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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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Abstract

Over the last few years, there has been considerable interest on the part of commercial fishers to move away from using gill nets, the traditional method for fishing for blue swimmer crabs in Western Australia (WA), to fishing with traps. Blue swimmer crab fisheries in WA are regulated by effort controls and most gill net fishers are restricted to hauling 1,000 metres (1,200 metres in the case of Cockburn Sound) of gill net per day.

The fieldwork in this study was initiated in March 1994 in Cockburn Sound and in January 1996 in the Peel-Harvey Estuary. It was aimed at establishing gill net to trap conversion ratios that would allow fishers to change from one gear type to the other without a resulting increase in the catching capacity of the gear types.

In a comparison of catches 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, the mean legal-sized crab catch made over a 24-hour period was 139.42 kg for 1,200 m of net and 1.24 kg/trap/day for traps. Based on these figures it would seem that an 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 that the catch rate declined significantly ($p = 0.0096$*) over the three month period. The net to trap conversion ratio for January was 50, compared with the other two months, both or which had conversion ratios of 40 traps/1,000 m of net.*

Aside from net to trap conversion ratios calculated from the fishing trials mentioned above, conversion ratios were also calculated for Cockburn Sound and Peel-Harvey Estuary using monthly compulsory catch and effort returns supplied by commercial trap fishers. These data showed that, over the five year period 1994-98 in Cockburn Sound, there were significant variations in catch rate from year-to-year ($p = 0.0128$*) and from month-to-month (*$p = 0.0001$*), but that these factors were not significant over the shorter (three year) period 1996-98 for which data were available for Peel-Harvey Estuary. Based on these data, conversion ratios of 67 traps per 1,200 m of net and 55 traps per 1,000 m of net were established for Cockburn Sound and Peel-Harvey Estuary respectively.*

Commercial blue swimmer crab landings reported in WA over the last 20 years, have shown a dramatic increase since the introduction of traps into this fishery. Based on the results of the compulsory catch and effort data presented above, there is good reason to believe that, in the case of Cockburn Sound the increase in catch has been due, in part, to an over-estimated net to trap conversion ratio introduced into that fishery. It is, however, considered unlikely that this explanation alone has accounted for the more than doubling of the commercial catch in Cockburn Sound that has occurred over the last five years.

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. Finally, there is evidence to indicate that traps maintain catch rates over a longer period through the year than do nets, particularly in the critical (winter and spring) periods when catch rates are low for both methods.

This paper has provided an analysis of considerations that should be taken into account for fisheries management purposes in the future when considering revisions to current net to trap conversion ratios, or when implementing these ratios to other blue swimmer crab fisheries that have yet to change from nets to traps.

1.0 Introduction

Blue swimmer crabs occur from Cape Naturaliste in Western Australia around the north of Australia to the south coast of New South Wales and in the warmer waters of the South Australian Gulfs as far as Barker Inlet in Gulf St Vincent (Stephenson and Campbell 1959). In Western Australia, high densities of crabs in the more populated south west of the State south of Perth (Figure 1), have made them a particularly important recreational fishing species (Dybdahl 1979, Ayvazian *et al*. 1997, Sumner unpub. data), with an estimated 76,000 people participating in the fishery in 1986/87 (Anon. 1989). 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.

Two very different styles of traps have been used by commercial blue swimmer crab fishers since this method of fishing has gained acceptance in Western Australia. In Cockburn Sound most of the catch is currently being made by hour-glass 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 hour-glass 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, trapping has been viewed by the agency, commercial fishers and the general public alike, 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.

2.0 Methods

2.1 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 (see Appendix 1 for the data log form used). 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 soaking. 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

2.2 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 log book data on their gill net fishing activity.

The estuary was divided into four areas (Figure 1) to examine the differences in catch rates by sub-area. The catch data were provided by fishers in numbers of crabs. In order that this 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.

2.3 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.

3.0 Results

3.1 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. Fewer ovigerous crabs were taken by traps than by gill nets, but traps caught a larger number of under-sized animals than did 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.

3.2 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 (Figure 1, 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.

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 (Figure 1 and 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.

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).

3.3 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. An 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 has 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.

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.

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.

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).

4.0 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 are:

(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 which 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 crabs remain more catchable 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. By contrast, Sumner (unpub. data) 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 41 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.

5.0 Future considerations

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. The consequences of the higher annual catch need to be considered by managers.

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 (Figure 11). 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, which, according to Potter and de Lestang (in press) and de Lestang (*pers. comm.*), is at 97 mm carapace width (CW) for females and 84 mm CW for males in the Leschenault and Peel-Harvey Estuaries. Egg production would, therefore, seem to be well protected.

One of the stated policy objectives of Fisheries WA, is to ensure that all blue swimmer crab resource user groups have equitable access to the fishery (Campbell 1997). There are no data to compare historic recreational crab catches in Peel-Harvey Estuary with commercial catches, but data for Cockburn Sound show that the share of recreational fishers in this area may have diminished substantially and their interests may, therefore, need to be addressed. An obvious benefit to a reduction in the number of traps used in the Cockburn Sound fishery, is that such a decision would probably serve to maintain higher catch rates in the commercial fishery over a longer period of time than is presently the case.

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. If the goal of managers is to peg landings at the levels that were achieved with nets, then it will be necessary to adopt further effort controls. Such controls could take the form of reducing the number of traps in operation in the fishery, or reducing the number of allowable fishing days per year.

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 its positioning within the trap, boat size or design, or electronic fishing aids. Should managers plan to retain this as an effort controlled fishery, then these factors will need to be carefully considered in the future. In particular, there is an urgent need to standardise on a particular trap size and design, so that future catch and effort statistics will be comparable.

6.0 Acknowledgements

The authors thank the licensees in the Mandurah Estuarine Fishery for their permission to publish data where there were fewer than five participants and to Mr Bruce Tatham for organising letters from the fishers giving this dispensation. Particular thanks go to those fishers in the Peel-Harvey Estuary and Cockburn Sound fisheries who assisted with the net to trap experiments. We also thank our colleagues, Mr Jim Christianopoulos for technical assistance and Ms Mervi Kangas, Drs Suzy Ayvazian, Nick Caputi, Henry Cheng and Jim Penn for their very useful comments on earlier drafts of this manuscript. The work was partially funded by Fisheries Research and Development Corporation Project No. 98/121.

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8.0 Tables

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

CATEGORY	GILL NET		TRAP	
	Numbers (per 1,000 m of net per day)	**Percent**	**Numbers (per trap per 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

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 made 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 (kg/1000m net)	14	8.6	20	8.6

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 Estuary, January-March 1996.

MONTHS	JANUARY			FEBRUARY				MARCH				TOTAL
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
Maximum (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
Minimum (kg/trap)	0.95	1.04	0.95	0.44	0.75	0.52	0.44	0.87	0.84	0.46	0.46	0.44

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

Month	Gill net catch rate mean (SE)(kg/1,000 m net)	Trap catch rate mean (SE)(kg/trap)	Conversion factor (traps per 1,000 m 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 (2.76)	1.16 (0.04)	41.2

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	1 GN	31.1395	0.0009
	2 GN	24.2606	0.0078
	6 GN	-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		

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

Month	Net mean catch rate (SE) (kg/1,200 m net/day)		Trap mean catch rate (SE) (kg/trap)		Conversion factor (traps per 1,200 m net)
January	91.72	(5.18)	1.45	(0.18)	63.26
February	84.54	(5.89)	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).

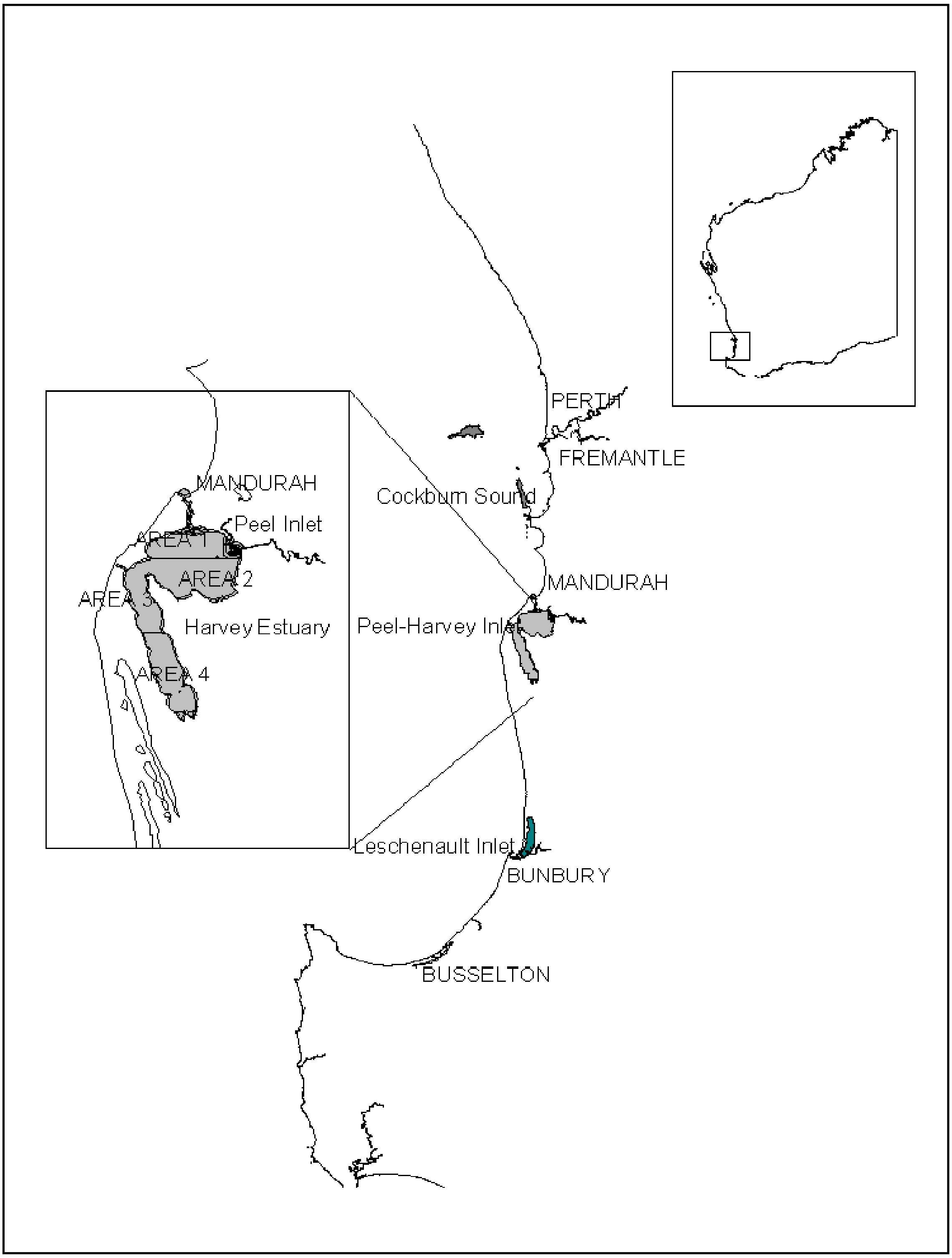
Month	Net mean catch rate (SE) (kg/1,000 m net/day)		Trap mean catch rate (SE) (kg/trap)		Conversion factor (traps per 1,000 m net)
January	80.89	(19.41)	1.41	(0.19)	57.37
February	60.36	(4.22)	1.06	(0.12)	56.94
March	71.12	(4.79)	1.00	(0.06)	71.12
April	97.60	(33.39)	0.97	(0.16)	100.62
May	45.10	(16.61)	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)	9.86
December	40.83	(12.88)	1.31	(0.16)	31.17
Overall	**58.86**	**(1.07)**	**1.07**	**(0.06)**	**57.15**

Table 12 Inter-annual 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	Net mean catch rate (SE) (kg/1,200 m net/day)		Trap mean catch rate (SE) (kg/trap)		Conversion factor (traps per 1,200 m 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 Inter-annual net and trap catch rates and net to trap conversion factors based on compulsory catch and effort data, for Peel-Harvey Estuary (January 1996 to June 1998).

Year	Net mean catch rate (SE) (kg/1,000 m net/day)		Trap mean catch rate (SE) (kg/trap)		Conversion factor (traps per 1,000 m 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**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Leschenault Inlet
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BUSSELTON
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AREA 2
AREA 3
Harvey Estuary
AREA 4

9.0 Figures

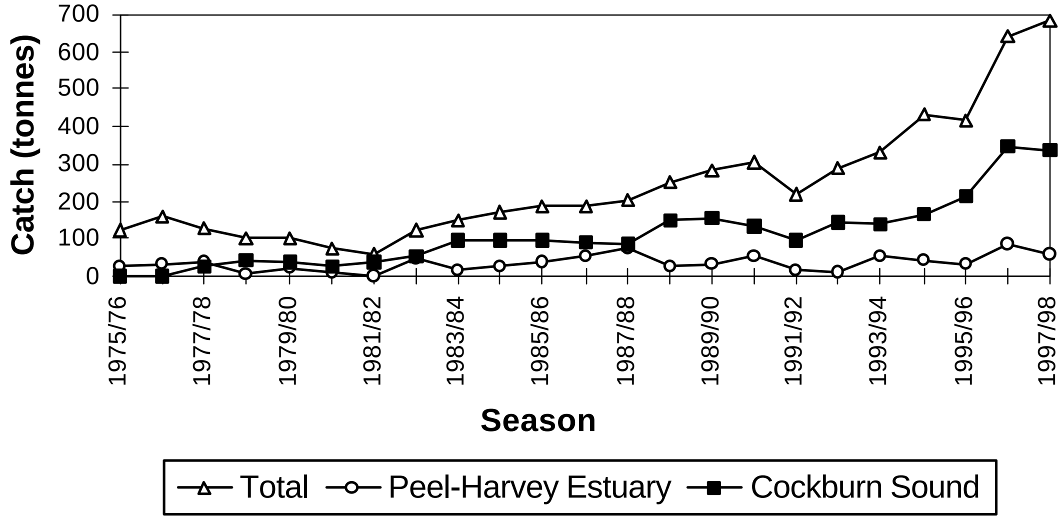
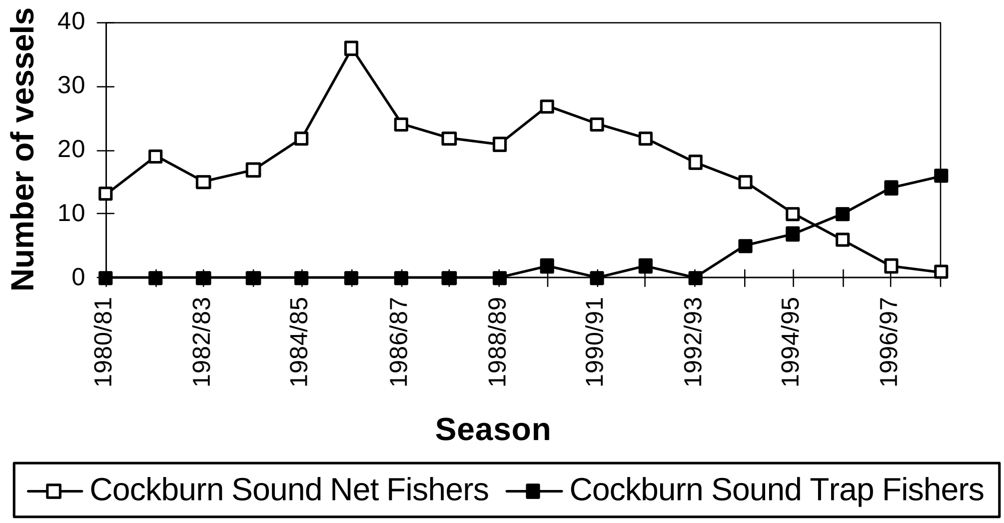


Figure 1 Map of south Western Australia showing key locations in the distribution and fishery for blue swimmer crab. INSET left: The Peel-Harvey inlet showing the four areas reported in blue



swimmer crab log book fishing statistics.

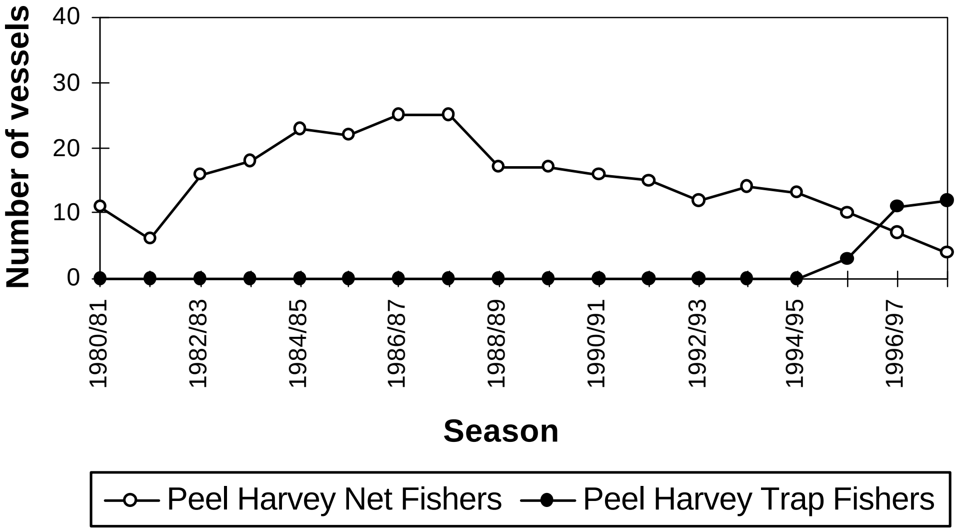


Figure 2 Blue swimmer crab landings in the Peel-Harvey Estuary, Cockburn Sound and over the whole Western Australian coast, 1975/76 to 1997/98.

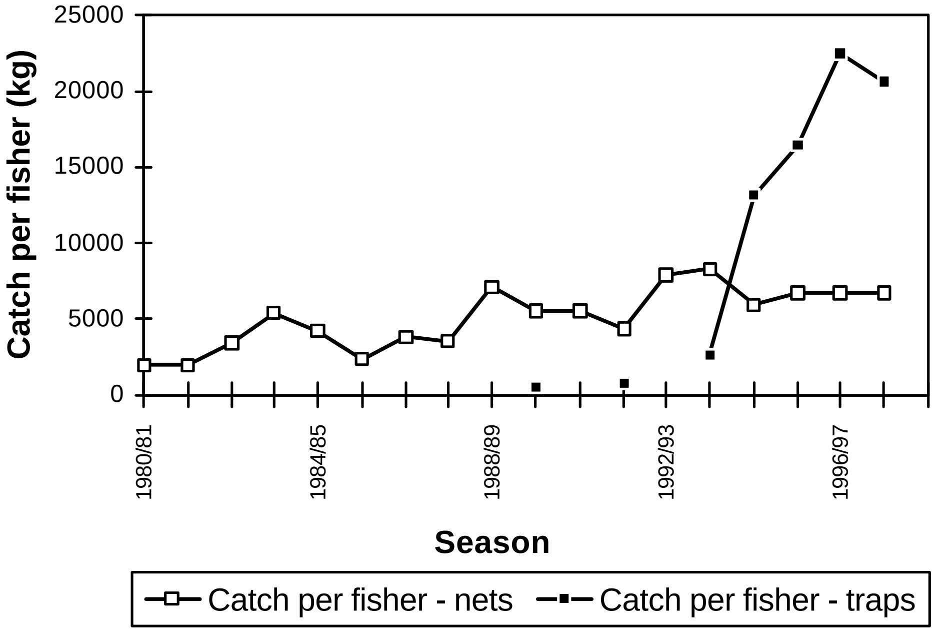


Figure 3 Numbers of fishers actively fishing for blue swimmer crabs with nets and traps in Cockburn Sound, 1980/81 to 1997/98.

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

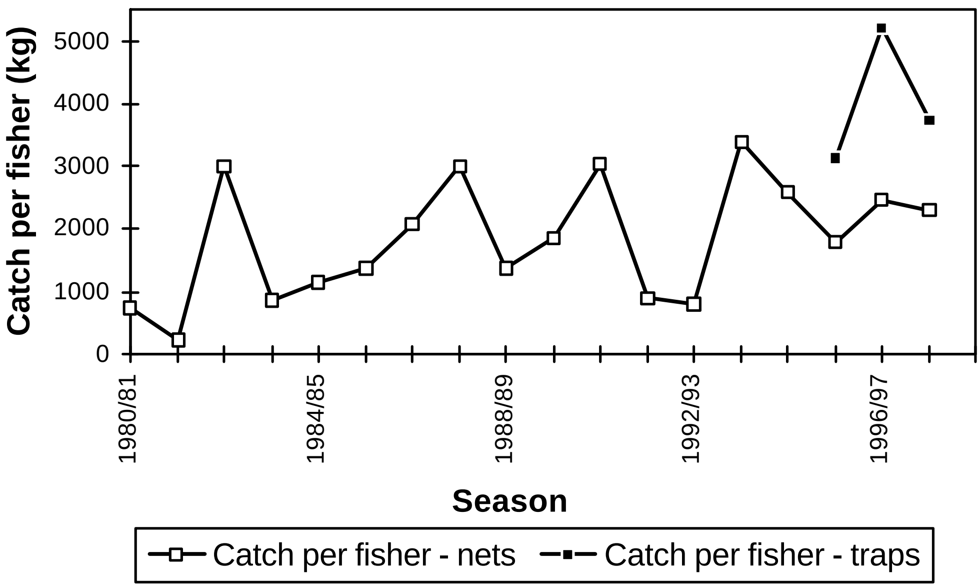
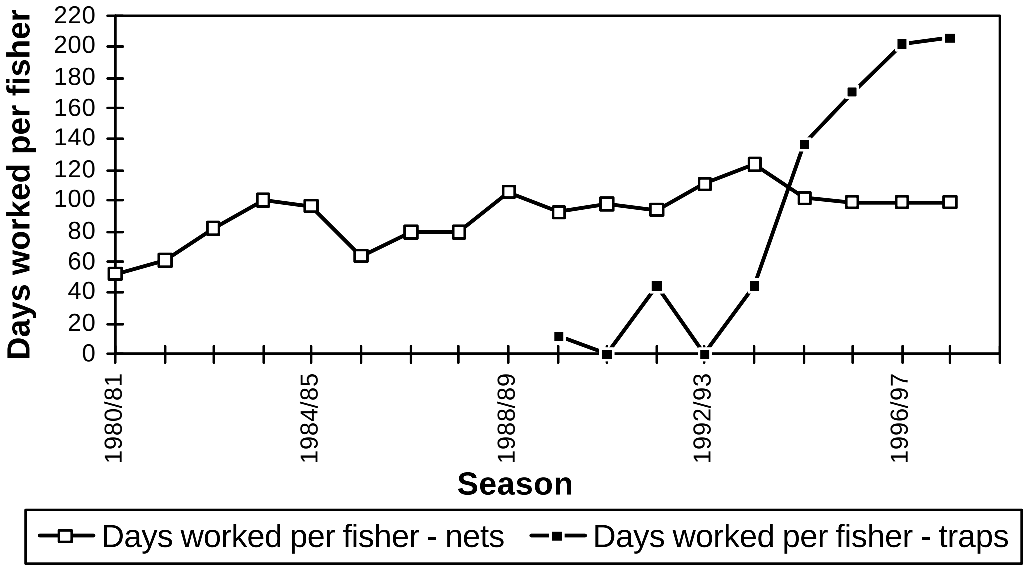


Figure 5 Mean seasonal blue swimmer crab catch per trap fisher and gill net fisher in the Cockburn Sound, 1980/81 to 1997/98. Data for catch per gill net fisher have been averaged between 1995/96 to 1997/98 to prevent breaching the confidentiality of information supplied by small



numbers of fishers.

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.

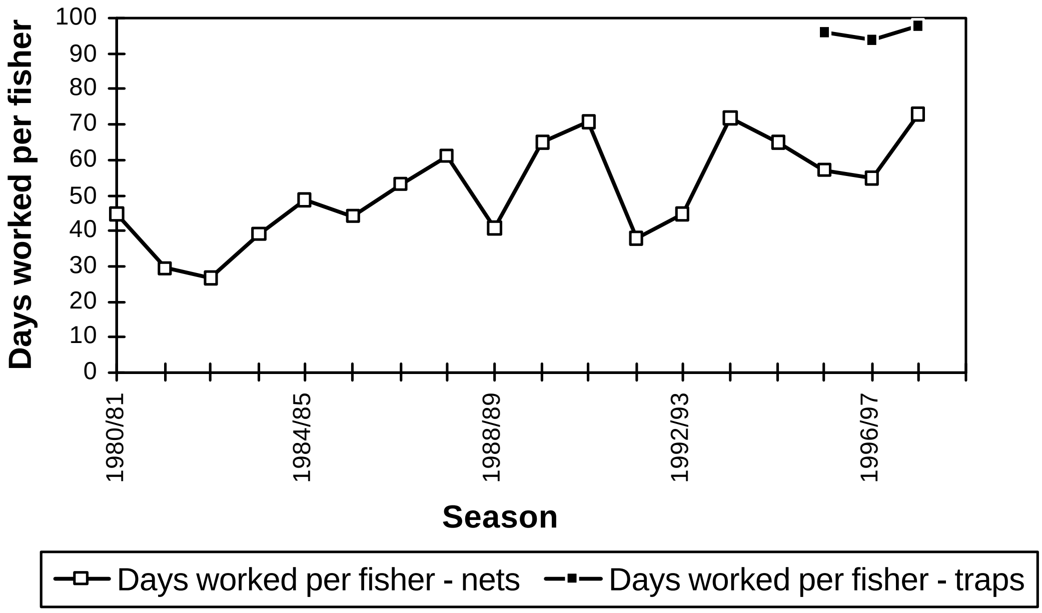
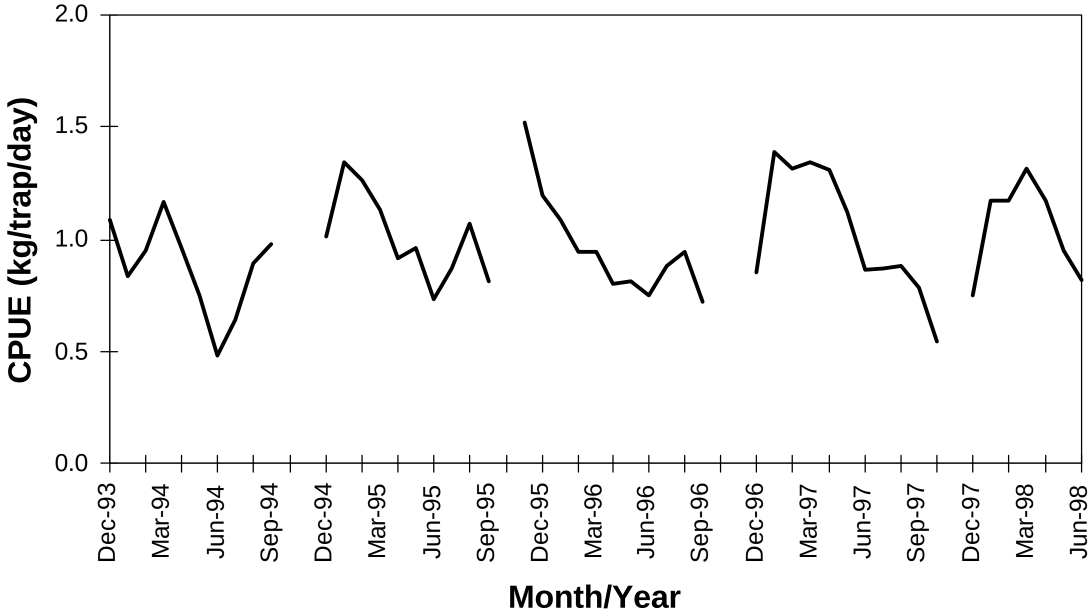
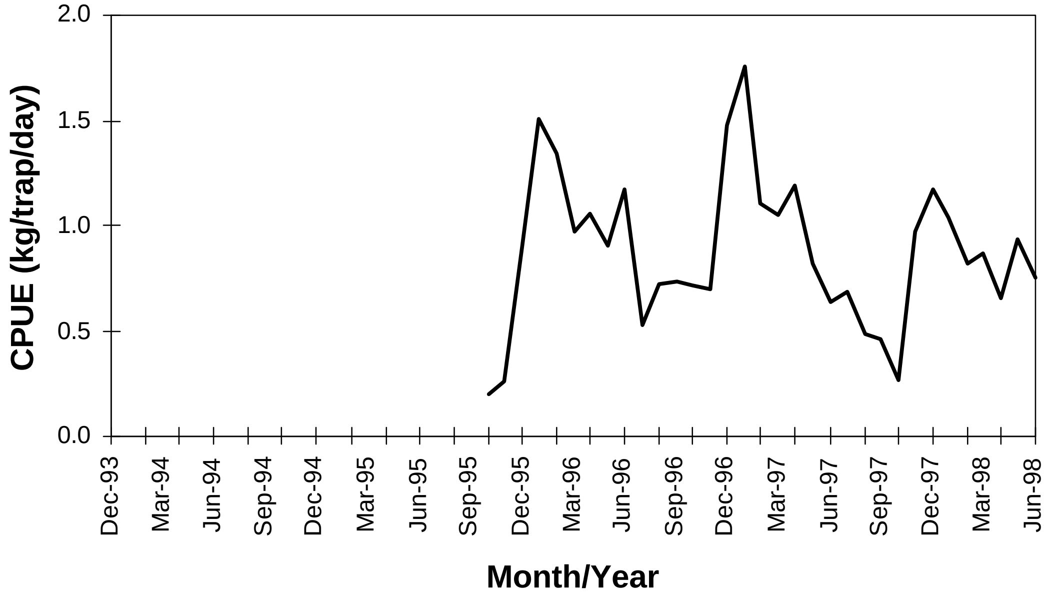


Figure 7 Mean number of days worked per season by blue swimmer crab trap and gill net fishers in Cockburn Sound, 1980/81 to 1997/98. Data for the number of days worked per fisher have been averaged between 1995/96 and 1997/98 to prevent breaching confidentiality of information



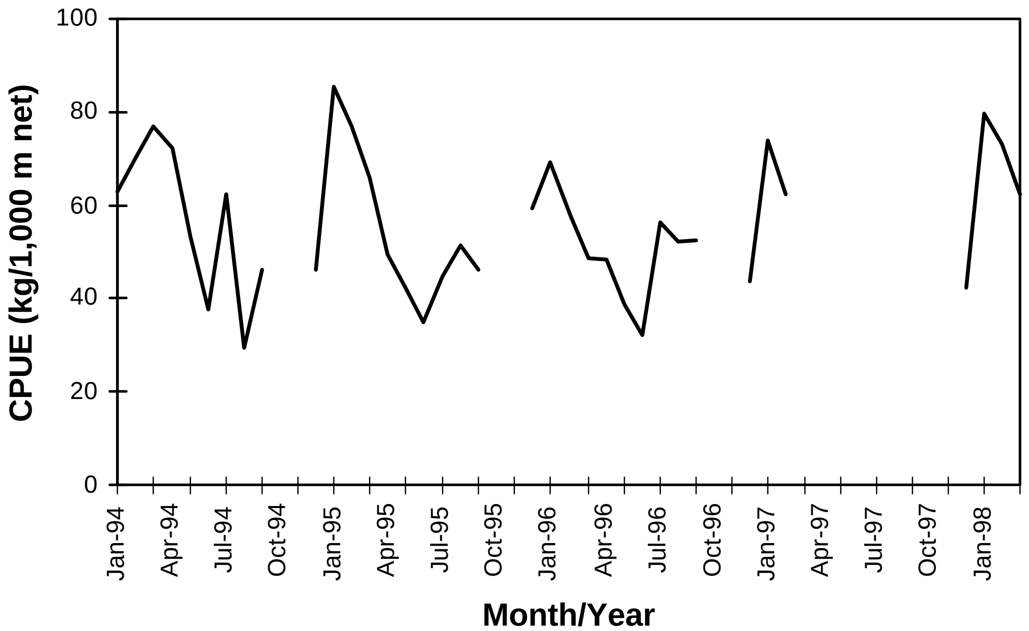
supplied by small numbers of fishers.

Figure 8 Mean number of days worked per season by blue swimmer crab trap and gill net fishers in



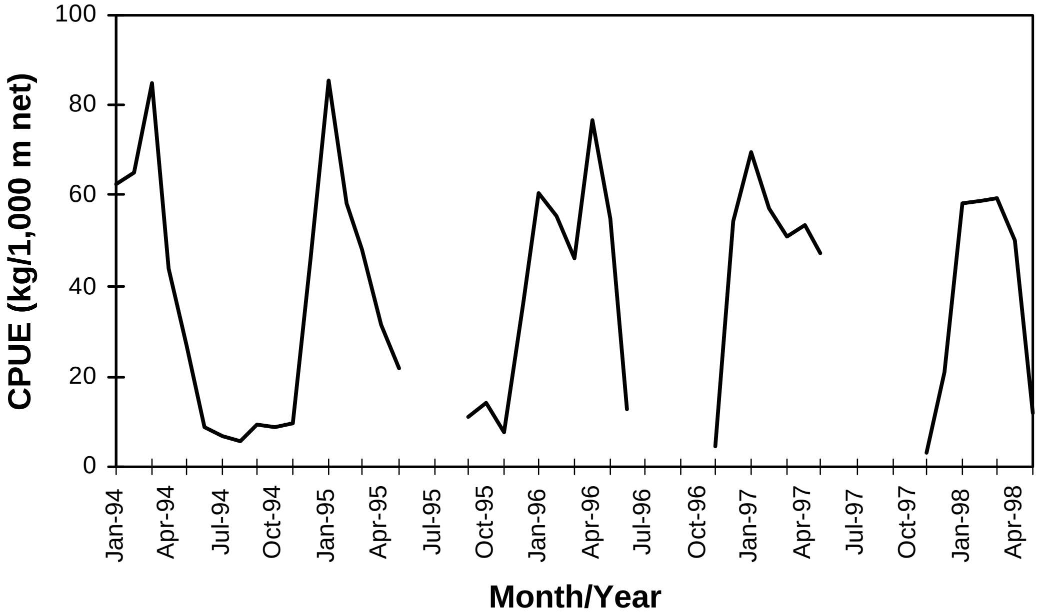
Peel-Harvey Estuary, 1980/81 to 1997/98.

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.

Appendix 1 Sample of the data form used to record daily pot fishing in the Cockburn Sound and Peel-Harvey net to pot conversion factor experiment. The net fishing data form is the same except total net length is required instead of pot lifts, along with mesh size and drop.

MONTHLY SHEET NO._____

MONTH/YEAR ______/ 1998	**LFB**
BLOCK/AREA ______/______	**POT DIMENSIONS (LxWxH)** ______x______x______(mm)
	WATER TEMP (^{o}C)
AVE. DEPTH (m)	**BAIT USED**

DAY OF MONTH	SET TIME	AREA	DURATION POTS SET IN WATER	NO. OF POT LIFTS	TOTAL WEIGHT (RETAINED CATCH)	DISCARDED						RETAINED	
						ALIVE			DEAD				
						SOFT	SMALL	BERRY	SOFT	SMALL	BERRY	FEMALE	MALE
(day)	(24 hr clock)	(Block no.)	(hours)	(number)	(kgs)	NUMBERS OF CRABS							

COMMENTS: