence of a large male in the trap may reduce the probability of subsequent entry by a smaller less dominant male. As trap catches in this study were dominated by males, this male hierarchy effect may in part be responsible for the presence of larger crabs in the traps, when it is evident from seine net and otter trawl catches that small crabs are also abundant. Similar interactions have also been reported for *Cancer productus*, *C. irroratus* and the spider crab, *Hyas araneus* (Miller, 1980). Another possible explanation for differential vulnerability to trap capture may be the habitat preferences of difference life cycle stages. Potter *et al*. (1983), working in the same estuary, has suggested that younger stages of *Portunus pelagicus* have a preference for shallow water, however as the crabs increase in size they tend to move away from the banks and into deeper water. This type of size related distribution has also been reported for *Scylla serrata* in eastern Australia (Hill *et al*., 1982). In general, commercial blue swimmer crab traps are set in deeper waters than typically sampled by a seine net, which may offer an explanation for the size discrepancy between these two methods. Although samples for the three methods used in this study were taken in slightly different locations the water depth was essentially similar.

During this study adult female crabs (> 97 mm) were under-represented in trap catches, representing 30.7% of the 72 mm mesh trap catches and 26.1% of 12 mm mesh trap catches. Similarly, Montano (1997) reports that pot catches, irrespective of mesh size, of *Callinectes sapidus* were composed of approximately 11% females and 89% males year round. Therefore, it appears from this study and others that crab traps have a greater tendency to catch male rather than female crabs (Miller, 1990; Montano, 1997; Potter and de Lestang, 2000). However, Smith and Sumpton (1989), working on *Portunus pelagicus* in Queensland state that both males and females were equally attracted to the baited traps, and that both sexes made the same number of total attempts to enter traps. Behavioural differences between the sexes, size classes and moult stages may explain the unequal vulnerability of individual crabs to trap capture. It is well known from previous field and laboratory studies of crustaceans that catchability and moult cycle have a strong correlation (Morgan, 1979; Williams and Hill, 1982; Miller, 1990). Heasman (1980) studying *Scylla serrata*, found that recently moulted females less than 150 m never entered commercial crab traps, however some recently moulted males as small as 120 mm did enter traps. In this study large crabs of both sexes were found in all moult stages in the traps. Although the number of legal size males in trap capture was higher than that of legal size females the major disparity between sexes is with sub adult crabs.

72 mm Trap and Seine Net

The 72 mm mesh trap displayed higher catches than the seine net for the months of January to June, followed by a subsequent decrease for both methods in July. Potter *et al* (1983) state that a marked decrease in catch each winter can be related to the movement of the 1+ crabs out of the estuary into the nearby marine environment. Trap catches continued at lower levels for September and October; whilst seine net catches performed better.

Seine net catches were generally low for the months January to June. In July catches decreased dramatically, this decrease is mirrored by a decrease in trap catches. Similarly, Potter *et al.* (2001) also found that seine netting in Peel Harvey during July and August yielded few crabs. In July catches of legal size crabs in seine nets were zero, this was mirrored by a decrease in total catch sexual maturity. As the sex ratio of seine net catches, was close to parity throughout the study, the dramatic decrease in catch numbers evident in traps is primarily due to a decline in legal size catch of both males and females. Seine net catches at this time are comprised primarily of crabs that have not yet reached sexual maturity. This may indicate that the legal size and sexually mature proportion of the population have moved out of the system at this time. Seine net catches increased in September and October surpassing trap catches during this period. Similarly, Potter *et al.* (2001) also found that mean monthly densities, of seine net catches in Peel Harvey, peaked in September in the channel region and in October in the basins, densities subsequently declined and remained constant until May or June.

Seine net, 72mm mesh trap and otter trawl.

There was a significant difference in catch size between the three methods, with seine net catches higher than both trap and otter trawl catch rates on all of the occasions sampled. The larger catch rate may in part be due to the ability of the seine net to disturb the upper sediment layer dislodging any buried crabs which may not ordinary be caught by more passive methods of capture. Trap catches were again primarily dominated by legal size male crabs while the sex ratio of seine net and otter trawl catches were closer to parity. Similarly Potter *et al.* (1983) working in Peel-Harvey, and Potter and de Lestang (2000) working in the Leschenault Estuary and Koombana

Bay, found that the sex ratio of crabs <90 mm CW caught by seine net and trawl were also close to parity. While there was a significant difference between trap catches and the other two sampling methods it is difficult to make any significant comparisons between the three gear types, as only three months of data are available.

Conclusion

While traps are a popular method of capture with commercial fishers, due to their bias toward large males, catches taken in crab traps are inadequate in representing the relative size and sex composition of the total population although they do provide a representative sample of the adult proportion. However, research and management, unlike commercial fishing, requires an unbiased method of sampling crab populations, which provides an accurate representation of the population, which is cost and time effective. An examination of the catches in terms of both numbers and sex ratio, in the samples collected by different methods in this study indicates that the behaviour of male and female crabs differs. Therefore, caution must be utilised when selecting both sampling methods and periods, as the selectivity of various gear coupled with the target species behaviour may result in biased data sets.

The survival of undersize blue swimmer crabs, *Portunus pelagicus* Linnaeus following capture, handling and release.

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Introduction

Sampling to provide estimates of the amount of blue swimmer crabs discarded by various fishing methods is currently underway. Preliminary information suggests that up to 100 tonnes are discarded by trap fishers in the two main regions in the state (Cockburn Sound and Peel-Harvey estuary), less than 2 tonnes by net fishers and an unknown quantity by trawlers and drop net fishers. Observation of recreational fishers behaviour indicate a varied treatment of crabs by different groups. Boat-based fishers using drop nets generally gauge and return undersized and berried crabs into the water immediately. Fishers scooping for crabs in shallow regions often retain undersize crabs (generally not berried individuals) for between five minutes and several hours depending on whether they have a gauge with them and how many crabs they have caught.

Various methods are used by the commercial sector to target crabs. Predominately they use crab traps, set (gill) nets and drop nets. Commercial crab traps in WA are usually an hourglass shape, although rectangular traps are sometimes used. Traps may be collapsible or rigid depending on tidal and current movement within the fishing region, and diameters vary between 0.8 m and 1.5 m. Typical commercial operations involve using a winch to haul crab traps to the surface from a depth of four to 20 metres, inverting the trap over a tub of iced seawater then shaking or physically pulling the crabs off the mesh and placing them into iced seawater. After varying amounts of time the crabs are removed from the tub, gauged, and undersize and ovigerous crabs are returned to the water by throwing them over the side of the boat from a height of approximately 2 m. Crabs are legally required to be removed from the tubs after no more than five minutes, however observations onboard commercial vessels and anecdotal evidence suggests that crabs may occasionally be left in iced seawater for up to 30 minutes.

Although less prevalent today, gill nets were the most common commercial method of catching crabs until the early 1990's (Melville-Smith *et al*., 1999). Net lengths were around 200 m, and nets were ideally pulled no more than 48 hours after setting. Catch was sorted by either progressively picking crabs out of the net as it was hauled onboard the vessel, or by pulling and bundling the net before transferring to calm waters where the catch was picked from the mesh. The time required to remove catch and by-catch from nets varied between one to several hours. In addition to being tangled in nets in the water column for up to 48 hours, any animals in nets that were bundled before picking were exposed to the prevailing weather conditions.

Crabs are also a by-product (retained portion) and by-catch (discarded portion) of prawn and scallop trawling operations in WA. Larger crabs are generally retained but all others are discarded with the rest of the by-catch. In the prawn and scallop fisheries otter trawls are towed along the seafloor. The nets are held open by boards which are weighted to move along the bottom and act as paravanes. The gear consists of funnel-shaped nets leading into a bag or codend that collects the catch. Trawl duration generally varies between one hour and three hours. The nets are hauled in and the catch from nets shaken onto a sorting table where the target species and by-product are kept and the rest discarded back into the sea. Sorting time varies depending on the overall volume of catch and by-catch composition but generally is between 15 minutes to one hour.

Recreational fishers are permitted to catch crabs by a variety of means, one of which includes wire scoop baskets. Fishers usually carry a scoop net and tow a bucket as they wade in the shallows along the coast or in estuaries. Crabs scooped are generally transferred into the holding bucket to be gauged at a later occasion. The amount of time that lapses between catching and gauging is unknown, as gauging may not occur until the fisher has returned to shore with their catch. Regulations specify that unwanted crabs must be returned to the water within five minutes of capture.

The survival of discarded crustacean species has been examined several times in recent years (Brown and Caputi, 1986; Kirkwood and Brown, 1998; MacIntosh *et al*., 1996;

Wassenberg and Hill, 1993; Zhou and Shirley, 1996). Studies on the survival of the red king crab *Paralithodes camtschaticus* and tanner crab *Chionoecetes bairdi* discards did not indicate any significant mortality from trap fishing (Zhou and Shirley, 1996; MacIntosh *et al.*, 1996). Kirkwood and Brown (1998) found that limb damage has a significant effect on survival of spanner crabs, *Ranina ranina*, while Brown and Caputi (1986) found that displacement and air exposure significantly affected the survival and susceptibility to predation of discards from the western rock lobster *Panulirus cygnus* trap fishery. Wassenberg and Hill (1993) used *Portunus pelagicus* in their experiment to examine the appropriate duration of experiments to measure the survival of animals discarded from trawlers. The authors described *P. pelagicus* as 'fairly robust', exhibiting 16% mortality over seven days after being caught in one-hour trawls.

This study has been aimed at determining the survival of undersize crabs caught by different fishing methods and returned to the water. With the exception of the survival of *P. pelagicus* in prawn trawls, little is known of the discard survival of this species from the most commonly used commercial fishing methods, traps and nets. Comparisons of techniques within and between fishing methods should enable the formulation of management recommendations to reduce mortality.

Materials and Methods

Trap discard trials

Commercially caught crabs were used for two experiments on 29 March 1999 and 10 January 2000. The undersize (< 127 mm CW in 1999 and < 130 mm CW in 2000) crabs were caught with 80 to 100 baited traps set throughout Cockburn Sound (Figure 1). Some small legal sized crabs (12%) were also included to increase the sample size, but no berried females were used in the trials. After removal from the trap, crabs were measured, sexed, damage noted and tagged using an external plastic numbered tag secured by a rubber band stretched between the spines of the carapace. The claws of the crab were secured using rubber rings. This method of crab identification and securing claws was used for all experiments. Crabs were exposed to air for no more than three minutes before being randomly treated in a number of ways; i) placed directly into a tub of seawater, or ii) placed into a tub of iced seawater for 5, 10, 15 or 20 minutes before being placed into a tub of seawater. The seawater was replenished regularly.

In March 1999, 141 crabs were caught, treated and held in 6 rectangular (39 cm x 59 cm x 87 cm) holding traps that were lowered to the sea floor. In the January 2000 experiment, 180 crabs were placed in two circular (1.2m diameter x 30cm high) and two rectangular (39 cm x 59 cm x 87 cm) holding traps. All traps were covered by a liner (5 mm mesh) to prevent predation by octopus.

Holding traps were lifted and survival of crabs was checked at 12, 24, 48 and 72 hours. Any individuals that had moulted were vulnerable to predation from other crabs in the holding traps and were released. During March 1999, one individual moulted at 24 hours, and was excluded from the experiment. No crabs moulted during the January 2000 experiment.
Water temperature was recorded and surface water samples tested for salinity during all of the experiments. Salinity was measured using a WTW MultiLine P4 meter with a TetraCon 325 Standard Conductivity Cell.

Gill net discard trials
Four gill nets (each 200 m long) were set by a commercial crab trap fisher in Cockburn Sound (32^{o} 11.17'S 115^{o} 46.05'E) on 11 April 1999 and on 6 March 2000 (32^{o} 06.492'S 115^{o} 44.977'E). Two nets were retrieved after 24 hours of soaking and two nets were retrieved after 48 hours soaking.

For each soaking time (24 or 48 hours) the first net that was retrieved was pulled into the boat and the net and all its contents were bundled and left for one hour. The net was not covered and the catch was exposed to the prevailing conditions of sun and wind. The crabs in the second net were removed from the net as it came out of the water. All by-catch from this net was also removed and returned to the water immediately.

As the catch was removed from a net, crabs were measured, sexed, tagged and secured as for the trap experiment, then placed in tubs of seawater. When both nets were sorted crabs were randomly placed in two rectangular holding traps that were lowered to the sea floor adjacent to where they were captured (Table 1). All crabs captured in the nets (both undersize and legal sized) were included in the experiment due to very low numbers of undersize crabs.

The holding traps were lifted from the sea floor to check for survival at 24, 48 and 72 (64 in March 2000) hours after initial placement of crabs into holding traps. As with the trap trials, any moulted individuals were removed from the holding traps. In 1999, two moults occurred at 48 hours from the 24-hour soak net with no air exposure and one moult occurred at 48 hours from the 24-hour soak net with one-hour air exposure. No crabs moulted during March 2000.

Trawl discard trials

The *RV Flinders* was used to conduct a trawl in Cockburn Sound (32°08'S 115°43'E) during 20 April 1999 and 29 February 2000. Twin-rig gear was towed at 2 knots with 50 mm mesh nets and 45 mm codends. To simulate a normal prawn trawling operation, the trawl duration was 60 minutes (average trawl duration in Shark Bay prawn fishery is 68 minutes). When nets were retrieved, undersize (<127 mm carapace width, from spine to spine) crabs were randomly sorted from the table and measured, sexed, tagged and secured as for the trap experiments. The amount of air exposure on the sorting table ranged from; 0-9 minutes, 10-19 minutes, 20-29 minutes, 30-39 minutes and 40-48 minutes during April 1999. In March 2000, all crabs were processed within 39 minutes (Table 1). Crabs were then randomly placed into a 200 L tank of circulating seawater, partitioned into 24 sections.

In April 1999, crab survival was checked in the circulating tank at 12 and 24 hours. At 24 hours, three moults were observed in the circulating tanks (one in the 0-9 minute exposure category and two in the 30-39 minute exposure category) and these were removed from the experiment. At 30 hours, *RV Flinders* returned to port and the crabs were transferred from the tank into two rectangular holding traps and placed on the seafloor next to the wharf.

Survival of the crabs was then checked at 48 and 72 hours. No moults were observed during this period.

In February/March 2000, the crabs were held in the circulating tank for two hours then were randomly placed in three circular holding traps and lowered to the seafloor. Survival of crabs was checked at 16, 40 and 64 hours (fitted in with commercial fisher schedule). Three crabs moulted at 16 hours and eight by 40 hours and these were removed from the holding traps and not included in the experiment.

Experimental trials on recreational scoop net discards, March 2000

On 20 March 2000, volunteer fisheries liaison officers, research staff and fisheries officers used scoops to catch 141 crabs in the Peel-Harvey Estuary, 120 km south of Perth. Upon capture, undersized crabs were measured, sexed, tagged and secured as for the trap experiment. The crabs were exposed to air for zero, 30, 60, 90 and 120 minutes before being transferred into tubs of seawater. When all treatment time had elapsed the crabs were randomly placed into four rectangular holding traps and lowered into the estuary. Survival of crabs was checked at 24, 48 and 72 hours. Poor water quality and/or suspended sediment in the estuary resulted in high mortality at 72 hours, hence results up to 48 hours only are analysed. One individual moulted at 48 hours and was not included in the analysis.

Analysis of Data

We examined the treatment effect on the mortality rate of the crabs for each of the fishing methods for the two years. For each fishing method, the crabs were randomly treated at a level of a treatment that has 4 or 5 different levels (Table 1). The response tested is the status of the crab, either being alive or dead. Due to the different number of crabs in each level of a treatment, a generalised linear model with logit link has been used to fit the data. One-way analysis of variance (ANOVA) test has been used to test whether the treatment effect was significant.

Results

Number of crabs in treatments for experimental trials

Between 20 and 40 crabs were used in each treatment for each fishing method, with the exception of gill nets, where low catch rates resulted in a reduced sample size (Table 1). Comparable numbers of male and female crabs were used in all trials except the January 2000 trap trials, where females accounted for only 12% of the discard catch and for the recreational scooper trial where only 10% of crabs caught were male. In the trap and net trials where catch rates of undersize crabs were low, smaller legal sized crabs were used to supplement numbers. Some slightly soft crabs were included in the experiments; however, newly moulted, very soft crabs were not used due to potential cannibalism (Kruse et al. 1994) within holding traps. If a crab moulted during the trial it was removed from the experiment.

Table 1: Number and sex ratio of crabs held in each experimental treatment during March and April 1999 and January and March 2000 in Cockburn Sound.

Method of capture	Treatment time					Sex	
Pots	**0**	**5**	**10**	**15**	**20**	**Males**	**Females**
March 1999	30	29	22	28	32	77	64
Jan. 2000	38	36	35	37	34	157	23
Nets	**24hr, 0hr**	**24hr, 1hr**	**48hr, 0hr**	**48hr, 1hr**			
March 1999	25	23	31	25		58	46
Feb. 2000							
Trawl	**0-9**	**10-19**	**20-29**	**30-39**	**40-48**		
April 1999	18	20	16	17	23	42	52
Feb/March 2000							
Rec Fisher	**0**	**30**	**60**	**90**	**120**		
March 2000	30	25	31	21	31	11	96

Seawater salinity and temperature during trap trials

During these experiments, surface water salinity was 36.9 ± 0.2 ‰ and temperatures between 19 to 25.0°C. Addition of ice to trial tubs reduced salinity to between 25.9 and 32.6 ‰ and temperature to between 4 and 18°C. These lower levels were within the range observed in ice/seawater tubs on commercial vessels during normal fishing operations (salinity range, 16.3 and 29.1 ‰ and temperature range, 1.4 to 18°C).

Survival using traps

Crabs caught with traps exhibited a low level of damage, with (mean ± 1 SE) 73.8% ± 1.6 and 91.7% ± 1.2 undamaged in 1999 and 2000 respectively (Figure 2). Leaving crabs in iced seawater for 20 minutes resulted in a mortality rate of around 10-20%. Mortality of crabs kept in iced seawater for 0-15 minutes was less than 10% (Figure 3) after 72 hours. However, there was no significant difference between mortality for treatment (1999, P = 0.996, 2000, P = 0.944) and year (P = 0.19) for crabs exposed to iced seawater for 0-15 minutes. Higher mortality was observed in March 1999 for crabs kept in iced seawater for 20 minutes. This may have been due to the inclusion of two males in this trial which were soft (recently moulted) and which subsequently died.

Survival using gill nets

Mortality of crabs over 72 hours in holding traps varied between 4 and 18% (Figure 4). Damage to crabs was low with (mean ± 1SE), 84.7% ± 1.0 and 72.4% ±1.4 of crabs being intact in 1999 and 2000 respectively (Figure 2). There was no significant difference in the survival of crabs picked from nets for 24-hour or 48-hour soaks or those left for one hour before picking for either soak time (April 1999; P = 0.56, March 2000; P = 0.57). It was apparent, however, that predation rates were higher for nets soaked for 48 hours with at approximately 15% of crabs being dead or predated (only claws or part of carapace remaining in net) on retrieval (dead crabs were not incorporated into experimental results). Lower survival was generally observed for the experiment conducted in March 2000 compared to April 1999 (P = 0.02). This may have been due to higher air temperatures (32-33^{o}C) on these days compared to April 1999 (~25^{o}C).

Survival using trawls

Initial mortality (dead on the table at time zero) was estimated to be 6% overall for intermoult crabs. No significant difference was observed for survival of crabs in the different treatments (P = 0.245), however, a higher level of mortality was observed in 2000 compared to 1999 (P = 0.003) (Figure 5). Crabs were physically more damaged in trawls compared to other fishing methods with (mean ± 1SE), 48.2% ± 4.6 and 45.5% ± 8.0 undamaged crabs in 1999 and 2000 respectively (Figure 2). However, this damage did not appear to cause significant mortality in crabs with 87-100% survival of crabs over 72 hours that had been exposed to air for 0-19 minutes. Initially, eleven to 17% of crabs died when exposed in air for 20-49 minutes (Figure 4). During the experiment in February 2000, it was observed that 33% of the female crabs that were caught were soft (recently moulted) and some died as a result of the trawling process. This resulted in an additional 14% increase in mortality of crabs at this time (sex ratio ~1:1).

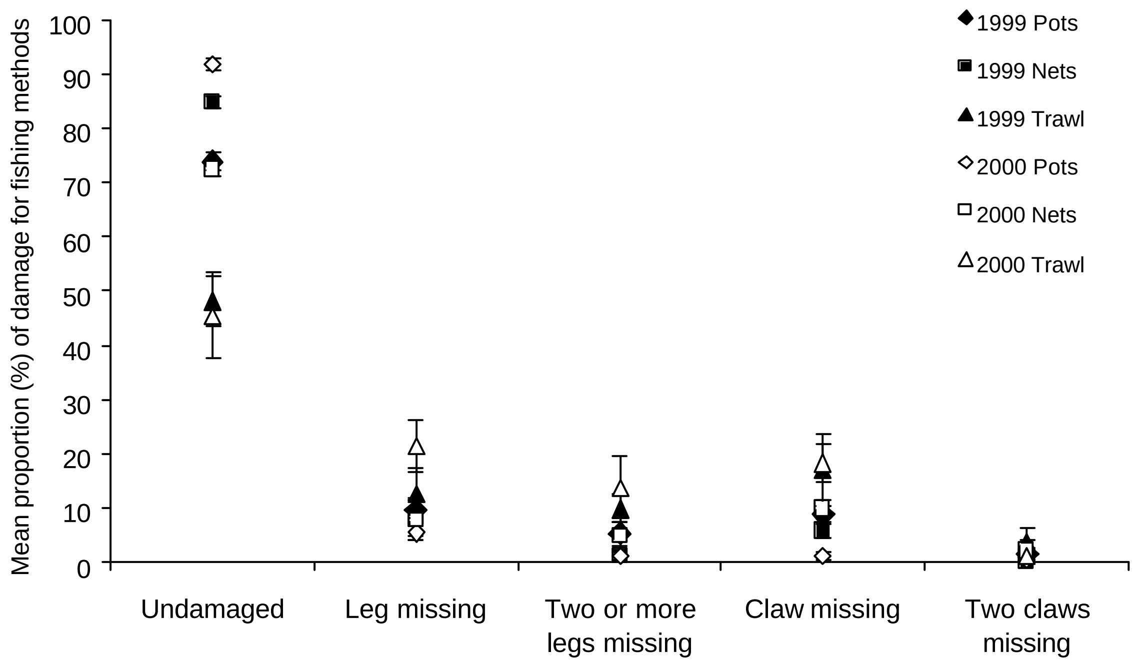

Figure 2: Damage sustained (mean±SE) by *Portunus pelagicus* for various fishing methods during discard experiments in 1999 and 2000

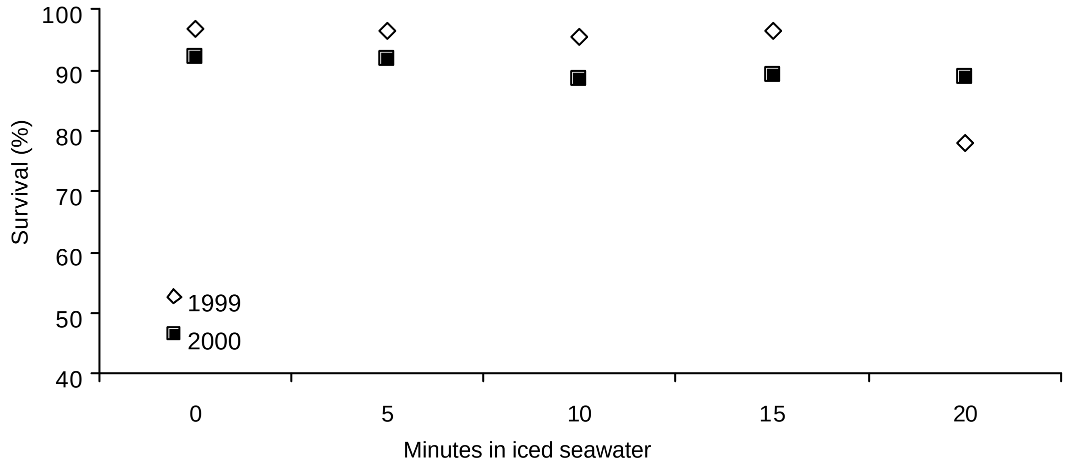

Figure 3: Survival of *Portunus pelagicus* (at 72 hours) caught by potting and immersed in iced seawater for varying periods of time during March 1999 and January 2000.

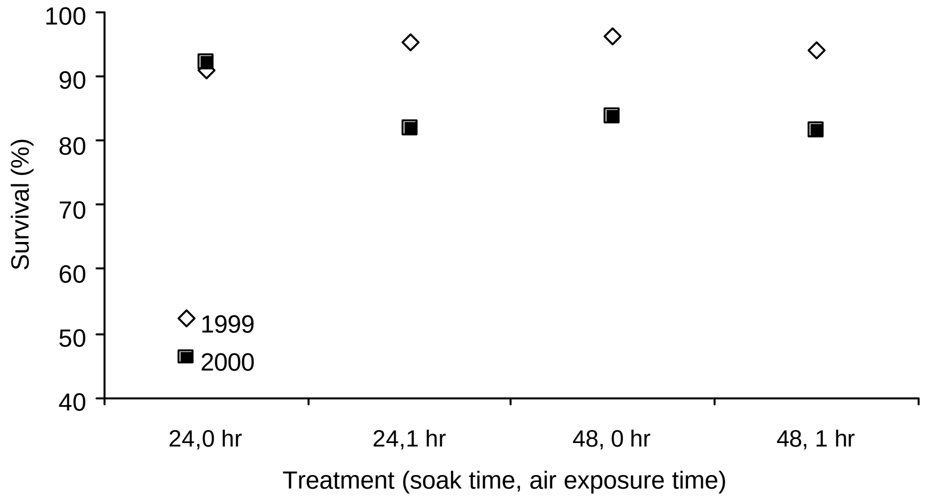

Figure 4: Survival of *Portunus pelagicus* (at 72 hours) caught by netting for 24 and 48 hour soaks with none and one hour air exposure during April 1999 and March 2000.

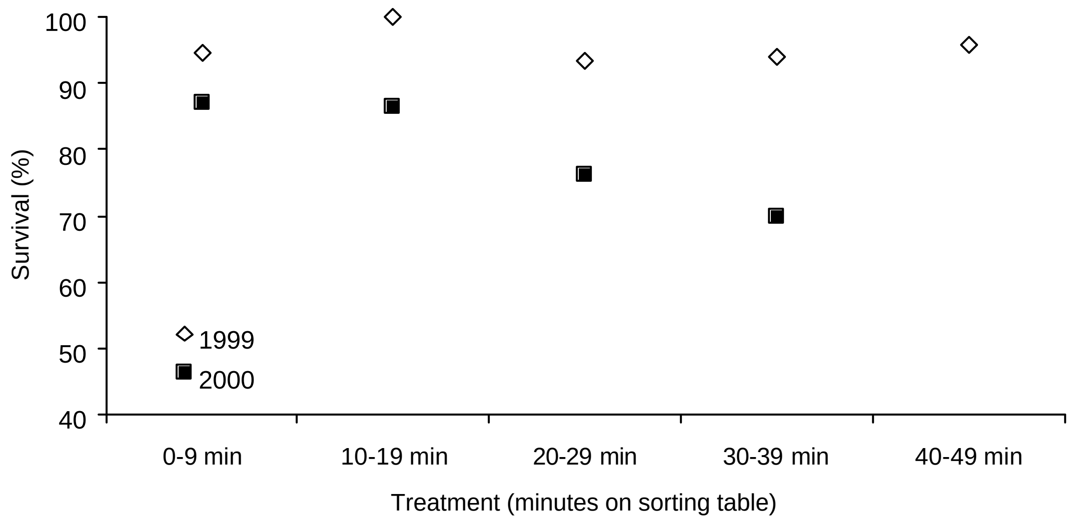

Figure 5: Survival of *Portunus pelagicus* (at 72 hours, 64 hours in 2000) caught by trawling and subjected to varying periods of air exposure during April 1999 and February/March 2000.

Survival using recreational scooping

A significant difference in survival was observed with air exposure time ($P = 0.00$). Survival of crabs exposed to air for less than 30 minutes was over 90% (Figure 6). Mortality of scooped discards increased to 33% after 1.5 hour and 53% after two hours air exposure. Scooping caused damage to 53.2% of crabs.

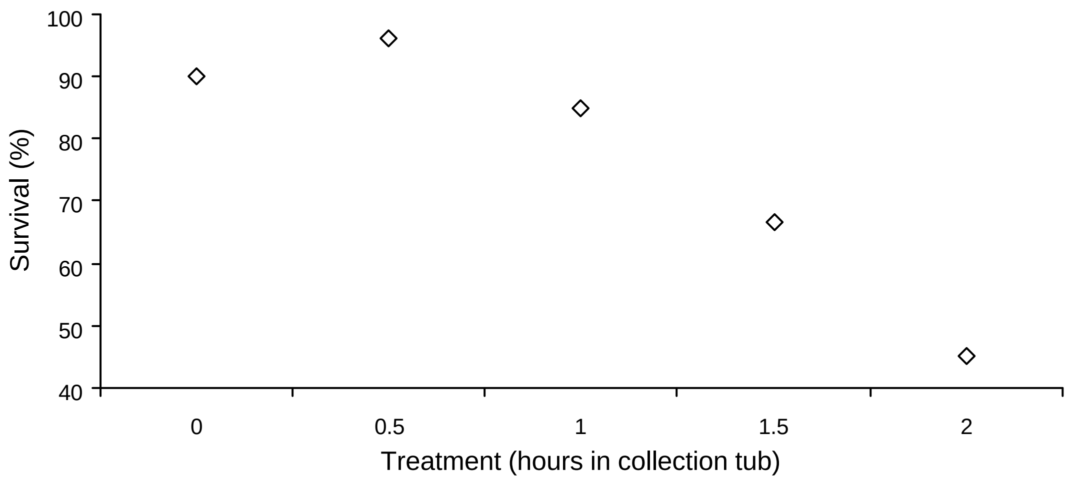

Figure 6: Survival of *Portunus pelagicus* (at 72 hours) caught by recreational scoopers and subjected to varying periods of air exposure in March 2000.

Discussion

The blue swimmer crab *Portunus pelagicus* is a robust species, with undersized or unwanted individuals exhibiting relatively low mortality for most fishing methods employed in Western Australia. Treatment differences in commercial fishing methods were found not to be significant, however, it appears that lengthy exposure to air or iced water has some impact on survival.

There were noticeable differences between the damage incurred by different fishing methods. Although autotomy is common in *P. pelagicus*, the loss of limbs did not appear to increase the mortality of individuals in these trials. This was clearly demonstrated in the trawling experiment where damage to crabs was greater than for trapping or netting, however this did not result in higher levels of mortality. Similar high rates (51% damaged) of injury from prawn trawlers in Queensland (Wassenberg and Hill, 1993) did not increase mortality of *P. pelagicus*.

Wassenberg and Hill (1989) found that 14% of crabs died from the effects of trawling whereas initial mortality in this experiment was found to be around 6% although experimental trawl durations were similar. We also found that trawling effects caused less than 20% mortality for crabs if they are sorted from the table within 20 minutes. Much higher mortalities of up to 40% can occur during moulting periods when the soft crabs are highly vulnerable. Wassenberg and Hill (1989) also found higher mortality in individuals that were undergoing moulting.

Seasonal differences were observed in survival rates, particularly for gill netting and trawling, that may be due to the physiological condition of crabs at the time and air temperature differences. Similarly, Wassenberg and Hill (1987) found that larger individuals were more robust than smaller individuals. Our study primarily focussed on undersized crabs and hence our size range was limited and was not tested.

In our experiments crabs were kept away from predators since they were unable to bury in the substrate and they lacked their normal defences since their claws were bound. Discard mortality rates observed in our trials may be biased since cannibalism of weaker individuals may have occurred even though the claws were bound. Furthermore, stress induced by retaining crabs in tanks in close proximity, interaction with other crabs and lack of feed may have increased mortality rates.

Secondary or sub-lethal effects may also be important but were not assessed in this study. Several studies of handling and discard effects on other crustaceans have shown a decrease in growth rates due to air exposure and injury (Brown and Caputi, 1985; Carls and O'Clair, 1990). Experiments on the red king crab, *Paralithodes camtschaticus* found the effects of handling was not significant on crab survival (Zhou and Shirley, 1996).

The Cockburn Sound crab fishery contributes to around half of the overall commercial take of crabs in WA and trapping has been the sole fishing method employed by commercial fishers since 1999. Recreational fishers generally fish for crabs using drop nets and diving in this region with minimal shore catches by scooping. An estimate of boat-based recreational catches in Cockburn Sound in 1996-1997 was approximately 92 000 crabs (18.8 tonne) (Sumner and Williamson, 1999) but no estimate of discards was published. It would be expected that handling mortality of these crabs would be relatively low. There is no estimate of shore-based catch for this region but is expected to be lower than boat fishing catches. During commercial catch monitoring in Cockburn Sound during 1999, it was estimated that 540 000 crabs were returned to the water. For an estimated discard mortality rate of 5-10% in Cockburn Sound, 25 000 to 55 000 individuals per year may die. If they had grown to commercial legal size they would have resulted in an additional available tonnage for capture of around 7-14 tonne and could potentially have added value to the industry of $30,000-50,000.

The Peel-Harvey Estuary is an area that is popular with recreational scoopers. A recreational survey by Sumner *et al*., (2000) estimated that 967 000 crabs were returned to the waters of Peel-Harvey Estuary by recreational fishers during a 12-month period from August 1998 to July 1999. Based on time periods that have been observed for recreational fishers to keep their catch out of water before sorting, it is likely, based on Sumner *et al.,* (2000) figures that between 10 to 42 tonnes of crabs may die in Peel-Harvey Estuary each year. This is between 3 and 14% of the estimated 289 tonnes caught by recreational fishers in the estuary in 1998/99. Scooping also causes damage to 53% of crabs, which may also affect survival and growth. Improved handling and immediate return to water of undersize or unwanted crabs is recommended.

Catch, effort and the conversion from gill nets to traps in the Peel-Harvey and Cockburn Sound blue swimmer crab (*Portunus pelagicus*) fisheries

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Introduction

Commercial fishing targeting blue swimmer crab can be traced back to the late 1950s in the Peel-Harvey Estuary and the mid-1960s in the case of Cockburn Sound (E.H. Barker, Fisheries WA *pers. comm.*). Traditionally, most of the commercial catch from this fishery has been taken using gill nets with a six inch (152 mm) stretch mesh. Fishers have had licences, which entitled them to pull up to 1,200 m and 1,000 m of crab gill net per day in Cockburn Sound and Peel-Harvey Estuary respectively.

Cockburn Sound crab fishers had been required to use gill nets up to 1994, but in that year fishers were given authority to trial traps at a rate of 100 traps for their 1,200 m daily gill net allocation. Allowing the fishers to use 100 traps in place of the gill net allocation was believed, based on a net to trap conversion trial conducted in March 1994 and described in this report, to have been an approximate conversion that would allow fishers to catch the same quantity of catch with either fishing method. Since 1994 and the production of this report, there has been no further investigation into net to trap conversion ratios in Cockburn Sound. The 100 traps: 1,200 m daily net allocation trialed in 1994 was gazetted, unchanged, in March 1995.

Success with traps in the Cockburn Sound fishery led to a call by fishers in the Mandurah Professional Fishers Association, to trial trap fishing for crabs in the Peel-Harvey Estuary. At the 1995 Annual General Meeting of that association, it was agreed by that body and by the agency, that a number of fishers would assist with an experiment which would provide data on trap and gill net catches and which would enable a conversion for the different gear types to be calculated for the area. The results of this experiment form part of this report.

Commercial blue swimmer crab fishers have used two very different styles of traps since this method of fishing has gained acceptance in Western Australia. In Cockburn Sound most of the catch is currently being made by hourglass shaped traps, which when set can stand as high as 450 mm. These large traps are unsuitable for the Peel-Harvey Estuary where much of the fishing takes place in shallower water sometimes less than one metre deep. As a consequence, most of the trap-caught catch in that area is taken using rectangular top-entrance traps or small hourglass shaped traps. The selectivity and catch rates of the trap types are likely to be different from each other, but no comparative fishing data are available.

Blue swimmer crab fishers have themselves been keen to convert from the traditional gill net method of fishing to trapping methods. Trapping is a less time-consuming method than gill net fishing. It has allowed fishers to work their dinghies (the maximum size allowed is 6.4 m) in harsher weather conditions than they were able to when they were restricted to gill nets. Additionally, the agency, commercial fishers and the general public have viewed trapping, as a more environmentally 'friendly' method that is less likely to retain untargeted species than gill net fishing. Trap fishing is seen as being less damaging to both the legal sized crabs, allowing them to be kept live for the developing live crab export market (Stevens 1995), and the discarded (under-sized and ovigerous) portion of the catch, allowing greater survival for animals that are returned to the sea. Implementation of the fishers' desire to move from gill nets to traps in Peel-Harvey Estuary and other parts of the fishery, has been delayed by the lack of information on appropriate factors for converting gill net licence allocations to trap allocations, without producing an increase in fishing effort.

This report outlines the methods used to establish an appropriate gill net to trap conversion ratio for fishers in the Cockburn Sound and Peel-Harvey crab fisheries. Several years have passed since traps were approved for use in Cockburn Sound and were trialed in Peel-Harvey. It is therefore now possible to examine changes in fishing patterns and landings that have resulted from, or at least been in part attributable to the change from nets to traps. It is suggested in this report that these experiences as to the way that catch and effort in Cockburn Sound and Peel-Harvey Estuary have responded to the move from nets to traps, may provide useful indicators as to what could be expected in other areas when trapping is permitted to replace netting for crabs.

Methods

Cockburn Sound fishing trials

In March 1994 during the trials to compare net and trap crab catching efficiency in Cockburn Sound, a trap and gill net fisher each kept detailed daily logbook records of their crab catch. The fishers mostly operated on the same days and generally in the same region of the Sound. Net data were available for months other than March 1994; however, this was the only month for which data for both nets and traps were available. Therefore, to avoid possible bias, data from this month only were used to estimate relative catching efficiency.

Records were kept of the area fished, depth range (m) and total daily crab catch. A sub-sample was taken daily from between 10-30 traps or a single 400 metre panel of netting, to provide the ratio of size to undersize, male to female, and in the case of females, ovigerous to non-ovigerous animals in the catch. A further sub-sample of 50-100 crabs was counted and weighed to provide an estimate of the mean weight of crabs retained in the catch. The trap fisher with whose gear the net catches were being compared, used between 54 and 95 traps per day and the gill netter pulled either 800 or 1,200 m of net per day.

Fishers used either two or three sets of nets in Cockburn Sound and set them for 48-hour periods. If two sets of nets were used, then they were alternated so as to allow the fisher to haul one net every 24 hours and leave the balance of the gear soaking for 48 hours, a period, which was considered to result in optimal crab catches. If three sets of nets were used, then one 800 metre set was hauled each day and was brought ashore to clear of the catch at leisure, while the other two were left soa king. Both methods resulted in the nets being left in the water for 48-hour periods, but with the first method 1,200 m of net would have been cleared per day, while only 800 m of net would have been cleared per day using the second method. The fisher whose gill net catches were used to derive the net to trap conversion factor in this study hauled 800 m drops of net each day. The fisher believed that crab catches double, or even marginally better than double what would have been expected for a 24-hour soaking period, were achieved by leaving the nets for 48 hours

Peel-Harvey Estuary fishing trials

Five Peel-Harvey crab fishers were granted concessions to their gill net licences in late 1995 enabling them to use 50 traps per day instead of their gill net concession of 1,000 m of net per day. One of the conditions relating to this concession was that they should complete daily log forms relating to their crab trapping activity. A second group of fishers agreed to supply daily logbook data on their gill net fishing activity.

The estuary was divided into four areas to examine the differences in catch rates by sub-area. Fishers provided catch data in terms of crab numbers. So that the data could be analysed by weight, fishers were asked to record the weight of an exact number of crabs taken from a single catch each week, so that the mean weight of a single animal could be calculated at periodic intervals through the season.

Daily catch rates, expressed as kilograms of legally marketable crabs retained per trap and per 1,000 m of net were calculated for the duration of the gear comparison trials. Unlike in Cockburn Sound, fishers in Peel-Harvey believe they obtain optimal catches for sets of 24 hours and therefore set and haul their nets daily.

Information on trap catches in the Peel-Harvey Estuary were consistently submitted only by a minority of those that were given the concession to use this method, and there were long periods, particularly in the winter months, when no fishing took place as much of the crab stock had migrated out of the estuary (Potter *et al.* 1983a, Potter *et al.* 1998). Gill net fishing data over this period of gear trials was even more limited than for trap fishing, with returns having been completed by only two fishers over a three-month period (January-March) in 1996. The paucity of net and trap data has limited any comparative analysis of the two gear types to January-March 1996.

Separate ANOVAs were undertaken using the above data, to examine factors influencing catch rates for the two fishing methods in the Peel-Harvey Estuary. These factors included the soaking times of the respective fishing gear, the month of fishing and the fisher supplying the data. In the case of trap fishing, fishing area was considered in the analysis as an additional factor. Fishing area was not considered as a specific factor influencing net catches, because all the gill net data were taken from a single locality. Daily catch rates were logarithmically transformed prior to analysis to normalise their skewed distribution.

Cockburn Sound and Peel-Harvey Estuary compulsory catch returns

Professional fishers in Western Australia are obliged to submit monthly catch and effort returns reported by one degree (60x60 minute) grid cells, or in the case of estuaries and major embayments, by the particular estuary or bay concerned. Such data are available for commercial blue swimmer crab operations from 1975/76 to date and have been used to provide historic comparative seasonal crab landings for Peel-Harvey Estuary, Cockburn Sound and the whole Western Australian fishery. The same data source has been used to show numbers of net and trap fishers in Cockburn Sound and Peel-Harvey, as well as their catch, effort and catch per unit of effort (cpue) each season.

With the change from nets to traps, there were numerous instances where licensees provided catch and effort data from both methods within the same season. The procedure that has been followed where these data have been used to examine seasonal catch per fisher, or number of days per season worked by fishers using one method compared with the other, has been to omit the contribution to catch and effort for that season, for any method where less than 60 per cent of the total effort for that season was fished using that method.

Monthly catch and effort return data have been used to examine year-to-year and month-to-month variations in catch rates for trap and gill net catches made in the Peel-Harvey Estuary and in Cockburn Sound. Particular attention has been paid to month-method interactions, to investigate whether the duration of the fishing season differed between methods, and year-method interactions, to investigate whether trap fishers have become more efficient relative to net fishers over the period that traps have been used in the fishery. There were few trap catches reported in Cockburn Sound prior to April 1994 and in Peel-Harvey Estuary prior to January 1996 and, therefore, ANOVA runs for these two areas have been limited from these dates onward to June 1998.

Results

Cockburn Sound fishing trials

The mean weight of legal-sized crabs caught using gill nets in March 1994 was 307 g and 336 g for crabs caught using traps. Proportions of crabs in the categories legal-size, under-size, ovigerous and dead are presented in Table 1. Traps than took fewer ovigerous crabs than gill nets, but traps caught a larger number of under-sized animals than gill nets. No dead crabs were recorded in traps, compared with nearly three per cent by number of all animals taken by gill nets being landed dead.

Based on sampling results, a 1,200 m length of net (the amount of gill net permitted to be hauled over a 24-hour period) provided a mean catch taken over a 48-hour period of 139.42 kg of legal-sized crabs. The mean (48 hour) catch for 1,200 m of gill net divided by the mean daily catch of a trap 1.24 kg/trap/day, has shown that an estimated 112 traps would be required to take a trap catch equivalent to that amount of gill net in Cockburn Sound.

Table 1: Proportions of blue swimmer crabs in four categories. Samples from commercial catches in Cockburn Sound during March 1994.

	Gill Net		**Trap**	
Category	No./1000m net/day)	Percent	No./trap/day	Percent
Size	200.3	89.8	4.7	60.4
Undersize	12.0	5.4	3.1	39.6
Ovigerous	4.5	2.0	<0.1	<0.1
Dead	6.4	2.8	0.0	0.0
Total	223.2	100.0	7.8	100.0

Peel-Harvey Estuary fishing trials

An ANOVA for all years for which there were trap logbook data available (January-August 1996, output summary not presented), showed catch rates to decline significantly over the course of the fishing season ($p < 0.001$). January to April showed the most similarities in catch rates, but these declined sharply thereafter to reach lowest catch rates in August. Since month was so significant, it was obvious that any comparative analysis of nets and traps would need to be restricted to only the months over which data were available for both gear types. Net logbook data were only available for January-March, so these were the only months for which trap and net data were analysed.

An ANOVA run for the Peel-Harvey Estuary gill net logbook data between January and March 1996 in Area 4 (Table 2) showed differences in catch rates to be significant over the three month sampling period ($p = 0.0096$) with catch rates declining from January to March (Table 3). There was no significant difference between the catch rates obtained by the two fishers who contributed to the data set, nor was the soaking period of the net found to be a significant influence.

Table 2: Summary of an ANOVA of CPUE for logbook reported gill net catches in Peel-Harvey Estuary, January-March 1996 (*F = F-statistic*).

Factor	Sum of squares	df	Mean Square	*F*	*P*
Licence No.	0.0058	1	0.0058	0.03	0.8742
Month	2.2425	2	1.1213	4.91	0.0096
Soak-time	1.4005	4	1.4005	0.3501	0.2002
Error	19.4269	85	0.2286		

Table 3: Summary of monthly logbook reported gill net catch rates in Peel-Harvey Estuary, January-March 1996.

Areas	January	February	March	Combined
N	33	36	24	93
Mean (kg/1000m net)	79.4	55.1	47.8	61.8
SD (kg/1000m net)	44.2	22	13.5	33
Median (kg/1000m net)	65	52.3	46.6	53.3
Maximum (kg/1000m net)	180	125	74	180
Minimum	14	8.6	20	8.6

An ANOVA run for trap logbook data over the period January to March 1996, showed fishing locality within the Peel-Harvey system to be highly significant ($p = 0.0001$) in influencing catch rates, Area 3 producing better catch rates than Area 2 (Table 5). Fishing month did influence log CPUE, but unlike the gill net data set or the longer January to August trap catch logbook data set mentioned above, it was not shown to be significant (p = 0.08, Table 4). Soak-time and individual fisher ability did not influence trap cpue significantly (p = 0.4538 and p = 0.6217 respectively, Table 4).

Monthly catch rates for the period over which logbook data were submitted are presented in Table 3 for gill nets and Table 5 for traps. Due to the limitation of the data, it has not been possible to establish a net to trap conversion factor that takes different fishing areas and seasons into account.

Table 4: Summary of an ANOVA of CPUE for logbook reported trap catches in Peel-Harvey Estuary, January-March 1996 (*F* = *F-statistic*).

Factor	Sum of squares	df	Mean Square	*F*	*P*
Licence No.	0.0608	3	0.0304	0.48	0.6217
Month	0.3256	2	0.1628	2.55	0.0809
Fishing Area	1.7008	1	1.7008	26.65	0.0001
Soak-time	0.6977	11	0.0634	0.99	0.4538
Error	10.9753	172	0.0638		

Table 5: Summary of reported monthly logbook trap catch rates by fishing area in Peel-Harvey, January-March 1996.

Months	**January**			**February**				**March**				
Areas	2	3	Total	2	3	4	Total	2	3	4	Total	All areas
N	3	25	28	24	41	12	77	22	35	28	85	190
Mean (kg/trap)	1.44	1.58	1.57	1.39	1.54	1.02	1.41	1.16	1.46	0.80	1.16	1.32
SD (kg trap	0.48	0.32	0.33	0.44	0.36	0.40	0.43	0.11	0.24	0.22	0.35	0.41
Median (kg/trap)	1.45	1.60	1.58	1.47	1.55	0.91	1.45	1.16	1.46	0.80	1.19	1.32
Max. (kg/trap)	1.91	2.27	2.27	2.24	2.23	1.74	2.24	1.39	1.94	1.28	1.94.	2.27
Min. (kg/trap)	0.95	1.04	0.95	0.44	0.75	0.52	0.044	0.87	0.84	0.46	0.46	0.44

As a result of the month-to-month influence on catch rates (Tables 2 and 4), separate conversion factors have been calculated for the three months for which logbook data have been submitted using the mean gill net catches for each month and the mean trap catch rates for all areas combined. The results are presented in Table 6. January had a somewhat higher conversion factor (50 traps per 1,000 m of net) than the other two months, which gave similar factors of approximately 40 traps per 1,000 m of net. The difference in January compared with the other two months is probably related to trap catch saturation in that month of peak catch rates. Catch saturation effects have been recorded in blue swimmer crab trap catches made in the Peel-Harvey Estuary in summer months by de Lestang (1997).

Table 6: Net to trap conversion factors for logbook reported catch rates in Peel-Harvey Estuary in January-March 1996.

Month	Mean gill net catch rate(SE) (kg/100m net)	MeanTrap catch rate (SE) (kg/trap)	Conversion Factor (traps/100m net)
January	79.35 (7.69)	1.57 (0.06)	50.5
February	55.11 (3.67)	1.41 (0.05)	39.1
March	47.79 (2.79)	1.16 (0.04)	41.2

Cockburn Sound and Peel-Harvey Estuary compulsory catch returns

Reported blue swimmer crab landings between the 1975/76 and 1997/98 seasons are presented for the commercial fishery as a whole and separately for Cockburn Sound and the Peel-Harvey Estuary in Figure 2. A historical breakdown of the number of licensed crab fishers is presented for Cockburn Sound (Figure 3) and for Peel-Harvey Estuary (Figure 4). Both Figures 3 and 4 clearly show the transition from gill nets to traps that have taken place in these areas of the fishery in recent seasons. The mean seasonal catch per fisher using gill nets and traps between 1980/81 and 1997/98 is presented in Figures 5 and 6, and the mean number of days worked per season by those same fishers is presented in Figures 7 and 8 for Cockburn Sound and Peel-Harvey respectively. Monthly cpue figures for Cockburn Sound and Peel-Harvey Estuary are shown for trap catches in Figures 9 and 10 and for net catches in Figures 11 and 12.

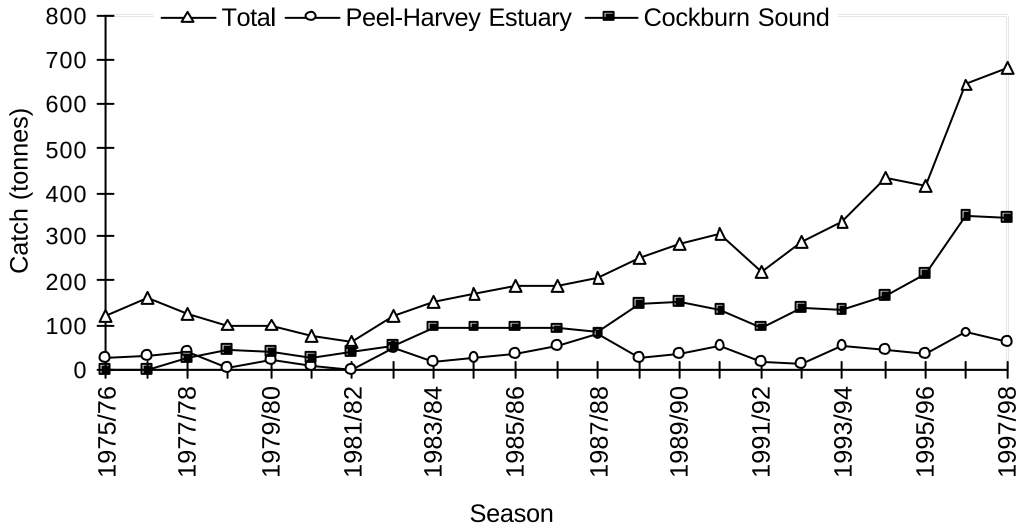

Figure 2: Blue swimmer crab landings in the Peel-Harvey Estuary, Cockburn Sound and over the whole Western Australian coast, 1975/76 to 1997/98.

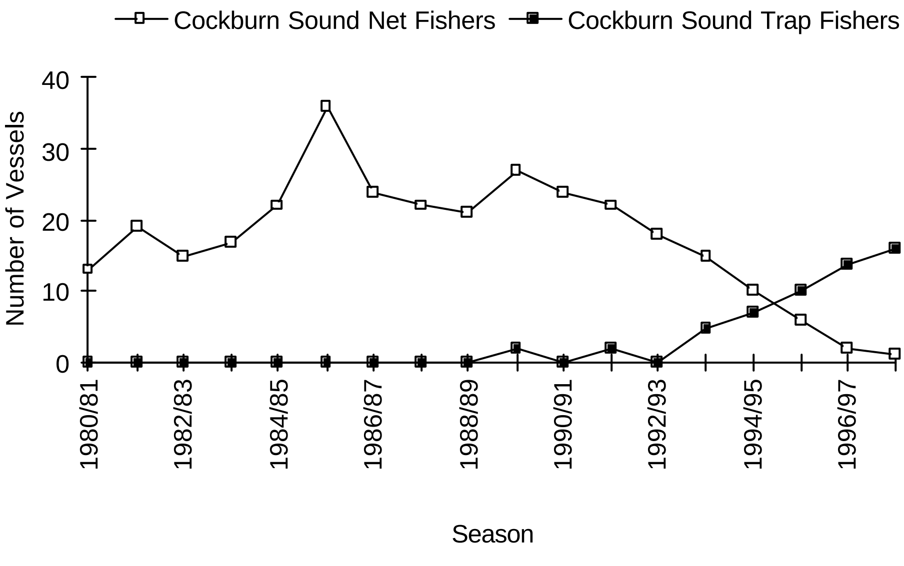

Figure 3: Numbers of fishers actively fishing for blue swimmer crabs with nets and traps in Cockburn Sound, 1980/81 to 1997/98.

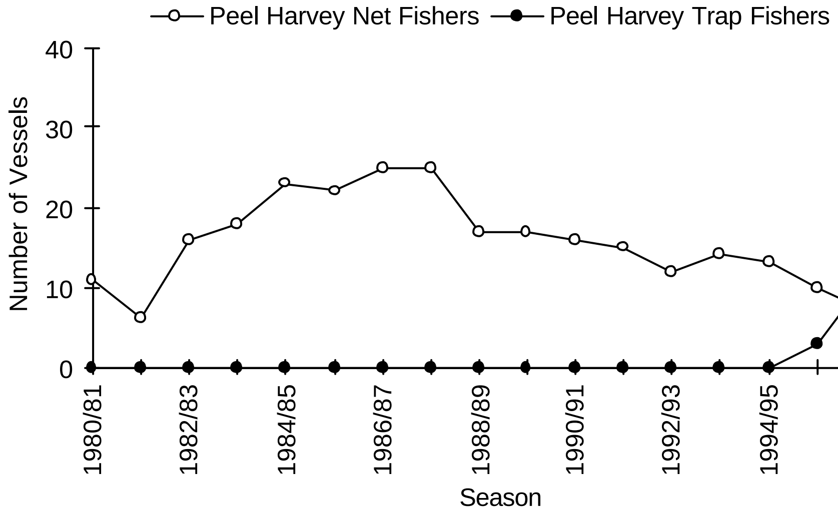

Figure 4:Numbers of fishers actively fishing for blue swimmer crabs with nets and traps in Peel-Harvey Estuary, 1980/81 to 1997/98.

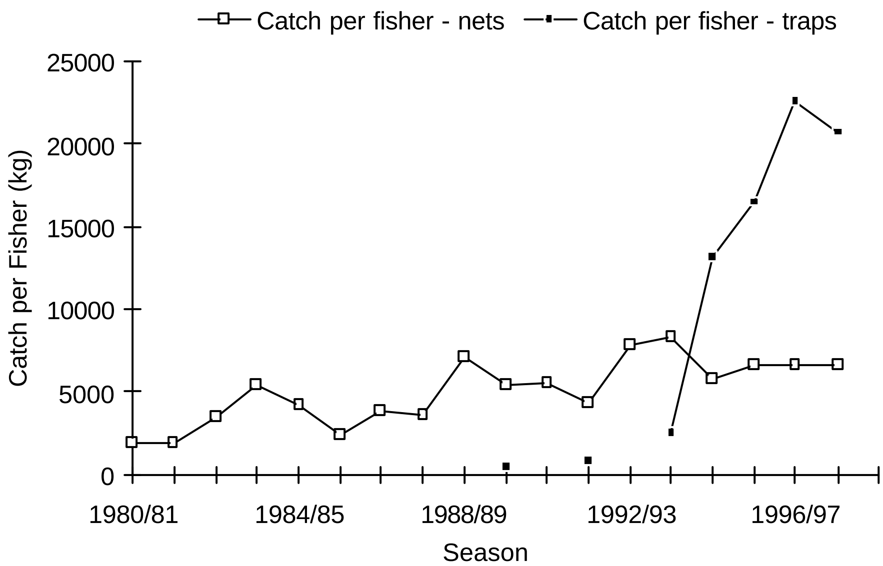

Figure 5: Mean seasonal blue swimmer crab catch per trap fisher and gill net fisher in the Cockburn Sound, 1980/81 to 1997/98.

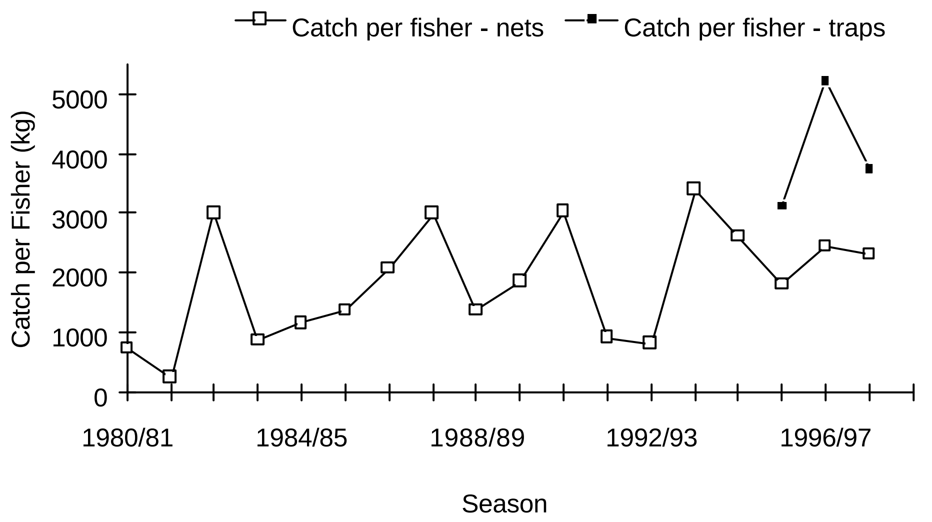

Figure 6: Mean seasonal blue swimmer crab catch per trap fisher and gill net fisher in the Peel-Harvey Estuary, 1980/81 to 1997/98.

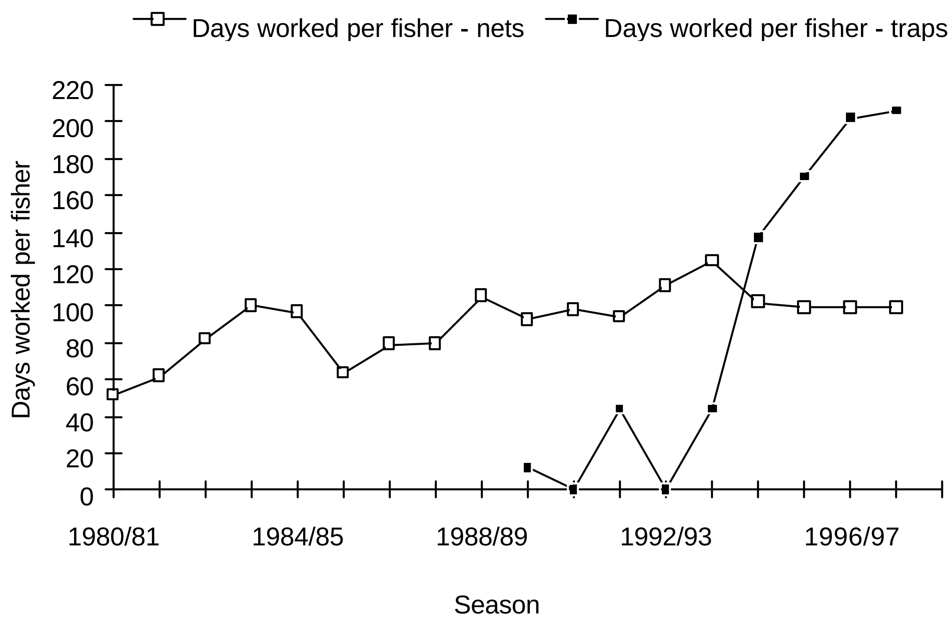

Figure 7: Mean number of days worked per season by blue swimmer crab trap and gill net fishers in Cockburn Sound, 1980/81 to 1997/98.

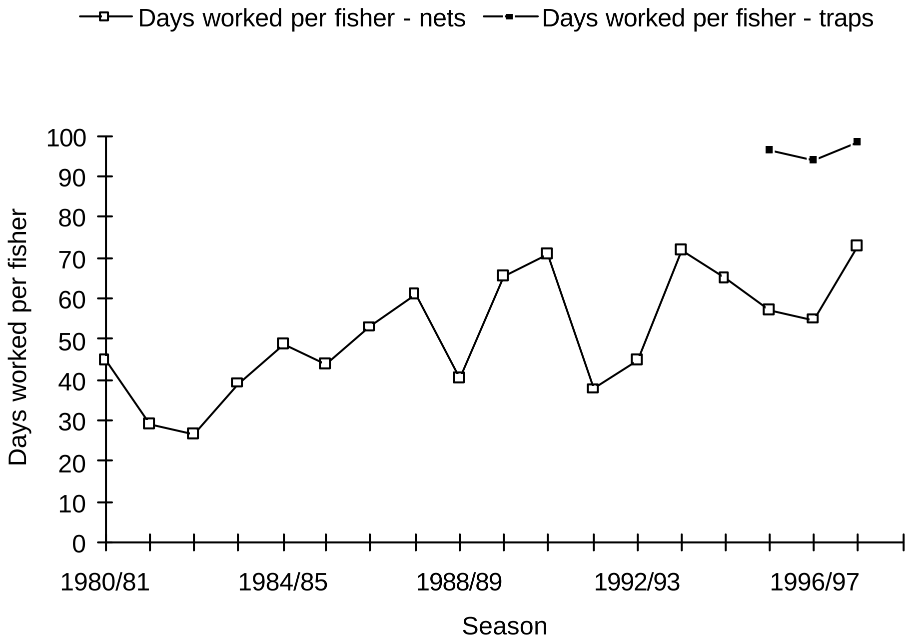

Figure 8: Mean number of days worked per season by blue swimmer crab trap and gill net fishers in Peel-Harvey Estuary, 1980/81 to 1997/98.

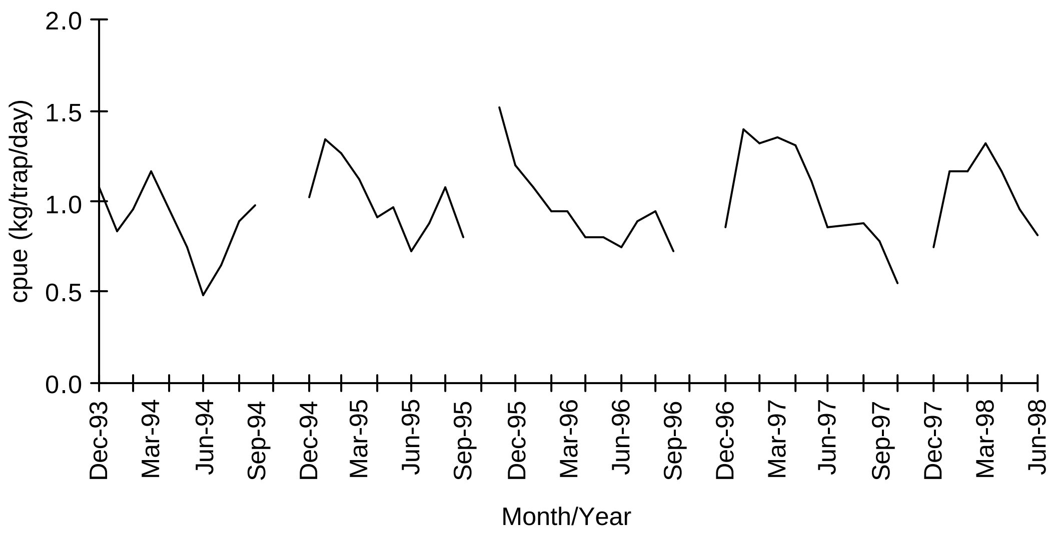

Figure 9 Catch per unit effort (in kg/trap/day) for the Cockburn Sound blue swimmer crab fishery, December 1993 to June 1998.

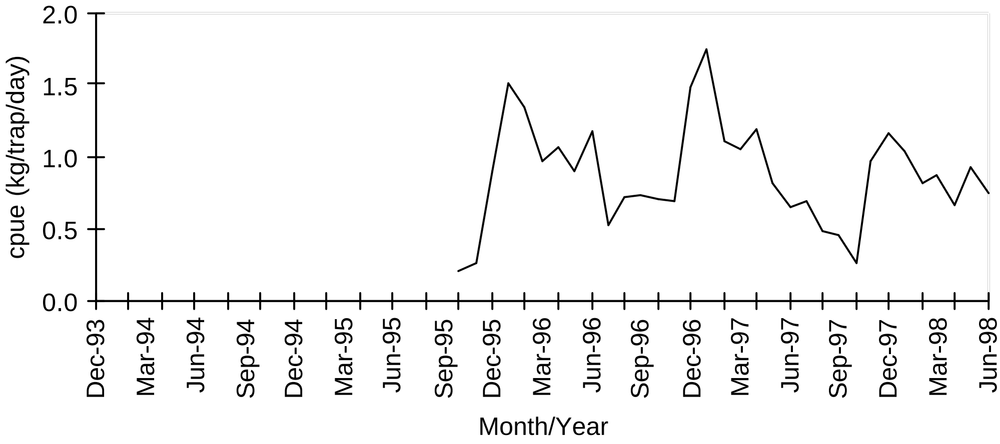

Figure 10: Catch per unit effort (in kg/trap/day) for the Peel-Harvey blue swimmer crab fishery, November 1995 to June 1998.

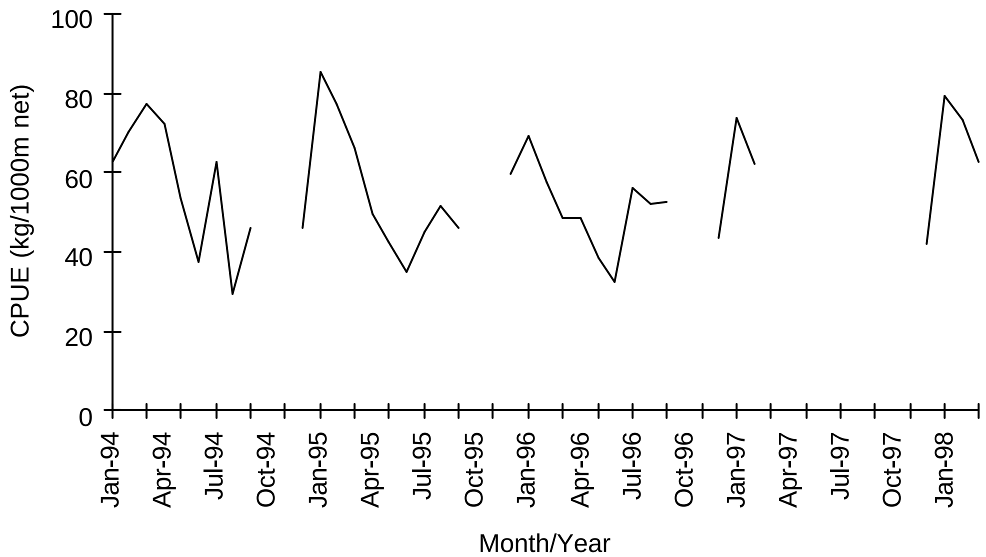

Figure 11: Catch per unit effort (in kg/1,000 m net/day) for the Cockburn Sound blue swimmer crab net fishery, January 1994 to March 1998.

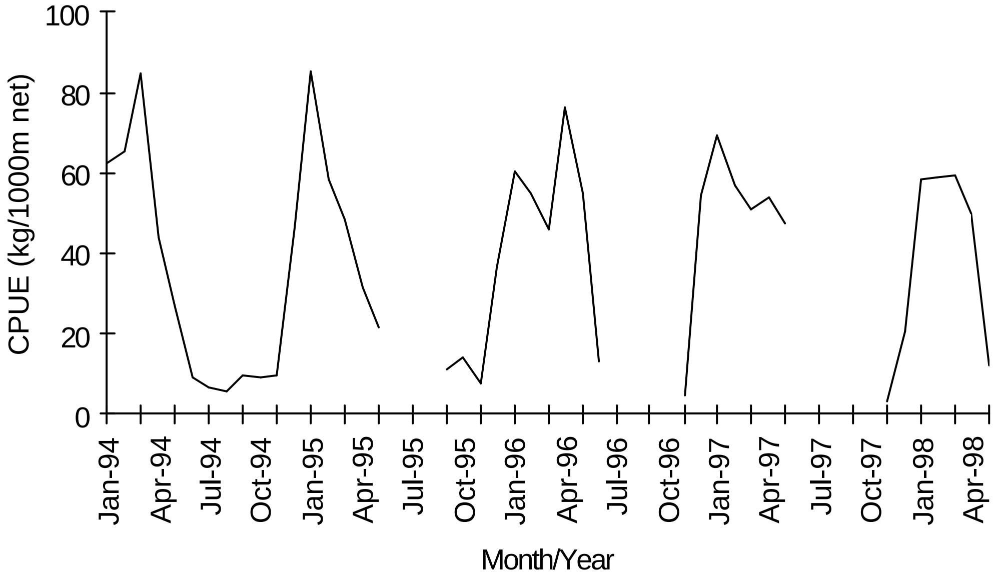

Figure 12: Catch per unit effort (in kg/1,000 m net/day) for the Peel-Harvey Estuary blue swimmer crab net fishery, January 1994 to May 1998.

ANOVA's were run using net and trap compulsory catch and effort cpue data from Cockburn Sound between April 1994 and June 1998, and Peel-Harvey Estuary between January 1996 and June 1998. The results showed that in Cockburn Sound there were significant variations in cpue from year-to-year (p = 0.0128) and from month-to-month (p = 0.0001) (Table 7), however, in the Peel-Harvey Estuary cpue variations were not significant for these factors (Table 9). The results further showed that there were significant interactions between month-method (p = 0.001) and year-method (p = 0.013) in the Cockburn Sound data (Table 7), indicating that there were strong inter-annual and inter-monthly differences in the way that the two gear types fished.

As all factors in the ANOVA were significant (Table 7), a further test has been done to extract significant parameters making up these factors (Table 8). For each year, month, method and interaction, a scaled estimate has been calculated in relation to a control parameter for each factor. These controls were 1998, December and Trapping. The interaction between month and method (Table 8) shows that netting in January and February had higher cpue values relative to trapping than June. These same interactions did not produce a significant result for the Peel-Harvey data (Table 9), but this may be due to the short time over which comparisons for the two gear types have been possible for this area.

Table 7: Summary of an ANOVA of CPUE in Cockburn Sound over months for which both trap and net data were available (April 1994 to June 1998, n = 66, *F* = *F-statistic*).

Factor	Sum of Squares	df	Mean square	*F*	Pr>*F*
Year	1005.56	4	251.39	3.66	0.0128
Month	3492.35	9	388.04	5.65	0.0001
Method	41546.53	1	41546.53	605.11	0.0001
Year*Method	1004.01	4	251.001	3.66	0.013
Month*Method	3342.44	9	371.38	5.41	0.001
Error	2609.08	38	68.66		

Table 8: Significant parameters which make up the ANOVA in Table 7 (GN= Gill netting)

Factor	Parameter	Estimate	Pr>|T|
Month*Method	1GN	31.1395	0.0009
	2GN	24.2606	0.0078
	6GN	-24.6769	0.0106

Table 9: Summary of an ANOVA of CPUE in Peel-Harvey over months for which both trap and net data were available (January 1996 to June 1998, n = 40, *F* = *F-statistic*).

Factor	Sum of Squares	df	Mean square	*F*	Pr>*F*
Year	222.55	2	111.27	0.21	0.8153
Month	7249	7	1035.57	1.92	0.1195
Method	20414.08	1	20414.08	37.85	0.0001
Year*Method	207.3	2	103.65	0.19	0.8267
Month*Method	7143.62	7	1020.52	1.89	0.1245
Error	10786.74	20	539.34		

Both areas showed indications that the number of traps equivalent to standard net lengths, may be larger in the summer and autumn months (January to April) than at other times of the year (Tables 10 and 11). This trend, would suggest that nets perform best relative to traps in summer and autumn. More data, particularly from the Peel-Harvey Estuary, will be required to confirm this observation. There are no data available for Cockburn Sound in October and November due to the closure to fishing in that area over those months. Month-to-month variability in the conversion factors recorded for Peel-Harvey Estuary is due to certain figures (mostly winter months) being based on few data.

Table 10: Net to trap conversion factors for Cockburn Sound (April 1994 to June 1998) obtained from raw data.

Month	Mean gill net catch rate(SE) (kg/1200m net/day)	MeanTrap catch rate (SE) (kg/trap)	Conversion Factor (traps/1200m net)
January	91.72 (5.18)	1.45 (0.18)	63.26
February	84.54 (8.89)	1.15 (0.07)	73.51
March	70.02 (5.76)	1.11 (0.11)	63.08
April	68.19 (13.85)	0.86 (0.04)	79.29
May	56.38 (6.12)	0.9 (0.11)	62.64
June	42.51 (2.82)	0.64 (0.08)	66.42
July	67.12 (11.34)	0.77 (0.06)	87.17
August	55.18 (3.42)	0.95 (0.08)	58.08
September	54.47 (4.58)	0.79 (0.05)	68.95
December	63.71 (10.37)	1.09 (0.13)	58.45
Overall	**66.71 (3.28)**	**1.00 (0.05)**	**66.71**

Table 11: Net to trap conversion factors for Peel-Harvey (January 1996 to June 1998).

Month	Mean gill net catch rate(SE) (kg/1200m net/day)	MeanTrap catch rate (SE) (kg/trap)	Conversion Factor (traps/1200m net)
January	80.89 (19.41)	1.41 (0.19)	57.37
February	60.36 (4.22)	1.06 (0.12)	56.94
March	71.12 (4.79)	1.00 (0.06)	71.12
April	97.60 (33.39)	0.97 (0.16)	100.62
May	45.10 (16.61)	0.90 (0.04)	50.11
June	16.17 (0.00)	1.29 (0.00)	12.53
November	7.10 (4.05)	0.72 (0.03)	9.68
December	40.83 (12.88)	1.31 (0.16)	31.17
Overall	**58.86 (1.07)**	**1.07 (0.06)**	**57.15**

Monthly and annual net to trap conversion factors for Cockburn Sound and Peel-Harvey Estuary, were calculated from the ANOVA runs used to generate Tables 7 and 9. These results, which have taken year-to-year and month-to-month variation into account, showed that 67 traps could be expected to produce a catch equivalent to 1,200 m of net soaked for 48 hours in Cockburn Sound (Table 12), and that 55 traps could be expected to produce a catch equivalent to 1,000 m of net soaked for 24 hours in Peel-Harvey Estuary (Table 13).

Table 12: Interannual net and trap catch rates and net to trap conversion factors based on compulsory catch and effort data, for Cockburn Sound (April 1994 to June 1998).

Year	Mean gill net catch rate(SE) (kg/1200m net/day)	MeanTrap catch rate (SE) (kg/trap)	Conversion Factor (traps/1200m net)
1994	70.20 (8.67)	1.41 (0.19)	49.79
1995	65.59 (6.60)	1.06 (0.12)	61.88
1996	58.42 (3.92)	1.00 (0.06)	58.42
1997	70.61 (11.32)	0.97 (0.16)	72.79
1998	86.05 (5.96)	0.90 (0.04)	95.61
Overall	**66.71 (3.28)**	**1.00 (0.05)**	**67.05**

Table 13: Interannual net and trap catch rates and net to trap conversion factors based on compulsory catch and effort data, for Peel-Harvey (January 1996 to June 1998).

Year	Mean gill net catch rate(SE) (kg/1200m net/day)	MeanTrap catch rate (SE) (kg/trap)	Conversion Factor (traps/1200m net)
1996	50.93 (8.85)	1.17 (0.10)	43.53
1997	63.28 (18.70)	1.11 (0.11)	57.01
1998	65.37 (17.47)	0.86 (0.06)	76.01
Overall	**58.86 (8.27)**	**1.07 (0.06)**	**55.01**

Discussion

There are numerous reasons that might explain the interest in the commercial blue swimmer crab fishery that has developed in recent years. One driving factor has certainly been an increase in demand for the product, since the industry began focusing on the development of export markets for crab in forms other than the traditional whole raw/cooked product. In recent times producers have been testing the markets with live as well as processed raw and cooked meat (Stevens 1995, Campbell 1997) and some success has been achieved in this regard.

It is difficult to quantify the extent to which the change over from nets to traps has played in increasing the commercial crab catch in the state. Cockburn Sound is the only area to date to have made a complete conversion from a net to a trap fishery and is currently responsible for producing over half of the Western Australian commercial blue swimmer crab catch. The increase in landings in that area between 1993/94 and 1996/97 (the years in which the major change-over from nets to traps has taken place) was 150 per cent compared to only a 50 per cent increase over that same period for the rest of the coast (percentages based on figures used to compile Figure 2). This large difference would suggest that traps have probably played a very significant part in the increase in landings.

The net to trap conversion factor introduced for Cockburn Sound in 1994, appears over-estimated based on the compulsory catch and effort data produced in this report. Results from the original one-month experiment conducted with the assistance of two commercial fishers in March 1994, suggest that 112 instead of the 100-trap limitation for 1,200 m of gill net, would have been the most appropriate conversion ratio. However, this contrasts strongly with more comprehensive conversion factor calculations that have made use of compulsory catch and effort data over a longer time frame. These data, covering all months of the year over a four year period (Table 12), suggest that 67 rather than 100 traps would have been a more appropriate conversion ratio for a daily haul from 1,200 m of gill net.

Several assumptions, however, have had to be made in comparing net to trap catches in Cockburn Sound, all of which could have biased the result in one or other direction. One of the assumptions most likely to have affected the sensitivity of the conversion factor calculation, was the restriction of the comparison of the two fishing methods in 1994 to just one month (March) of the year. It is apparent from the ANOVA incorporating the interaction between month and method (Table 7), that fishing success significantly differs at different times of the year. The results of that ANOVA run (Table 8), show that traps are less effective than nets in Cockburn Sound during summer and autumn, and since March falls into that period it would have been likely to have produced a higher net-trap conversion ratio than had the trial taken place during winter or spring months. Ideally, a trial of the type reported here should have been conducted over a full twelve-month period, by a group of participants using both gear types, in order to have avoided the potential bias that may have resulted from month-to-month variability in the data.

Other factors, which may have biased the Cockburn Sound net to trap conversion ratio results:

(i) Net fishers often did not use the same net length every day - either using their maximum entitlement or only part of it. Since compulsory catch and effort data only recorded number of days fished, net length utilised and catch made per month, it was not simple for them to adjust their monthly net-length figure to reflect their day-to-day effort variations. Few, if any, fishers would have attempted to make these adjustments. The majority stated their maximum entitlement and so calculations based on these data may have over-estimated fishing effort.

(ii) The state of the gill nets; new nets are considered by fishers to have better catch rates than old. Effort was made to use gill nets of an intermediate age in this study so as not to influence the result.

(iii) Both fishers who assisted with the trap and gill net catch information fished in areas of similar crab density and were of similar ability. The two fishers generally worked in similar areas and were both very experienced fishers. It is therefore believed that this assumption was valid.

When the net to trap conversion experiment was carried out in Cockburn Sound in 1994, the use of traps for crab fishing was unfamiliar to most of the participants in this fishery. It would be expected that, over time, fishers would become more skilled at using traps as they became more familiar with the gear, and there have been some refinements to traps over this period with the intent of improving their catching efficiency (e.g. covering the traps with larger mesh net than was used when traps were first introduced). Data presented in Table 12 showed no indication of improving efficiency with traps over time. In fact, the improving net to trap ratios in the first few years after the introduction of traps does cast doubt as to whether the increase was due to some currently unexplained decrease in efficiency of traps over those years or simply to error around the mean.

Soaking periods of gill nets and traps were shown to be not significant in the Peel-Harvey analysis (Tables 2 and 3) as there was very limited variation in soaking times in the data set, because most settings were made over a 24-hour period. Had there been more variation, it is likely that this factor would have produced a significant result when soaking times were either particularly long or particularly short. Of more significance to the conversion factors calculated from the fishing trials in January to March 1996, is the strong likelihood (which has been borne out to some extent by visual analysis of compulsory catch and effort data in Table 11 and logbook data in Table 6), that the two types of fishing gear may have given different conversion ratios in the January to March period, to what they would have had if the trials had been conducted in winter or spring. It is also apparent that there is some inter-annual variability in calculated conversion ratios (Table 13), which may have affected the results in Table 6, however, at this stage, based on less than three years of data, year-to-year variation in catch rates is not significant in the Peel-Harvey Estuary (Table 9).

In the Peel-Harvey system, gill nets tend to be set in deeper water in the channels, while traps by comparison have, until recently, been attached to individual buoys and as such have needed to be set away from channels to prevent them from being a hazard to boating. Since the two gear types frequently fish different localities in the estuary, they could be fishing different (but interacting) sub-populations of the crab fishery. It would seem likely that the data in Table 4 were obtained from nets set in the channels, while the trap data in Table 5 were probably from the fringes of the channel. It is unclear how this might have influenced the conversion factor result.

Based strictly on the conversion factors calculated in Table 6, it could be concluded that if the management objective is to keep the daily catch made by traps to a similar level to that made by gill nets, then the appropriate trap to net conversion should be 44 traps to 1,000 m of net (based on the mean of the conversion ratio for January to March 1996). If, however the net to trap conversion factor were to be based on the compulsory catch and effort return data (Table 13), then 55 traps for 1,000 m of net would appear to be more appropriate.

Reported total blue swimmer crab landings over the last twenty years show that there has been steady overall growth in the fishery, with particular emphasis on the period in the 1990s (Figure 2). Landings in Cockburn Sound have closely reflected catch trends in the State, a fact that is not surprising considering that the area currently accounts for around half of the Western Australian commercial catch. Peel-Harvey Estuary by comparison has a variable history of crab landings. Some of the troughs in crab landings (Figure 2) coincide with years when big algal blooms of the blue-green algae *Nodularia spumigena* have resulted in reducing the dissolved oxygen levels in the estuary to levels which have led to mortalities of *P. pelagicus* (and many other species) and also caused many of the species in the estuary, probably blue swimmer crabs included, to migrate either out of the estuary or to parts of the estuary less affected by the blooms (Potter *et al.* 1983b). The construction of the Dawesville Cut in 1995, which linked the estuary in locality 3 to the ocean (Figure 1), has increased the exchange of water between the sea and the estuary and has prevented the development of conditions that gave rise to the algal blooms of earlier years. Crab landings have generally increased since the construction of the Dawesville cut and there is evidence (Potter *et al.* 1998) to suggest that this may be at least in part, due to better crab recruitment into the estuary since the construction of the channel.

The number of fishers licensed and actively fishing for crabs in Cockburn Sound (Figure 3) and Peel-Harvey Estuary (Figure 4) peaked in both areas in the 1980s. Both fisheries were rationalised in the early 1980s and the licence conditions of those fishers who were not maintaining a given minimal usage of their concession, were removed in the interests of reducing latent effort in the fishery. In the 1997/98 season there were 16 fishing units in Cockburn Sound and 25 in the Peel-Harvey Estuary that were entitled to use crab fishing gear. In the case of the Peel-Harvey Estuary fishery only 17 of the fishing units reported landing blue swimmer crab in that season. As of 1998, all Cockburn Sound crab fishers have ceased using gill nets and now use traps.

Trials are underway in Peel-Harvey Estuary to determine public opinion on allowing commercial fishers to use traps instead of nets in the estuary. Trials with five trap fishers using 50 traps each were permitted in the 1995/96 season and this was extended to ten fishers in the 1996/97 and 1997/98 seasons. The number of traps per fisher was reduced from 50 to 40 in the 1997/98 season. It is anticipated that further moves away from net and towards trap fishing will take place in the future.

The seasonal catch per net fisher in Cockburn Sound has shown only a very slight increase over a 15-year period (Figure 5). In Peel-Harvey Estuary over this same period the inter-annual variation of landings made by gill nets were variable with no real long-term trend (Figure 6). Both fishing localities have shown sharp increases in annual landings by trap fishers compared with net fishers since the introduction of that method. The down turn in catch per fisher per trap in Peel-Harvey Estuary in 1997/98 (Figure 6) is due to the reduction in the permitted number of traps that fishers were allowed to use in that area in the past season. There has been a clear difference in the number of days worked by net compared to trap fishers, with the latter group tending to work far more frequently than the former in both areas (Figures 7 and 8).

The higher seasonal catches for trap fishers compared with net fishers in both Cockburn Sound and Peel-Harvey Estuary is very obvious. There would seem to be a number of possible reasons that might have contributed towards this discrepancy, these include:

- In the case of Cockburn Sound there is good evidence to suggest that the net to trap conversion ratios were overly generous and this would certainly have contributed towards the increase in the mean annual total catch per trap compared to net fisher (Figure 5).
- The generosity of the net to trap ratio in Cockburn Sound does not explain the continued increase in mean annual landings by trap compared with net fishers in that area and this trend has also been noted in the Peel-Harvey Estuary data (Figure 6), even though calculated net to trap conversion ratios are not very different from those that were trialed by selected fishers in the 1996 and 1997 seasons. The main reason for this increase is considered to be the greater number of days per year that were worked by trap compared with net fishers. Prior to the change over from nets to traps, fishers were working approximately 100 days/year in Cockburn Sound and 60 days/year in Peel-Harvey Estuary. In the 1997/98 season that time had increased to approximately 200 days in Cockburn Sound and 100 days in Peel-Harvey Estuary.

Those fishers that continued to use nets showed no real change from the historical number of days they fished per year. A possible reason for the increased number of days fished per year by trap fishers is fishing with traps is easier than fishing with nets, combined with the fact that the traps can be used in rougher weather than nets. This is evident from the ANOVA analysis in this report, as blue swimmer crabs remain catchable by traps for much longer into the year than by nets.

- The fact that, as mentioned earlier, traps seem to be more effective in winter and spring than nets, appears to have encouraged some trap fishers to work in months that had not been available to them for crab fishing in the past. Catch and effort statistics show that around the end of May, those fishing crabs in Peel-Harvey Estuary with nets have traditionally ceased their crab fishing due to insufficient crab catches and have moved into some other fishing activity (e.g. fishing for cobbler, mullet or whiting). Since the introduction of trap fishing, catches have stayed high enough to have encouraged at least some trap licensees to continue fishing throughout the year, albeit at a low catch rate (compare Figures 10 and 12). The reason why are more readily caught in traps than in nets in the winter months is unknown, but may be related to them becoming less active at the end of summer (therefore less catchable by nets), but still attracted to bait (therefore catchable by traps).
- In Cockburn Sound, net fishers were entitled to have a limit of 2,400 m of net, but were only permitted to pull 1,200 m in any 24-hour period. Some fishers were in the practice of setting the full 2,400 m of net and then pulling and clearing 1,200 m after a 48-hour period. Others rotated 800 m of net each day so that they always had 1,600 m of net in the water, but were able to remove one 800 m drop of net each day and take that home to clear of crabs at their leisure. Most Cockburn Sound trap fishers are now utilising their full 100 trap allocation when fishing and so the latent effort, that was not being used by those net fishers who were only pulling 800 m of net instead of the 1,200 m that was available to them, is now being utilised.
- Improved survival of under-size or ovigerous crabs caught and released in traps compared with nets during March 1994, may be another contributing reason for the larger annual landings since the change over from nets to traps. Despite the large

quantity of small animals retained in the traps, none were found to be dead after being retrieved from traps set for up to 24 hours, whereas nearly three per cent of net-caught crabs were recorded as dead at capture (Table 1). However, nets are very selective in terms of the size of animals that they retain and only a small part of the catch was smaller than the legal minimum size. By comparison, over a third of the trap catch (39.5 per cent) was sub-legal (Table 1). It is unfortunate that catch composition samples for the two fishing methods are only available for one month (March 1994), because this result may not have been representative of all seasons. However, based on these figures, the less than three per cent tonnage that would have been lost to the fishery through mortality caused by gill netting (Table 1) would have been small compared with the increase in landings since the change-over to traps and would not have been capable of explaining more than a small part of the increased landings of recent times.

- Ovigerous crabs appeared to be slightly more common in gill nets than trap catches, however, this small difference in percentage of ovigerous animals (2.03% compared with 0.05%) may simply have been reflecting the fact that the proportion of legal-sized (and therefore definitely mature) crabs was greater in gill nets than traps (Table 1).

There is some evidence to suggest that the recreational blue swimmer crab catch in Cockburn Sound may have declined in recent years. Dybdahl (1979) estimated the annual recreational blue swimmer crab catch taken by recreational boat users in 1978 to have been 199 tonnes. His survey method of sampling in the day and monitoring boat launchings by trailer counters, however, may have over-estimated those recreational fishers supposedly targeting crabs by including fishers launching at other times of the day to target other species. In contrast, Sumner and Williamson. (1999) undertook a boat ramp survey in the Sound from September 1996 to August 1997 and estimated the recreational boat catch of blue swimmer crabs to be 19 tonnes. This later survey, which was aimed at recreational fin fish rather than crab catches, was only conducted between 0800 and 1600 and did not use trailer counters. This survey, therefore, may have under-estimated crab catches, since it could not account for any recreational boats returning to boat ramps outside of these hours.

In summary, it is likely that the apparent decrease in recreational crab catches in Cockburn Sound over the 18-year period between 1978 and 1996, is overstated due to differences in the sampling methods employed by the two surveys. The decrease does however; contrast with the reported commercial crab catches which have increased by 765 per cent over this same period. The inference must be drawn that an unknown, but possibly significant portion of the increased commercial catch of recent times may be due to the decline in recreational landings.

Determinations of yield and egg per recruit analysis for *P. pelagicus* in Cockburn Sound.

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Introduction

Management strategies currently in place for blue swimmer crabs in Australia vary from state to state in terms of both method of measurement and minimum legal size, with Queensland having the most conservative management strategy by prohibiting the landing of female crabs and having a legal minimum size of 150 mm (CW) for males. In WA management strategies include: gear restrictions, a minimum carapace width (CW) and a requirement to return all berried females to the water. Recreational restrictions in WA include a size limit of 127 mm CW for all areas, while the minimum carapace width for the commercial fisheries varies according to the region. In recent years the commercial fishers in several regions have voluntarily elected to raise the minimum carapace width (i.e. Cockburn Sound to 130mm CW and Carnarvon to135mm CW). The objective of this component of the study was to examine the issues relevant to changing the minimum legal size for blue swimmer crabs.

Size at which a fished species reaches sexual maturity is a common way of determining minimum legal size. This rational is based on allowing a species the opportunity to reproduce before being fished. However, Potter *et al*. (2001) state that blue swimmer crabs in Cockburn Sound reach sexual maturity well before the current minimum legal size (130 mm CW), with females reaching sexual maturity at 86 mm CW and males at 96 mm CW. Therefore a more appropriate method to examine the minimum legal size and related issues is by using a yield-per-recruit model.

Yield-per-recruit (YPR) models are useful for assessing levels of fishing mortality in exploited fish stocks. A yield-per-recruit model assumes equilibrium conditions with mortality, growth, and recruitment being constant over the life of the fish and further assumes that growth rates and mortality are not density dependent and the effects of declining recruitment due to reduced egg production are not taken into account. Although the assumptions may not be appropriate for many stocks, it is a useful model when little catch and effort data is available. Estimation of appropriate F, fishing mortality rate and /or size of recruitment to the fishery is facilitated by the theory of fishing developed by Beverton and Holt (1957), who developed formulae for the yield available from a given cohort over its fishable life span as a function of mortality, growth, and size of recruitment into the fishery. The theory developed by Beverton and Holt (1957) gives total yield available from a cohort when

1) the rates of fishing mortality and natural mortality are constants independent of age (above some age, t_c, of recruitment into the fishery)
2) growth is given by the von Bertalanffy growth curve
3) there is no dependence of reproductive life history on growth or mortality.

There are two common applications of the yield per recruit in fishery assessment and the economic value per recruit can be used in much the same way.
These are:

1. Calculation of minimum legal size age at first capture that maximizes the yield per recruit under the current fishing mortality.
2. Calculation of the best fishing mortality for a given age/size at first capture.

However, in order for stocks to persist, successive generations must replace each other. This means that fishing should not reduce the egg production or amount of eggs per recruit below a threshold level that is necessary for replacement. Eggs per recruit is used to examine the implications of a given fishing regime to lifetime fecundity and consequently the change in egg to recruit survival that would have to occur to maintain the recruitment at the unfished level.

Methods

MathCAD 2000 was used to determine yield per recruit and egg per recruit analysis. Estimates of growth parameters for *Portunus pelagicus* from Cockburn Sound were obtained from Potter *et al.*, 2001 (Table 1). The value of natural mortality (*M*) used in the calculations was 1.7; this value was obtained from Sukumaran and Neelakantan

(1998). The other values of natural mortality used in figures 2 and 3 (1, 1.5 and 2.0) were used to formulate scenarios either side of the already established natural mortality for the species

Table 1: Estimates of growth parameters for Cockburn Sound (from Potter *et al.* 2001).

Parameter	Female	Male
$L_{infinity}$	161.3	166.0
K	1.01	0.98
to	0.1	0.11
C	1	0.96
tsS	0.76	0.7818

Unlike fish, whose growth can be described by a single continuous growth function, the growth of crabs is discontinuous due to the fact that crabs must moult in order to grow. A mature crab may stay approximately the same size and weight for many months but then increase in size and weight by more than 20% over a period of a couple of weeks as the crab moults. To allow for the step-wise growth of crabs a derivation of a von Bertalanffy growth model, incorporating seasonal variation in growth was applied.

$$L(t,i) := L_{infinity_i} \cdot \left[1 - exp\left[\left(-K_i\right)\cdot\left(t - to_i\right) + \frac{C_i \cdot K_i \cdot sin\left[2\cdot p \cdot \left(t - ts_i\right)\right]}{2\cdot p} - \frac{C_i \cdot K_i \cdot sin\left[2\cdot p \cdot \left(to_i - ts_i\right)\right]}{2\cdot p} \right]\right]$$

where $L_{infinity}$ is the estimated carapace width, *K* is the curvature parameter, *to* is the theoretical age at which the estimated carapace width is zero, C (where 0= C =1) determines the relative amplitude of the seasonal oscillation and *ts* (where 0= *ts* =1) determines the phase of seasonal oscillation with respect to *to*. This function is a modified form of the von Bertalanffy growth curve that was developed by Hoening and Choudary Hanumara (1982) and independently by Somers (1988).

Results and Discussion

Both males and females reach legal size of 130 mm in approximately 15 – 18 months (Figure 1), indicating that in the first 15 - 18 months of life they are vulnerable to the fishery. According to the model used, males and females grow at approximately the same rate with the growth curves of the two sexes displaying similar patterns. Potter *et* *al.* (2001) state that small 0+ recruits start appearing in near shore shallow waters of Cockburn Sound as early as January, the samples also indicated that there were two discrete size groups present. The first size group was comprised of small crabs and corresponded to the new 0+ recruits, while the second group was mainly comprised of the 1+ age class. Potter *et al.* (2001) also state that the smaller class could be easily followed through sequential size frequency distributions until November when they had reached the end of the first year of life at approximately 50-80 mm CW.

Yield per recruit curves on *F* (Figures 2 & 3) illustrate that the yield of blue swimmer crab in Cockburn Sound could be maximized by decreasing t_c (legal size) to 87 mm CW, which corresponds to a crab 7 months old, over most of the range of *M* (1.0-2.0). A reduction in legal size would mean that gains in yield per recruit could be substantial. At the current legal size 130 mm CW, which corresponds to a crab 1.4 years old, yield per recruit for blue swimmer crabs in Cockburn Sound is below its maximum for all but the lowest value of *M* tested.

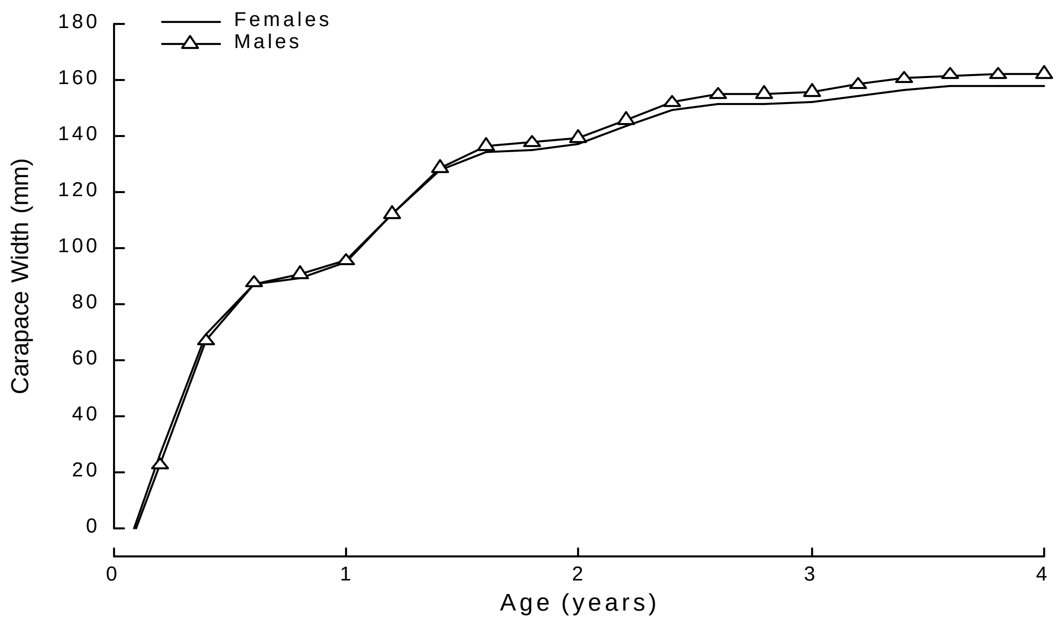
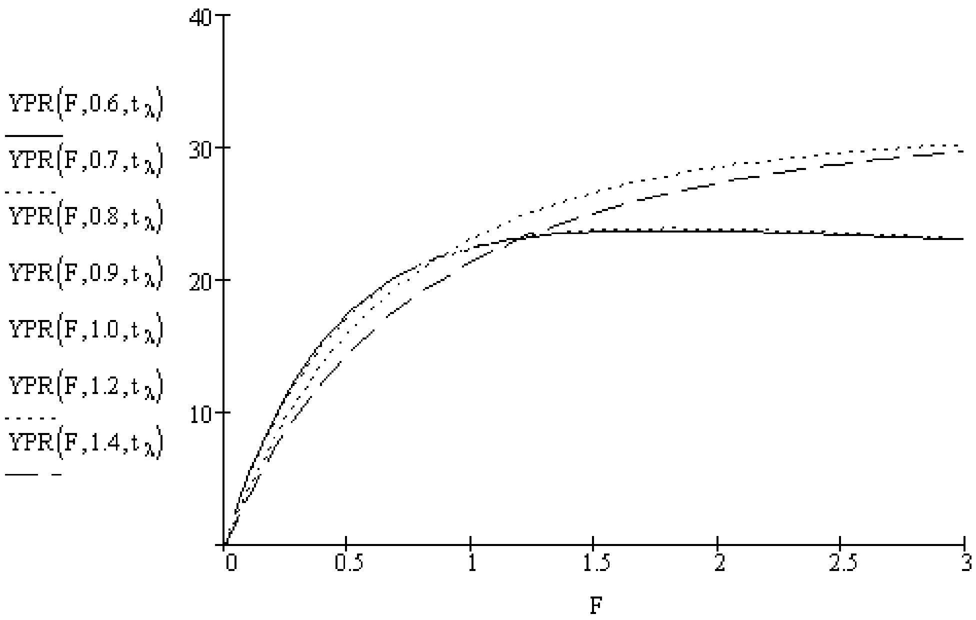


Figure 1: Size/age relationship of both male and female blue swimmer crabs in Cockburn Sound.

A



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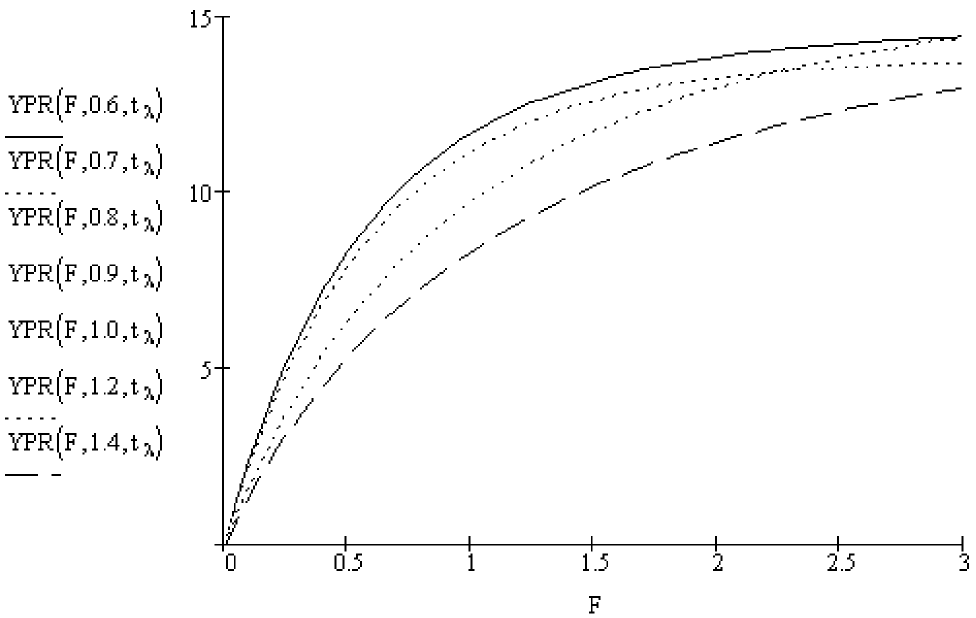

Figure 2: Yield per recruit (YPR) curves on *F* (Fishing mortality) for estimated age of first capture (t_c = 0.6-1.4), with various levels of natural mortality (*M*). A) *M* = 1.0 B) *M* = 1.5

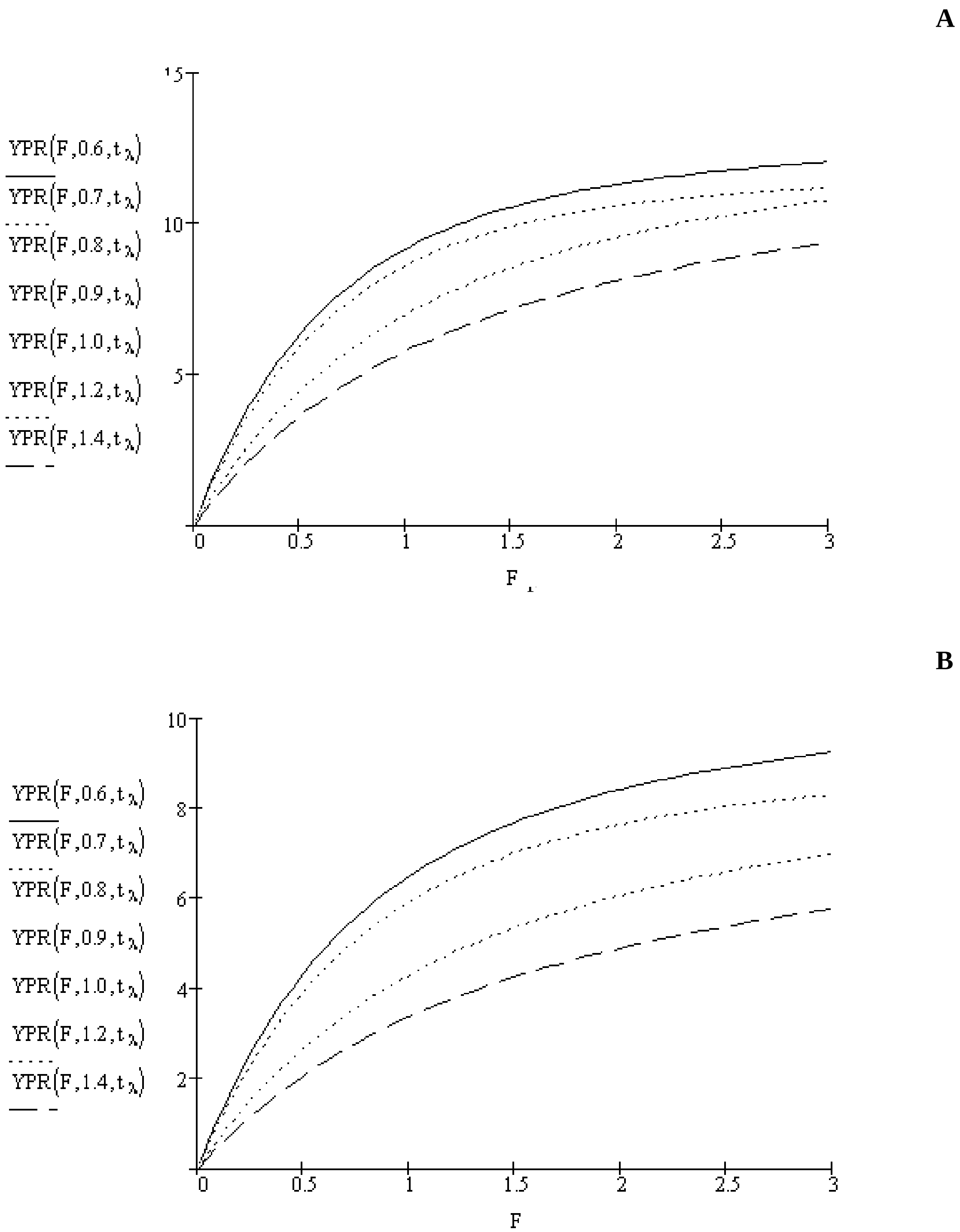

Figure 3: Yield per recruit curves (YPR) on *F* (fishing mortality) for blue swimmer crabs for estimated age at first capture(t_c = 0.6-1.4) and with various levels of natural mortality (*M*). *M* = 1.7 B) *M* = 2.0

However, yield per recruit is not the only consideration when altering minimum legal size regulations. It is essential that the unfished proportion of the stocks have sufficient reproductive capacity to be self-sustaining. Size at maturity analysis indicates that 50% of female blue swimmer crabs are sexually mature (CW_{50}) at approximately 90 mm CW (Figure 4) that corresponds to a crab approximately 11 months old (Figure 5). Similarly Potter *et al.* (2001) state that the carapace width of the smallest female crab that was found to have reached maturity, i.e. undergone its pubertal moult, in Cockburn Sound was 85.2 mm CW. However the CW_{50}s of sexually mature females in Cockburn Sound ranged from 85.2 mm to 87.9 mm with an average of 86.2 mm CW.

Analysis of fishing mortality verses eggs per recruit for different values of age at first capture (Figure 6) indicates that high levels of fishing mortality (*F*) would result in large decreases in eggs per recruit at low age of first capture i.e. 0.2, 0.3 and 0.35 (0-51 mm CW). However at higher ages of first capture i.e. 0.4, 0.45 and 0.5 (70-81 mm CW), eggs per recruit remains relatively consistent even at high levels of fishing mortality.

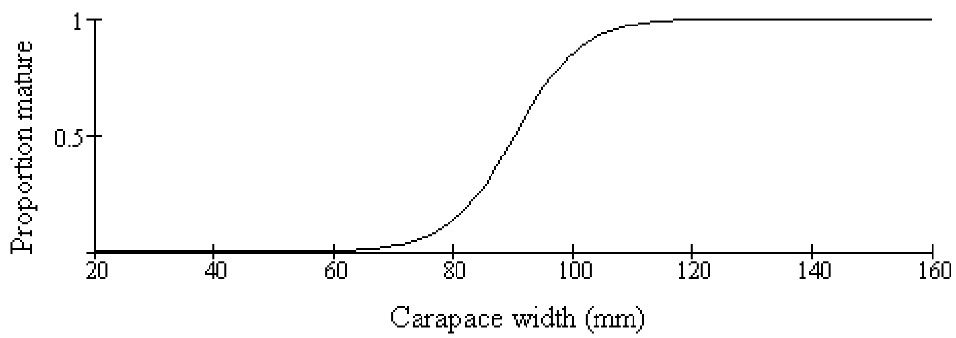

Figure 4: Carapace width (mm) at M_{50} (50% of population is mature) for female blue swimmer crabs

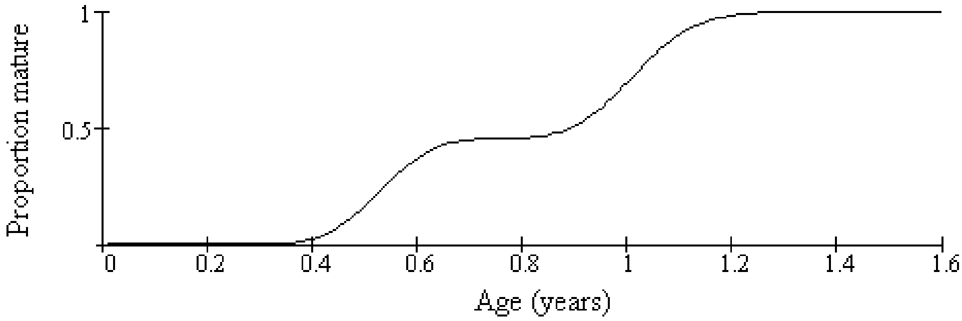

Figure 5: Age in years at M_{50} for female blue swimmer crabs.

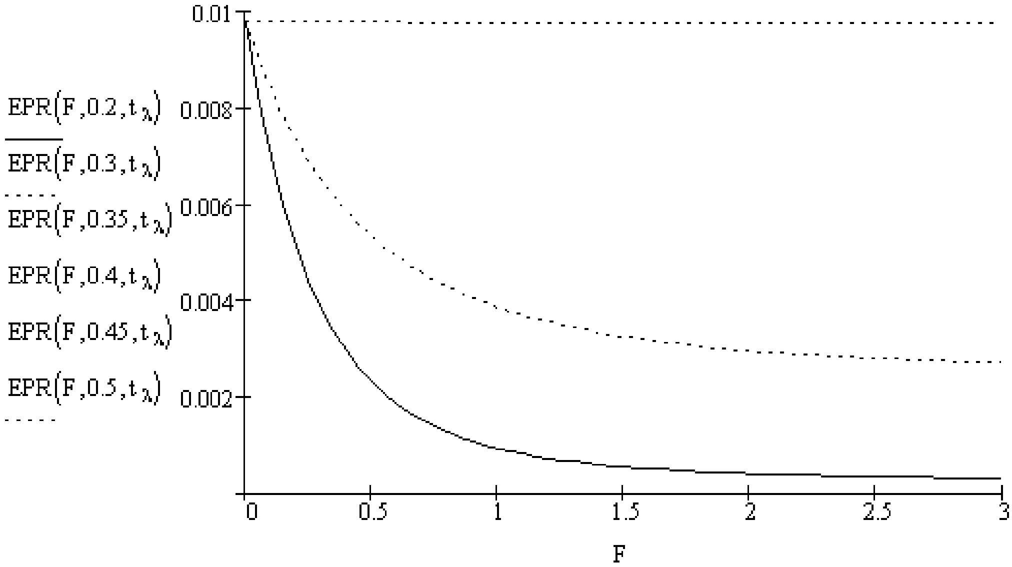

Figure 6: Fishing mortality (F) vs eggs per recruit (EPR) for different values of age at first capture (t_c).

Conclusion

Blue swimmer crabs display rapid growth and have relatively short life cycle, reaching the current legal size of 130 mm CW within 18 months. Similarly, Potter *et al.* (2001) working on *P. pelagicus* in five water bodies (Leschenault and Peel-Harvey estuaries, Koombana Bay, Cockburn Sound and Shark Bay) state that in these estuaries and embayments *P. pelagicus* typically start to attain minimum legal size in late summer, when they are approximately one year old. Potter *et al.* (2001) also found that growth rates of the species in different embayments and estuaries on the lower west coast of Australia did not differ markedly.

Yield per recruit analysis indicated that lowering the minimum legal size to approximately 87 mm CW could substantially increase yield. Similarly, females typically reach maturity (CW_{50}) at 90 mm CW and are highly fecund. Egg per recruit analysis displayed that even high fishing mortality had a minimal effect on fecundity of crabs between 69-81 mm CW. Potter *et al.* (2001) also states that while the sizes at which females typically reach maturity (CW 50) in the five water bodies examined were significantly different from each other those sizes were always well below the minimum legal size for capture, with females in Cockburn Sound typically reaching sexual maturity at 86.2 mm CW.

Therefore given the short time to reach both sexual maturity and legal size and the high fecundity of the species, a reduction in the current legal minimum size to a size which provides maximum sustainable yield (MSY) appears plausible due to the ability of the resource to quickly recover from heavy exploitation. However, this may not be a viable management option for this species for several reasons. Firstly, the traps currently used by fishers allow the escape of undersize (<130 mm CW) crabs; replacement or modification of these traps would be expensive. Blue swimmer crabs currently have a beach price of approximately $4.50, depending on the season and demand, however based on extensive market research several fishers believe that introducing a smaller minimum legal size will result in unmarketable crabs. Therefore despite biological information which suggests a smaller minimum legal size may maximize yields, due to market demands fishers are voluntarily opting to raise the minimum legal size in many of the state's commercial blue swimmer crab fisheries i.e.135 mm CW in the Carnarvon.

Benefits

The fisheries data collected by this project in conjunction with the biological parameters determined by other projects, primarily FRDC 97/137 will be used to develop a clearer understanding of both the population biology and fishery dynamics of blue swimmer crabs. A better understanding of both these components will allow more accurate stock assessments to be conducted and more effective management of blue swimmer crab stocks, which will benefit both commercial and recreational fishers.

Further Development

The combination of previous projects conducted by both the Department of Fisheries and Murdoch University have ensured that we now have a sound understanding of the major areas of blue swimmer crab biology, however an area which requires further research is the development of an effective tagging technique to validate growth information which has until now been obtained using length frequencies.

Similarly there is also a need for further research to be conducted on the recruitment of juvenile blue swimmer crabs into the major commercial fishing grounds to identify which areas within these regions may be acting as important nursery grounds and to aid in the development of a recruitment index for the fishery. This work is the subject of a current FRDC funded grant being conducted by the Department of Fisheries.

General conclusions

The following summary highlights the objectives of the project and serves to illustrate that the project has successfully achieved its objectives.

1. To establish a log book and catch monitoring programme for the fishery.

Both a logbook and catch-monitoring program have been established for the commercial blue swimmer crab fisheries in the major areas on the south west coast. At this stage the value of the logbook and catch monitoring data in determining regional catch trends is limited due primarily to the length of the dataset. However, the programme is ongoing and as the dataset expands logbook and catch monitoring information will be invaluable in determining trends that can be used for more effective management of the fishery. To improve the value of this data for future monitoring and management of the fishery greater liaison between fisheries managers and industry is required to encourage a higher rate of participation in areas which until now have been reluctant to participate and to encourage the return of regular and accurate information from current participants.

2. To establish the effect of trap selectivity/efficiency on the size composition, sex ratio and moult stage of the catch in the two major regions.

Several types of gear were trialed for their effectiveness in sampling blue swimmer crabs. The gear trialed included two types of traps with different mesh sizes, 12 mm and 72 mm stretch mesh, seine nets and an otter trawl. There was a significant difference in the catch rate between the two mesh traps ($p<0.01$), with the 72 mm trap having the highest catch rate, while catch composition varied by month. A comparison of seine net and 72 mm mesh trap catches indicated that the catch rate of each gear type varied depending on the sampling period. However, the 72 mm mesh trap had a consistently higher proportion of males (2:1), legal sized crabs (2.3:1) and sexually mature crabs (2:1) than the seine net. Analysis of the three gear types (72 mm trap, seine net and otter trawl) indicated that there was a significant difference in the catch rate between methods ($p=0.03$); with the seine net having the highest catch rate, catch composition i.e. sex and size also varied according to the sampling method used.

3. To establish discard mortality for recreational and commercial fishing methods. Gear methods will include recreational drop netting, commercial trap fishing, tangle netting and trawling.

Undersize and ovigerous crabs are caught when the distributions of legal and sub legal crabs overlap. Catching and subsequent handling of undersize and ovigerous crabs can have a detrimental impact on their survival once returned to the water. Pot fishers, keeping crabs in iced seawater for more than 15 minutes caused mortality rates of 5-20%, as did net fishers who retrieved their nets after 24 hours. A higher level of predation was observed in nets soaked for 48-hours. Subsequent mortality is relatively low from handling and air exposure of up to one hour. Trawling damages more crabs (about 50%) than other fishing methods (about 20%). During an hour trawl, the overall mortality at the time of capture was around 14%. Higher mortality was observed during moulting periods when crabs were softer and susceptible to crushing. The recreational fishing method of scooping caused significant mortality (33-53%) when crabs were exposed to air for 1.5 to 2 hours. Scooping also caused damage to 53% of crabs.

4. To establish conversion factors for relating the effort for traps to that of the historical tangle nets.

This examination of net to trap conversion factors was motivated by concern by managers about the very substantial escalation in annual landings in those areas of the fishery that have moved from nets to traps.

In the case of Peel-Harvey Estuary, the transfer from nets to traps has been recent and data are still too incomplete to show any real effect on exploitation rates. By comparison, the change from one gear type to the other is complete in Cockburn Sound and the effects of these changes can be viewed in their entirety.

In Cockburn Sound there has been no obvious change to catch rates resulting from the increase in crab landings since the move to traps. This would suggest that current exploitation rates are not having an adverse impact on the Cockburn fishery. Furthermore, the 127 mm minimum legal size limit is well above the size at which 50 per cent of crabs attain sexual maturity.

While it is clear that the generosity of the net to trap conversion factors, as well as improvements to trap fishing gear and skills of the fishers, have all played a part in the increased landings since traps were introduced to Cockburn Sound and Peel-Harvey Estuary, the main reason for the increased catches has been that fishers work more days per year when using traps compared with nets. As trap fishing for blue swimmer crabs is a relatively new technique (at least in Western Australia), it is likely that the fishery will experience significant advances in gear technology in the short to medium term. Such advances could take the form of changes to trap design, bait type or positioning within the trap, boat size or design, or electronic fishing aids.

5. To assess the status of the various Western Australian fisheries for blue swimmer crabs, integrating information derived from this and other concurrent FRDC projects.

The integration of length frequency data and growth and mortality parameters determined by the current study and Murdoch University (FRDC project 97/131) indicate that blue swimmer crabs display rapid growth and have a relatively short life cycle, reaching the current legal size of 130 mm CW within 18 months. Similarly, Potter *et al.* (2001) state that *P. pelagicus* typically start to attain minimum legal size in late summer, when they are approximately one year old and that growth rates of the species in different embayments and estuaries on the lower west coast of Australia do not differ markedly.

Potter *et al.* (2001) state that while the sizes at which females typically reach maturity (CW_{50}) in the five water bodies examined were significantly different they were always well below the minimum legal size. Similarly, the results from both this study and Potter *et al.* (2001) suggest that females reach maturity well below the current minimum legal size (130 mm CW), at 90 mm CW and 86.2 mm CW respectively. Yield per recruit analysis indicated that lowering the minimum legal size to could substantially increase yield. While egg per recruit analysis indicated that females are highly fecund as even high levels of fishing mortality had minimal effect on the fecundity on crabs between 69-81 mm CW.

Therefore given short time to reach both sexual maturity and legal size and the high fecundity of the species a reduction in the current legal minimum size to a size closer to that which provides maximum sustainable yield (MSY) appears plausible due to the ability of the resource to quickly recover from heavy exploitation. However, despite biological information that suggests a smaller minimum legal size, fishers are voluntarily raising the minimum legal size in many of the state's commercial blue swimmer crab fisheries due to market demands.

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Appendix 1: Intellectual Property

NA

Appendix 2: Staff

Principal Investigator:	Roy Melville-Smith
Research Scientist:	Mervi Kangas/ Lynda Bellchambers
Technical Officer:	Sonia Anderton/ Emily Stewart
Casual Technical Officer:	Andrew Prindiville/ Scott Evans