Evaluation of Crystal Crab (*Chaceon bicolor*) resources on the south coast of Western Australia

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FINAL REPORT

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May 2006

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2003/077 **Evaluation of Crystal Crab (*Chaceon bicolor*) resources on the south coast of Western Australia.**

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OBJECTIVES:

1. Determine the size composition and relative densities of Crystal Crab on the south coast of Western Australia.
2. Estimate the sustainable annual yield of Crystal Crab from the south coast of Western Australia.
3. Tag 1000 undersize or berried Crystal Crab on the south coast of Western Australia that will provide data to the Department of Fisheries, Western Australia for future growth and movement analyses.
4. Investigate the effect of trap size and the use of bait saving devices on the catchability of Crystal Crab.

NON TECHNICAL SUMMARY

OUTCOMES ACHIEVED TO DATE

Data have been collected on the size distribution and the relative abundance and distribution of Crystal Crab, *Chaceon bicolor*, on the south coast of Western Australia that will allow managers to plan for the development of the Crystal Crab fishery in this region to its optimal sustainable harvest level. These results have been used, in consultation with the Department of Fisheries, Western Australia and an independent statistician, to estimate the maximum sustainable yield for the Crystal Crab fishery on the south coast. The information gained during this survey has been shared with the Department of Fisheries, Western Australia, and the licensed crustacean fishers on the south coast of Western Australia, who together, may now develop the fishery in an orderly and environmentally and economically sustainable manner.

The licensed crustacean fishermen on the south coast of Western Australia recognised that a resource of Crystal Crab, *Chaceon bicolor* existed between Cape Leeuwin (*ca* 115º E) and the South Australian border (129º E). In order to develop this resource to its optimum and sustainable potential, there was first a need to determine the relative abundance and distribution of this species in that region. Since a substantial commercial fishery for this species exists on the west coast of the state, it was important to collect data from the south coast that could be compared with data from the existing west coast fishery in order to estimate a sustainable annual yield for the south coast fishery based on the catch return data from the west coast fishery. The relative abundance and distribution and size distribution of Crystal Crab have thus been studied on the south coast of Western Australia between approximately 115º 20’ and 123º E, data that has not previously been available.

These data were collected by trained research personnel aboard professional fishing vessels operating under Department of Fisheries, Western Australia exemptions from the Fish Traps Prohibition Notice, prohibiting the take of Crystal Crab on the south coast of Western Australia during the period that this research was conducted. The costs of collecting data were partially offset by the ability of fishers to recoup some expenses through the sale of landed product. A large amount of high quality data was thus able to be collected at a relatively small cost.

Crystal Crabs were caught in commercial quantities between *ca* 115º 20' and 119º 20' E in depths generally ranging from 400 to 900 m. This depth range is greater than that reported for commercial quantities of this species on the west coast of Western Australia, *i.e.* 500 to 800 m, and may reflect a greater area of suitable habitat at those depths or more appropriate water temperatures for this species between 400 and 900 m on the south coast of the state.

The mean catch per unit of effort (cpue), calculated as the landed weight of Crystal Crabs per trap lift, was 1.16 kg per trap lift in the Albany zone (west of 120 º E) and very low, *i.e.* <0.1 kg per trap lift in the Esperance zone (east of 120 º E). Low catch rates in the latter zone may be attributed to factors other than low densities of Crystal Crab, including very high numbers of sea lice which rendered bait, and therefore the ability of traps to attract Crystal Crab ineffective within a very short period of time. The cpues in the Albany zone were similar to those reported for the west coast Crystal Crab fishery between 2001 and 2003, *i.e.* 1.15 kg per trap lift, and much higher than those reported at the inception of that fishery. These data, in combination with the areas on both coasts where Crystal Crab are expected to occur, *i.e.* between the 300 and 900 m (as fished on the south coast during this research project) and between the 450 and 1220 m depth contours (depths quoted for the distribution of this species on the west coast of Western Australia), were used to estimate conservative potential annual yields of 20 to 26 tonnes per annum. When the calculations were restricted to only the areas on the west coast that were commercially fished between 2001 and 2003, maximum yields of between 56 and 108 tonnes per annum were estimated for the Albany zone off the south coast of Western Australia.

The highest landed catch rates and cpues were recorded at depths between 701 and 800 m in the Albany Zone and were approximately 1.5 crabs and 1.6 kg per trap lift. In contrast, the mean size of Crystal Crabs that were captured decreased with increasing depth to a minimum between 701 and 800 m. The highest cpues were recorded during the summer months and catch rates of male Crystal Crabs were on average four times greater than that of females, except in water depths between 301 and 400 m, where females were more abundant.

Catches per unit of effort were greater in larger traps than in smaller traps, with cpues proportional to the volume of the traps used, *i.e.* traps that were three times greater in volume captured three times the amount of Crystal Crabs when fished at similar depths in the same area at the same time of year. The use of bait saving devices in this area where sea lice infestation was not apparent did not affect this ratio.

The carapace lengths of male Crystal Crabs ranged from 77-194 mm with 89% of individuals being between 110 and 149 mm, while that of the females ranged from 78-149 mm with those between 100 and 119 mm accounting for 84% of that sex. The average carapace length of male Crystal Crabs was significantly greater than females, with mean lengths of 136 and 115 mm, respectively, recorded. The mean lengths of landed male and female crabs, *i.e.* with a carapace length >103 mm, were 137 and 120 mm, respectively.

This study also showed that the mean carapace lengths of male and female Crystal Crabs on the south coast of Western Australia are currently larger than those recorded on the west coast, *i.e.* 136 and 119 mm, respectively for males and 115 and 106 mm, respectively for females. The maximum recorded size of male Crystal Crabs was also greater on the south coast than the west coast, while that of females was similar.

A total of 17 species other than Crystal Crab, representing five taxonomic categories were also captured during this research survey, though in relatively low numbers. The greatest contributing taxonomic category was the Decapods, which were caught in less than 6% of traps set. Of the decapods, King Crab (*Pseudocarcinus gigas*) was the dominant species caught, occurring in 3.5% of traps with less than six individuals captured per 100 trap lifts. *Pseudocarcinus gigas* below the minimum legal length for capture accounted for two thirds of the total take of that species. Since there is a significant overlap in the distributions of the commercially important King Crab and the Crystal Crab, management plans must take into account the capture of King Crab while targeting *C. bicolor.*

KEYWORDS: deep sea crabs, abundance, size, distribution, yield.

ACKNOWLEDGMENTS

Gratitude is expressed to the south coast commercial fishermen who have enabled this project to be completed, in particular Greg Sharp (Leading Edge Fishing) and Dennis Gaunt (Mulataga Aquaculture) and their staff. Their professionalism and dedication to the research outcomes was inspirational and refreshing. Our thanks are also extended to Roy Melville-Smith, Sam Norton and Adrian Thompson from the Department of Fisheries, Western Australia, who assisted with data analyses and project design.

We are particularly indebted to Associate Professor Norman Hall from the Centre for Fish and Fisheries Research who independently analysed the catch data collected during this research project and provided the chapter entitled: Assessment of potential yield of Crystal Crab *Chaceon bicolor* from the south coast of Western Australia.

We would also like to thank the onboard technicians that were instrumental in collecting the data that was required for this project:

Mr. Matthew van Neiuwkerk

Mr. Luke Symes

Mr. Matthew Hofstee

Mr. Jim Burton

Mr. David Riggs

1.0 GENERAL INTRODUCTION

1.1 THE CRYSTAL CRAB *CHACEON BICOLOR*

The Crystal Crab, *Chaceon bicolor* (Figure 1.1), previously marketed as the Snow Crab, is part of the family Geryonidae, which includes other commercially harvested crabs such as *Chaceon quinquedens* (Wigley *et al.* 1975), *Chaceon maritae* (Melville-Smith 1988), *Chaceon notialis* (Defeo *et al.* 1991) and *Chaceon affinis* (López Abellán *et al.* 2001). *Chaceon bicolor* inhabits the deeper waters of Australia and New Zealand (Jones and Morgan 2002) being found predominately in depths of 450 to 1220 m, where temperatures typically range from 4 to 6.5º C (Melville-Smith *et al.* in press, Smith *et al.* 2004*a*). In Western Australia, this species is distributed along the west coast as far north as Exmouth (*ca.* 22º S) (Melville-Smith *et al.* in press) and along the south coast at least as far as 125º E (Department of Fisheries Western Australia, Catch and Effort Statistics).

Similar to other deep sea crabs including the King Crab, *Pseudocarcinus gigas* (Levings *et al.* 1996), and deep sea species from diverse taxa (*e.g.* Koslow *et al.* 2000), Crystal Crabs are assumed to be slow growing and relatively long lived (Smith *et al.* 2004*a*). The lack of retained hard body parts that are necessary for ageing individuals however, means that either direct observation or long term tag and recapture programs are required to determine the age structure and growth rates of these species. To date no such studies have been undertaken for *C. bicolor* and thus there are no data on the growth rates of this species.

Smith *et al*. (2004*b*) estimated the size at sexual maturity of female Crystal Crabs on the lower west coast of Western Australia to be *ca.* 90 mm carapace length (CL) and that of males to be *ca.* 94 mm. Those authors caution that due to selective sampling associated with capture in traps, those sizes at maturity are likely to be underestimates of the true sizes at maturity for this species. Additionally, Smith *et al.* (2004*d*) have demonstrated that *C. bicolor* spawn throughout the year on the lower west coast of Western Australia, with ovigerous females captured in 11 months of the year. The lack of a distinct breeding season for this species is similar to the reproductive cycle described for other deep sea species and may reflect the lack of seasonal environmental variation, such as temperature and day length in their habitats (*e.g.* Melville-Smith 1987, Smith *et al.* 2004*d*).

Figure 1.1. The Crystal Crab, *Chaceon bicolor*. Photograph courtesy: Blue Office Productions.

1.2 THE COMMERCIAL FISHERY FOR *CHACEON BICOLOR*

While *C. bicolor* is distributed at least through southern Australia and New Zealand, it is only targeted professionally in southern Western Australia, where a relatively new fishery exists. Crystal Crab was first taken commercially in Western Australia in 1997 and by 2000, 143 tonnes were landed (Department of Fisheries, Western Australia, Catch and Effort Statistics). Maximum landed weights were attained in 2001 when over 222 tonnes were landed, while the maximum effort occurred one year earlier with *ca.* 250 000 trap lifts. The annual catch has remained above 193 tonnes in 2002 and 2003 (Smith *et al.* 2004*a*). The vast majority of Crystal Crabs were taken from the lower west coast with relatively small amounts landed on the south coast of the state. Landed weights on the south coast peaked in 2002 when just less than 10 tonnes were landed (Smith *et al.* 2004*a*).

Catches per unit of effort (cpue) of Crystal Crab on the west coast have increased progressively from 0.11 kg per trap lift in 1998 to 1.16 kg per trap in 2002 and 2003 (Smith *et al.* 2004*a*). This increase has been attributed to the rapidly increasing knowledge of professional fishers of the most appropriate areas and techniques for capturing Crystal Crab, rather than an actual increase in the abundance of this species (Smith *et al.* 2004*a*).

The catchability of Crystal Crab remains constant throughout the year, showing no obvious changes with month or season (Smith *et al.* 2004*a*), which may reflect the relatively constant environmental conditions of the deep sea habitat and the fact that spawning occurs throughout the year (Smith *et al.* 2004*d*). Significant differences in the catchability of male and female *C. bicolor* on the west coast have however been demonstrated, with the cpue of female crabs markedly lower than that of males (Smith *et al.* 2004*a*). This situation has also been described for other crustaceans, including other *Chaceon* species, and has been attributed to a number of behavioural characteristics including increased aggression in males (Bovbjerg 1956) and the avoidance of traps by ovigerous females (Melville-Smith 1987), rather than actual differences in the sex ratios of those species.

Unlike the west coast Crystal Crab fishery, on the south coast this species forms part of a multi-species fishery, which includes Champagne Crab (*Hypothalassia acerba*), King Crab (*Pseudocarcinus gigas*), Southern Rock Lobster (*Jasus edwardsii*) and Western Rock Lobster (*Panulirus cygnus*). Unlike those species, the transport of *C. bicolor* requires submersion in refrigerated holding tanks, which often necessitates the use of purpose built or modified fishing vessels.

1.3 NEED

Following good returns being reported for the west coast Crystal Crab fishery in early 2002, there was a corresponding sudden and substantial interest in developing the Crystal Crab fishery on the south coast of Western Australia. It was decided that if no action was taken to determine the sustainable harvest for Crystal Crabs in this area, fishing effort would increase to a level where the sustainability of the fishery may be at risk. To this end, the Minister for Agriculture, Forestry and Fisheries approved an amendment to the Fish Traps Prohibition Notice, which prohibited the take of Crystal Crabs on the south coast of the state from 11 October 2002 to 30 September 2003, while management arrangements for the South Coast Crustacean Fishery (including Crystal Crabs) were to be further developed. The prohibition to take Crystal Crab was subsequently extended to 15 November 2004 and has since been lifted to enable commercial crustacean fishers to take Crystal

Crab on the south coast of the state, with fishers restricted to using only the number of traps that they are licensed to target Rock Lobster with during the Rock Lobster season.

There was thus an important need to determine the relative abundance and distribution of *C. bicolor* along the south coast of Western Australia in order that the development of the fishery for this species along the 1500 km of coastline from Cape Leeuwin to the South Australian border could progress in an orderly manner to ensure the future sustainability of the resource.

1.4 OBJECTIVES

1. Determine the size composition and relative densities of Crystal Crab on the south coast of Western Australia.
2. Estimate the sustainable annual yield of Crystal Crab from the south coast of Western Australia.
3. Tag 1000 undersize or berried Crystal Crab on the south coast of Western Australia that will provide data to the Department of Fisheries, Western Australia for future growth and movement analyses.
4. Investigate the effect of trap size and the use of bait saving devices on the catchability of Crystal Crab.

2.0 GENERAL MATERIALS AND METHODS

2.1 SAMPLING OF *CHACEON BICOLOR*

Crystal Crab were sampled on four commercial vessels, all of which had limited previous experience fishing for this species and where owners had shown a particular interest in the outcomes of this research. An amendment to the Fish Traps Prohibition Notice, prohibiting the take of Crystal Crab on the south coast of the state while management arrangements were further developed, required that vessels taking part in this research operated under exemptions from the Department of Fisheries, Western Australia. Fisheries exemptions prohibited the retention of all female crabs for the first part of the research period (until 30 May 2004) and ovigerous females thereafter. Those, and all crabs less than 103 mm carapace length (=120 mm carapace width) were returned alive to the water immediately after measuring and/or tagging. Sampling was conducted between December 2003 and October 2004.

2.1.1 Sampling area

The survey area extended from the South Australian border (129º E) to Cape Leeuwin (*ca.* 34º 20’ S, 114º E), Western Australia, between the 300 m and 1500 m depth contours (Figure 2.1). The area between 129º and 125º E and was divided into eight zones of half degree widths and the area between125º E and 34º 20’ S, 114º E into 61 zones of 10 minute widths. Transects were plotted on the eastern boundary of each zone between 300 and 1500 m. Each of the transects between 129º and 125º E were to be surveyed in a generally north-south direction where possible and at least every third transect between125º E and 34º 20’ S, 114º E, *i.e.* at 30 minute intervals, was to be surveyed in a similar way. However, inability of the vessels’ hydraulic systems to retrieve fishing gear from water depths in excess of 1000 m restricted the sampling to between *ca.* 300 and 900 m (Figure 2.2). Additionally, the generally west to east direction of the currents experienced in the waters near the shelf break on the south coast (Cresswell 1991, Cresswell and Peterson 1993) necessitated that, at best, strings of traps be set in a southwest-northeast or northwest-southeast direction, on a 45º angle across the depth contour to avoid tangling of the fishing gear.

Where bottom type was prohibitive to trap fishing, *i.e.* around underwater canyons and over steep areas, the onboard research assistant verified the bathymetry by visual analyses of echo soundings and that particular zone was not fished (Figure 2.1).

2.1.2 Distribution of fishing areas to professional fishers

Two vessels were chosen by consensus amongst the professional participants to sample the area between 129º and 125º E based on vessel requirements including size and holding capacity and the willingness of participants to survey this remote area. However, since one of those vessels opted out of the research project before that area was surveyed, it was decided that this region would not be sampled during the current research for safety reasons (see Figure 2.1).

The zones between 125º E and 34º 20’ S, 114º E were distributed randomly in even numbers to all four commercial participants, who were then permitted to “trade” zones in order to reduce travelling time and costs, *i.e.* most participants traded so that their zones were located in a relatively small section of the survey area.

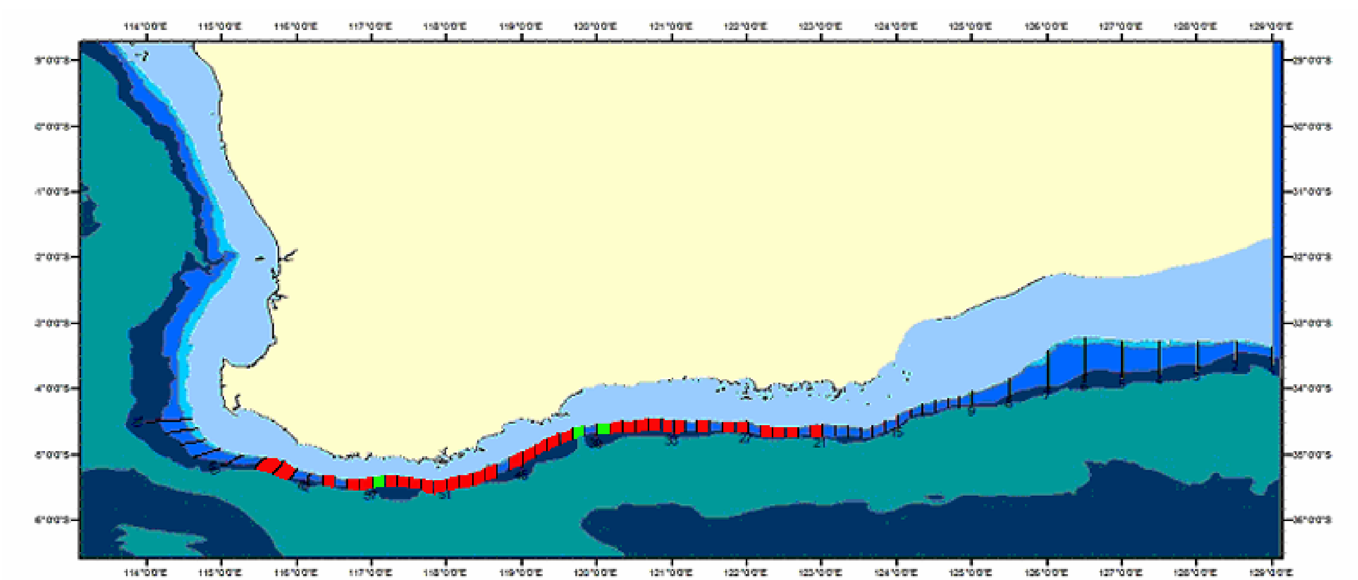

Figure 2.1. Zones fished (red) and zones that were surveyed and considered inappropriate for fishing for Crystal Crab (green) on the south coast of Western Australia.

2.1.3 Standardisation of fishing gear and techniques

In order that data collected by different fishing vessels was comparable, variables that may have influenced the results, including material differences such as variability in fishing gear (trap type and configuration, number of traps per line and bait used) or other intangible differences (such as the skill and expertise of the fishers operating the gear) were minimised.

Skill differences between fishers were mitigated through training and sharing of fishing techniques and by defining a series of small areas that could be fished by each participant (see section 2.1.2), thereby attempting to reduce the influence of an individual's skill on where traps were placed.

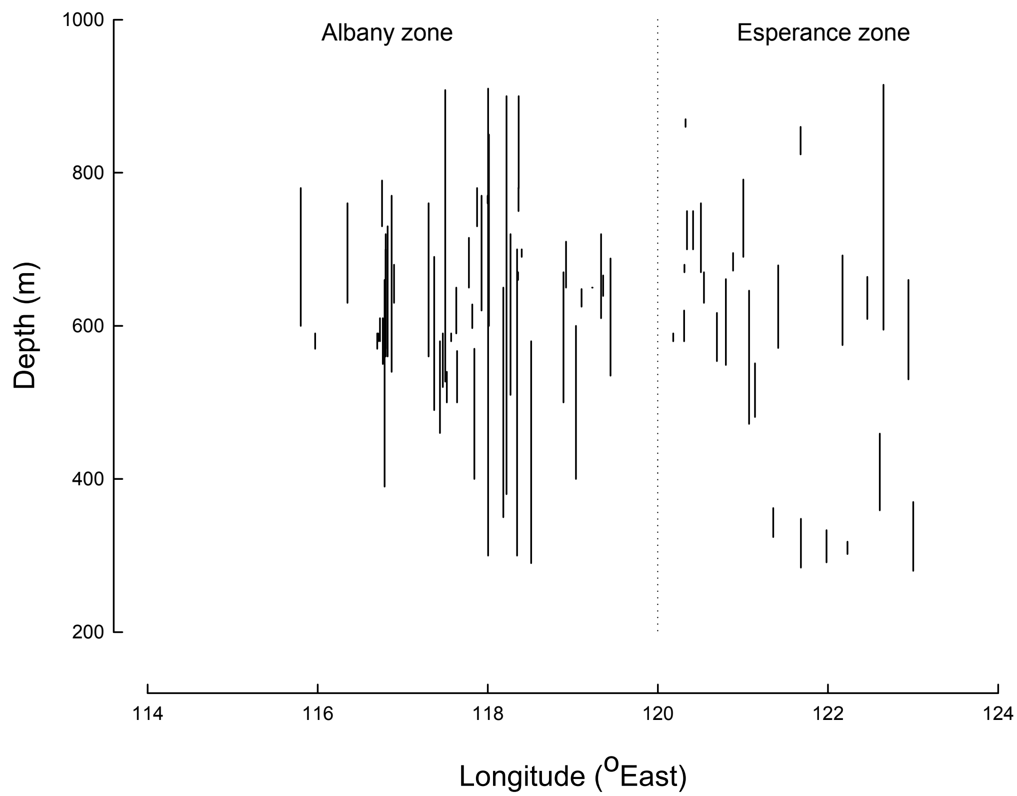

Figure 2.2. Depth range and longitude of each string of traps set on the south coast of Western Australia.

Fishing gear was standardised with only "Elvinco" recreational rock lobster traps used for the size distribution and abundance surveys. These traps are used extensively by commercial fishers in both the west coast and south coast Crystal Crab fisheries, and are 675 mm long, 350 mm wide and 475 mm high with a circular top entrance that is 190 mm in diameter and 200 mm deep (Figure 2.3). Each trap was weighted with 5 kg of iron, the escape gaps covered and attached to a main line of up to 100 traps, each 55 m apart, with a heavier (up to 30 kg) ballast at the start, centre and end of each line. Two baits were used in each trap, one a standard bait basket containing Pilchard (*Sardinops neopilchardus*) and the other cutlets or heads of Western Australian Salmon (*Arripis truttacea*). Minimum and maximum soak times of two and four days, respectively were agreed upon.

Figure 2.3. Amateur rock lobster traps used for the size distribution and abundance surveys.

2.1.4 Onboard sampling of commercial catches of *Chaceon bicolor*

Qualified research assistants were on board the commercial vessels for all but five of the trips targeting Crystal Crab. The date, time, GPS position and water depth were recorded at the start and end of each string and the number of days that the traps had been fishing, *i.e.* soak time, was noted. Positions were also recorded for each 50 m depth interval (*e.g.* at 350 m, 400 m *etc*.). These data, in combination with the known spacing of the traps, and the assumption that there was a constant slope between each 50 m depth interval, enabled the fishing depth of each individual trap to be later estimated. Each trap was monitored as it arrived on deck and biological data recorded for each Crystal Crab. Total landed weight was provided by the fishers on return to port.

All catch other than Crystal Crab was recorded to the lowest possible taxon, and in the case of other commercial deep sea crabs, whether they were of minimum legal size was also recorded. Where a species could not be identified, a sample was frozen and kept for later identification.

On the few occasions that a research assistant was not on board, start and end positions and depths were recorded for each line by the fisher, as was the total number and weight of Crystal Crab landed.

2.2 MEASUREMENTS

Biological data were recorded for each Crystal Crab including sex, carapace length (CL), shell state, missing limbs and ovigerous stage. Sex was determined by examining the abdominal flap of each crab, with males' flaps being relatively narrow and short in contrast to females' which have a much broader abdominal flap (Figure 2.4). Mating abrasions on the upper region of the second pair of legs of males was recorded if present and for females, sexual maturity was recorded. Sexual maturity of female Crystal Crabs was determined by examination of the gonadapores of the vulvae, with the vulvae openings of immature individuals appearing thin and closed and those of mature females appearing open and much larger. Shell state was assigned to one of three stages; with stage one being a relatively newly moulted and clean shell and stage three being a significantly blackened shell, the result of chitinous bacteria. Where a crab had very recently moulted, *i.e.* possessed a soft carapace, this was also recorded.

The stage of development of the eggs of ovigerous females was assessed macroscopically and assigned to one of three stages of development based on the colour of the developing eggs. Stage I eggs are light brown/orange in colour and show no discernable internal features when viewed under a dissecting microscope (Figure 2.5a). As development continues, they appear dark brown (Figure 2.5b) due to the embryonic eye spot progressively dominating the colour. The eye spots are clearly visible under a dissecting microscope in stage III eggs, which are macroscopically identified by their dark purple/black colour (Figure 2.5c).

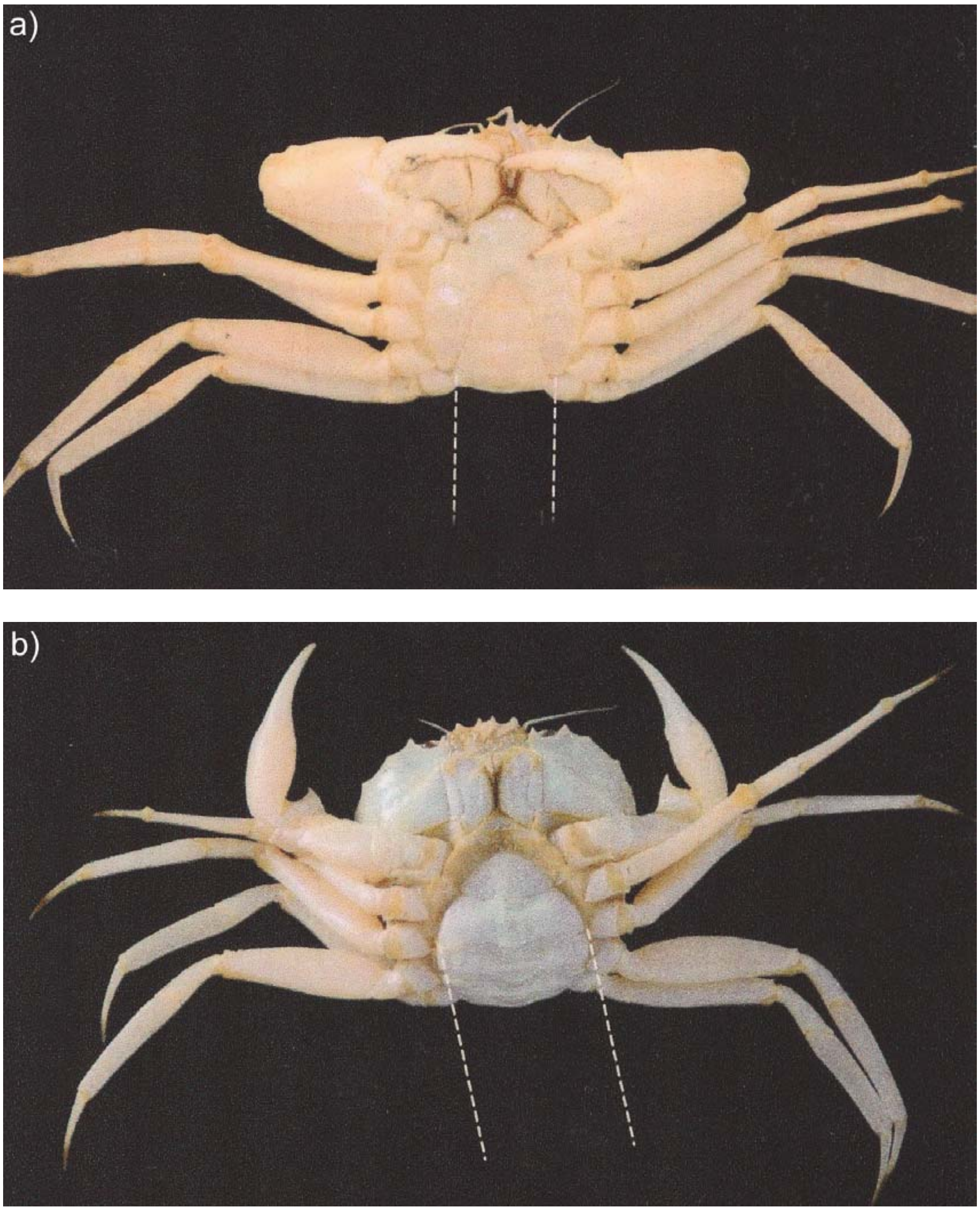

Figure 2.4. Ventral view of a) male *Chaceon bicolor* showing narrow abdominal flap and b) female *C. bicolor* showing relatively broad abdominal flap. Scale bars represent 40 mm. Photographs courtesy: Department of Fisheries, Western Australia.

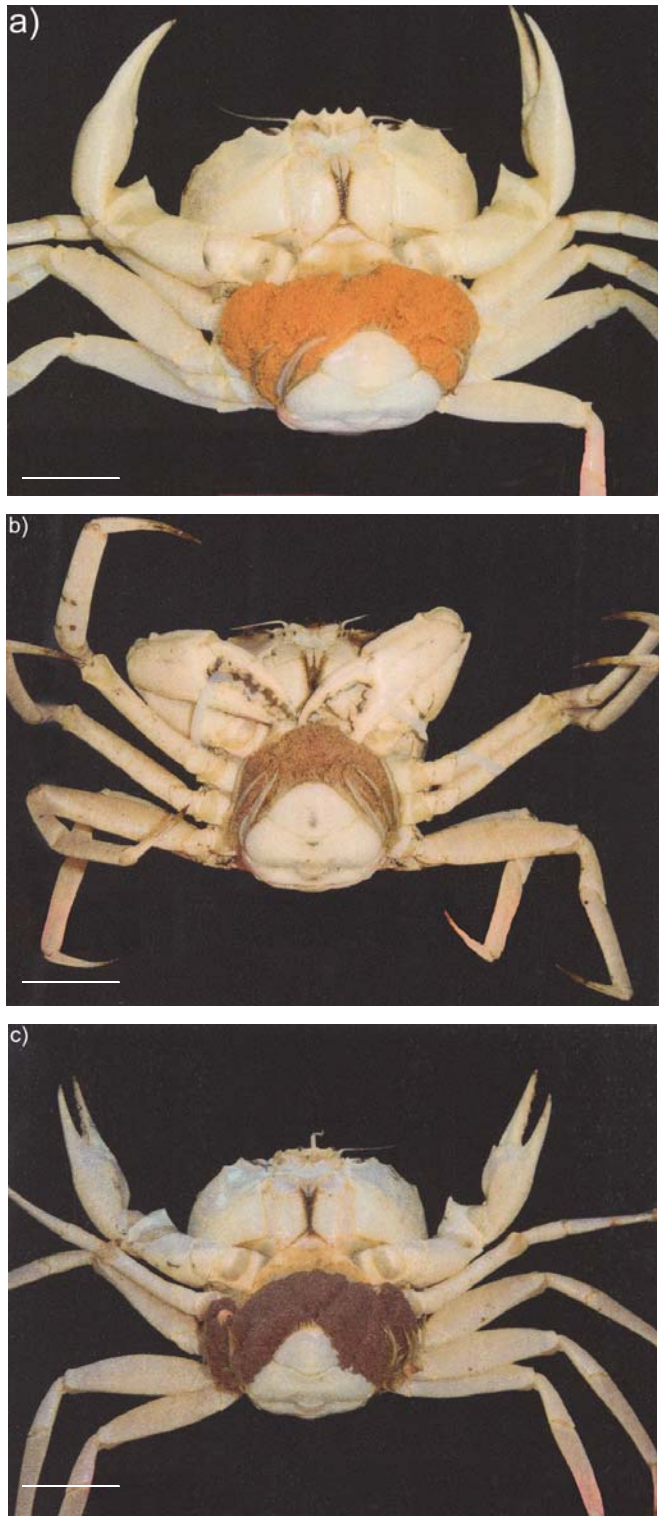

Figure 2.5. Ovigerous *Chaceon bicolor* at a) stage 1, b) stage 2 and c) stage 3 of egg development. Scale bars represent a) 30 mm and b), c) 24 mm. Photographs courtesy: Department of Fisheries, Western Australia.

2.3 TAG AND RELEASE OF *CHACEON BICOLOR*

A number of undersize (<120 mm carapace width) Crystal Crabs that were landed in good condition, *i.e.* alive and possessing no missing limbs, were tagged and released immediately upon capture. Crabs were tagged with Hallprint TBA1 t-bar tags using an Avery Dennison Mark III tag applicator. Tags were inserted into the right hand side of the carapace into the medial epidermal suture line between the third and fourth limbs, fixing the t-bar into the branchial cavity (Figure 2.6). In addition to the above biological data recorded for each tagged and released Crystal Crab, the time, position and water depth were also recorded for each release. Crabs were released without the use of release weights.

Figure 2.6. Tagged *Chaceon bicolor* showing tag insertion point into the suture line between the third and fourth limbs. Photograph courtesy: Department of Fisheries, Western Australia.

3.0 SIZE DISTRIBUTION OF *CHACEON BICOLOR* ON THE SOUTH COAST OF WESTERN AUSTRALIA

3.1 INTRODUCTION

Although size distribution data exists for other commercially important south coast Western Australian deep sea crabs, including the King Crab, *Pseudocarcinus gigas* (Levings *et al.* 1996) and the Champagne Crab, *Hypothalassia acerba* (Smith *et al.* 2004*c*), to date no such data has been collected for the Crystal Crab, *Chaceon bicolor* in this region. A recent study by Smith *et al.* (2004*a*) has gathered important biological information for the latter species, including size frequencies and distributions on the west coast of Western Australia. That study has shown that similar to other deep sea crabs, *e.g. H. acerba* (Smith *et al.* 2004*c*) and *Chaceon affinis* (Pinho *et al.* 2001), average carapace lengths (CL) of male Crystal Crabs are significantly greater than females, with the mean and maximum lengths of all captured *C. bicolor, i.e*. including undersized individuals, recorded at 119 mm and 169 mm for males and 106 mm and 148 mm for females. Those authors also demonstrated significant differences in the mean CL of Crystal Crabs caught in the southern and northern regions of the study area, which was designated as south and north of approximately Geraldton, WA (28º 50’ S), with the average size of this species being significantly greater in the southern region.

In order to obtain data for *C. bicolor* on the south coast of Western Australia that was comparable to those data collected for this species on the west coast, the aim of this chapter was to determine the size distribution of this species on the south coast and in particular, to ascertain whether the size of this species varies spatially in that area and/or with sex, season and/or water depth.

3.2 MATERIALS AND METHODS

3.2.1 Measurements

The CL of each Crystal Crab captured was measured to the nearest 1 mm (Figure 3.1). Carapace length was used because it is considered more reliable than carapace width (CW), which can vary with the age of the carapace as the lateral teeth wear (pers. comm., Dr. Melville-Smith, Department of Fisheries, Western Australia, Smith *et al.* 2004*a*). It must be noted however, that CW is the measurement that is used by industry for the management of the fishery for this species.

Other biological and physical data were collected as described in the *General Methods* section.

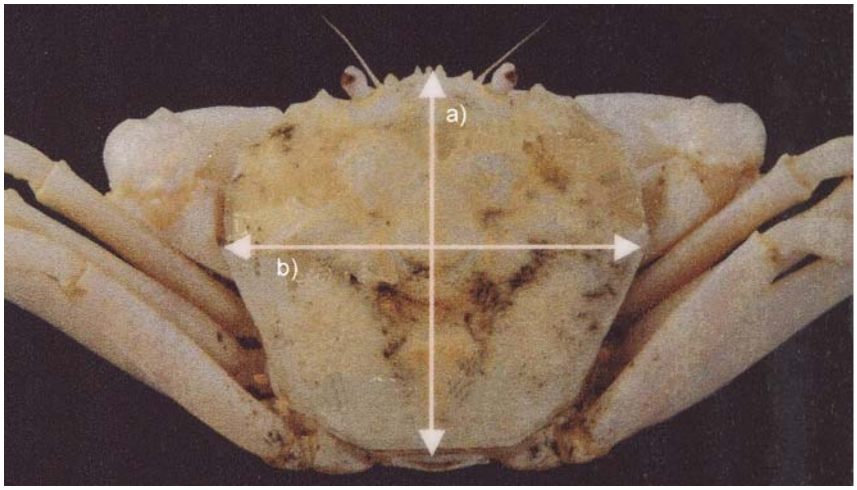

Figure 3.1. The two carapace measurements used for measuring *Chaceon bicolor*, a) carapace length (CL) and b) carapace width (CW). (Photograph courtesy: Department of Fisheries, Western Australia).

3.2.2 Data analyses

The carapace lengths of all Crystal Crabs were subjected to analysis of variance (ANOVA) considering sex, depth category, region and season as factors. Depth categories were defined as 100 m intervals, *i.e.* between 301 and 400 m, 401 and 500 m, 501 and 600 m, 601 and 700 m, 701 and 800 m and 801 and 900 m. Regions were defined as the Esperance zone, the area east of 120º E, and the Albany zone, west of 120º E. The data were logarithmically transformed to account for the heteroscedasticity evident in the raw data and then subject to four-way ANOVA using SPSS. The arithmetic means and 95% confidence intervals are presented for any significant factors.

3.3 RESULTS

Analyses of variance demonstrated significant differences in the mean CLs of Crystal Crabs between sex, depth and season but not between the two regions tested (Table 3.1). None of the interactions between the factors were found to be significant.

The CLs of male Crystal Crabs ranged from 77-194 mm with individuals between 110 and 149 mm accounting for 89% of the catch of male crabs, while that of the females ranged from 78-149 mm, with individuals between 100 and 119 mm accounting for 84% of the total catch of females (Figure 3.2). The mean lengths of all males and females captured were 136 and 115 mm, respectively, while the mean lengths of landed crabs (*i.e.* >103 mm CL) were 137 and 120 mm for males and females, respectively, and 132 mm for both sexes combined. The maximum CLs recorded for male and female *C. bicolor* were 194 and 149 mm, respectively, while the minimum lengths were 77 and 78 mm, respectively

Table 3.1. Mean squares and significance levels for four-way ANOVAs of carapace lengths of *Chaceon bicolor* captured on the south coast of Western Australia. Depth categories were defined as 100 m intervals between 301 and 400 m, 401 and 500 m, 501 and 600 m, 601 and 700 m, 701 and 800 m and 801 and 900 m. Regions were defined as the Esperance zone, the area east of 120º E, and the Albany zone, west of 120º E. $^{**}p < 0.01$, $^{***}p < 0.001$.

	df	Mean square
Sex	1	0.185***
Depth	5	0.023***
Region	1	0.006
Season	3	0.013***
Sex x Depth	5	0.004
Sex x Region	1	0.000
Depth x Region	3	0.003
Sex x Season	3	0.002
Depth x Season	7	0.003
Region x Season	2	0.006
Sex x Depth x Region	2	0.001
Sex x Depth x Season	6	0.005
Sex x Region x Season	1	0.001
Depth x Region x Season	4	0.004
Residual	2384	0.002

The mean CLs of both male and female Crystal Crabs were greatest in traps set in depths between 401 and 500 m, with mean lengths of 143 and 121 mm, respectively, recorded (Figure 3.3). Carapace length decreased with depth for both males and females, down to 800 and 900 m, respectively (Figure 3.3). Male crabs captured below 800 m were slightly larger than those caught between 701 and 800 m.

The mean CL of captured male *C. bicolor* was greatest during the winter months (143 mm), least during autumn months (133 mm) and similar in spring and summer months (136 mm), while that of females was relatively constant throughout the year (Figure 3.4).

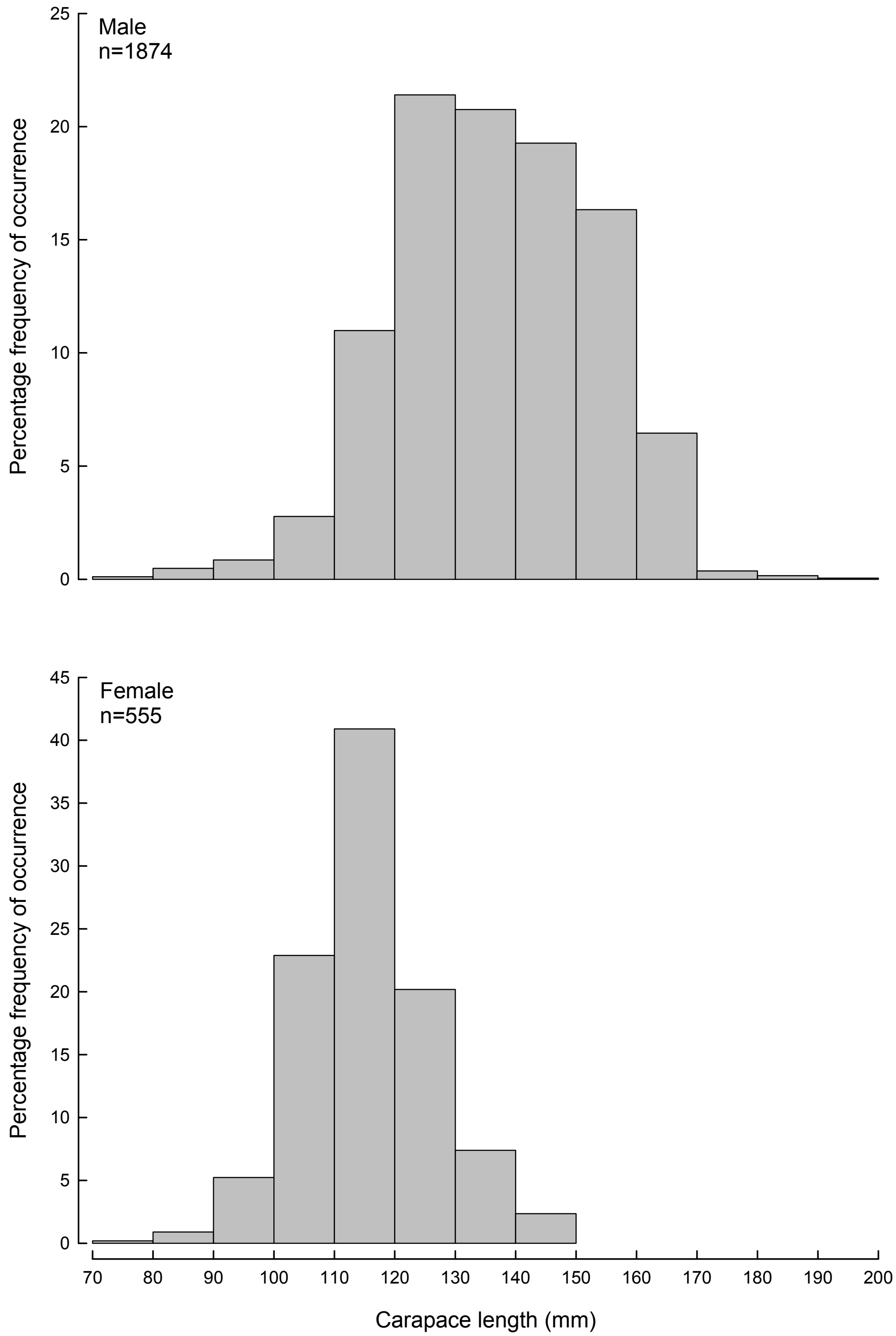

Figure 3.2. Length frequency histograms for male and female *Chaceon bicolor* in sequential 10 mm length classes captured on the south coast of Western Australia. *n* = sample size.

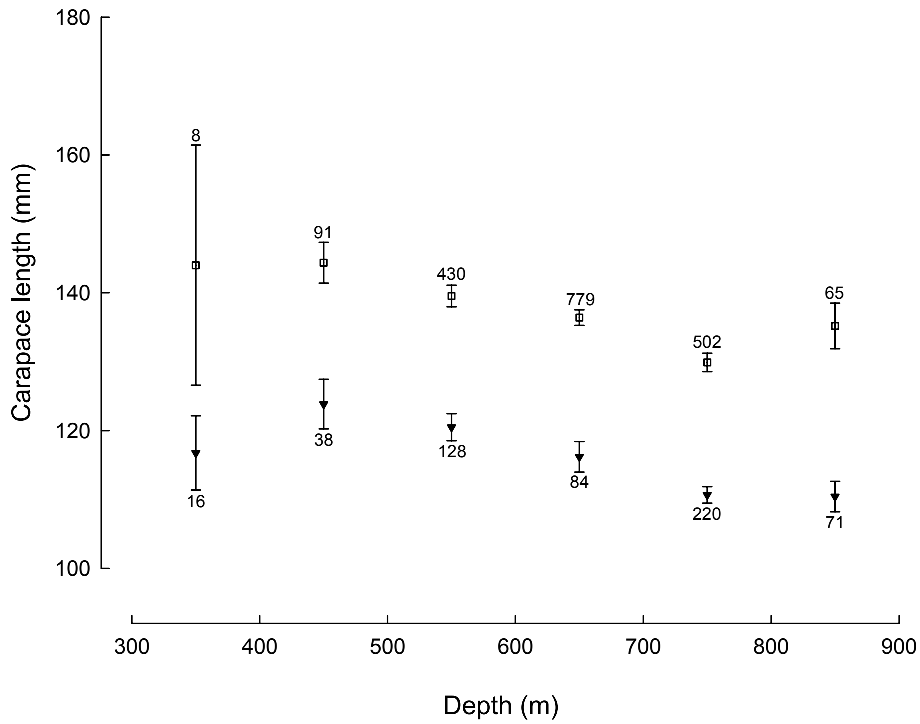

Figure 3.3. Mean carapace lengths and their 95% confidence intervals for male (squares) and female (triangles) *Chaceon bicolor* captured in different depths. Sample sizes are shown for each mean.

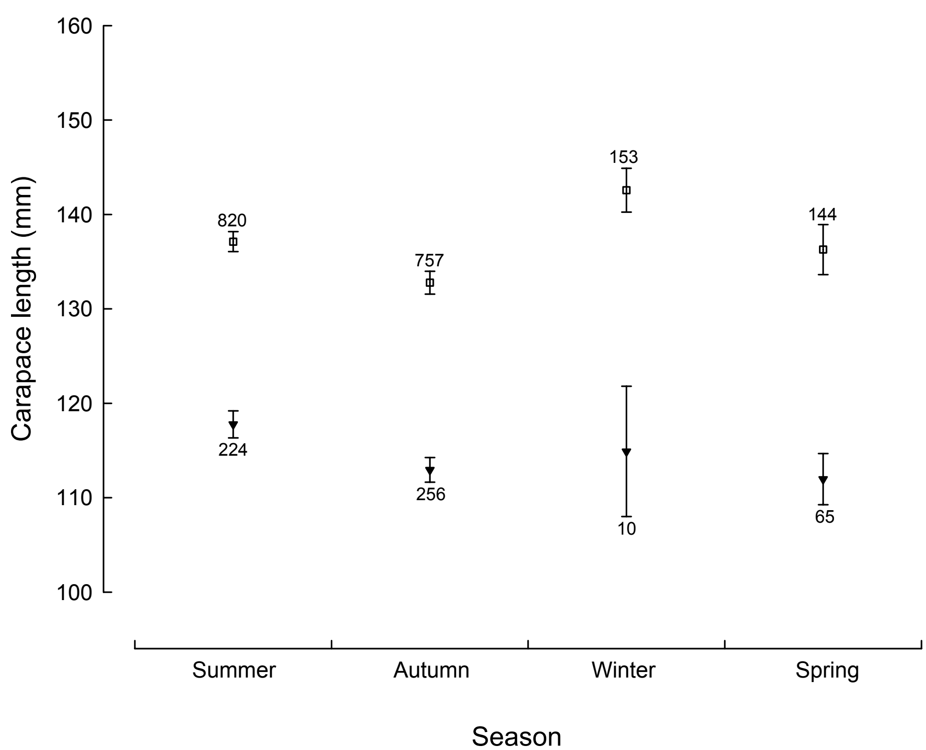

Figure 3.4. Mean carapace lengths and their 95% confidence intervals for male (squares) and female (triangles) *Chaceon bicolor* captured in different seasons. Sample sizes are shown for each mean.

3.4 DISCUSSION

The results of this study have demonstrated that the mean CL of male *C. bicolor* is significantly greater than that of the females on the south coast of Western Australia, *i.e.* 136 and 115 mm, respectively. These results parallel those reported for this species on the west coast of Western Australia (Smith *et al.* 2004*a*), for other species of the *Chaceon* genus (*e.g.* Defeo *et al.* 1991) and for two other deep sea crab species that occur in the same region as *C. bicolor*, namely *H. acerba* (Smith *et al.* 2004*a*) and *P. gigas* (Levings *et al.* 2001). The maximum size recorded for male Crystal Crab on the south coast far exceeded that for females, *i.e.* 194 and 149 mm, respectively, results that are again similar to those recorded for this species on the west coast (Smith *et al.* 2004*a*).

Comparisons of the results obtained during this study and those for the west coast (Smith *et al.* 2004*a*) demonstrate that the mean CLs of male and female *C. bicolor* on the south coast of Western Australia are currently larger than those recorded on the west coast, *i.e.* 136 mm and 119 mm for males and 115 mm and 106 mm for females. The maximum size of males was also greater on the south coast, with maximum CLs of 194 and 169 mm, respectively, while those for females were similar, *i.e.* 149 and 148 mm, respectively. These findings follow those of Smith *et al.* (2004*a*), who described a significantly larger mean size of Crystal Crabs captured in the southern region of the west coast to the northern region and may be the result of reduced fishing pressure in the south, or alternately, increased food availability and/or reduced competition for resources. However, there were no differences in the mean size between the Albany and Esperance zone, although catch data indicated that relative densities of Crystal Crab were much lower in the latter region (see Section 4). This may indicate that fishing pressure rather than competition for resources is the dominant factor influencing the average and maximum sizes of this species.

In fact, while these data suggest a significant difference in the average size of this species between the south and west coasts of Western Australia, it is important to note that the mean size of Crystal Crabs on the west coast was approximately 10 mm larger at the inception of that fishery, *i.e.* before exploitation of that stock occurred (pers. comm., Dr. R. Melville-Smith, Department of Fisheries, Western Australia). It is thus expected that, on the south coast, the mean size of Crystal Crab will decline progressively as the unexploited stock is harvested. Anecdotal evidence suggests that this has occurred with other deep sea crustaceans on the south coast, including King Crab and Southern Rock Lobster (pers. comm., Mr. Sharp, south coast professional crustacean fisherman). Alternatively, the reduction in the average landed size of these and other species may be the result of growth overfishing, which selects for the fastest growing individuals (*e.g.* Conover and Munch 2002).

The generally decreasing body size of Crystal Crab with depth is similar to other deep sea crustaceans and may reflect a partial partitioning of resources as described for other species such as *Chaceon fenneri* and *Chaceon quinquedens* (Lockhart *et al.* 1990) and *H. acerba* (Smith *et al.* 2004*c*). This size distribution may also be a result of physiological requirements of different stages of this species' life history, *i.e.* similar to some other marine species where juveniles exhibit a greater ability to withstand extreme environmental conditions due to increased osmoregulatory ability and/or other physiological adaptations. Water depths greater than *ca* 900 m were not sampled during this survey, and thus, it was not possible to determine whether very small individuals, *i.e.* <75 mm CL, that were not captured during the current sampling regime inhabit those deeper waters, thereby providing further resource partitioning and a possible "resource sink" for this species which can not be harvested commercially.

4.0 DISTRIBUTION AND ABUNDANCE OF *CHACEON BICOLOR* ON THE SOUTH COAST OF WESTERN AUSTRALIA

4.1 INTRODUCTION

Chaceon bicolor has been caught in commercial quantities off the west coast of Western Australia between approximately 32.5 and 22º S since 1997 (Catch and Effort Statistics (CAES), Department of Fisheries, Western Australia). Exploratory fishing north of 22º S has indicated that the distribution of this species does not extend north of that latitude (CAES, Department of Fisheries, Western Australia). South and east of 32.5º S, Crystal Crab were thought to occur along the south coast, possibly as far as the South Australian border (129º E) (Melville-Smith *et al.*, in press).

Following the rapid expansion of the Crystal Crab fishery on the west coast between 1998 and 2000, there was a corresponding interest in developing a fishery for this species on the south coast. Professional south coast fishers who were already licensed to take deep sea crustaceans in the area began fishing for this species with reported catches increasing from very low amounts in 1997 to about 10 tonnes in 2002 (CAES, Department of Fisheries, Western Australia). Since the south coast crustacean fishery is managed as two separate regions during the Southern Rock Lobster season, *i.e.* the Albany Zone (west of 120º E) and the Esperance Managed Fishery *i.e.* the Esperance zone (east of 120º E), licence holders from one region are not permitted to fish in the other during the season. Fishers that were interested in developing the fishery, who were mainly Albany Zone fishers (pers. comm. Mr. Greg Sharp, south coast professional crustacean fisherman), were not able to fish for this species in the Esperance Managed Fishery zone during the Southern Rock Lobster season, so little effort was exerted in the area east of 120º E and corresponding low catches were recorded (CAES, Department of Fisheries, Western Australia). Therefore, while the distribution of *C. bicolor* is known to extend east from Cape Leeuwin, little is known of their actual distribution east of the Albany zone, *i.e.* east of 120º E.

In order to ensure that development of the Crystal Crab fishery off the south coast of Western Australia proceeds in an environmentally sustainable and economically viable way, this study was undertaken to determine the distribution and relative abundance of this species in that region. An additional objective was to ascertain whether different trap sizes and bait saving devices influenced the catches per unit of effort of this species.

4.2 MATERIALS AND METHODS

4.2.1 Measurements

The number of male, ovigerous female and non-ovigerous female *C. bicolor* were recorded for each trap and the CL of each crab were measured to the nearest 1 mm. The date, depth, geographical position and soak time, *i.e.* number of days that traps were permitted to fish, were recorded for each transect line as described in the *General Methods* section.

The weight of each individual crab was calculated according to the length-weight relationships derived from data collected by Smith *et al.* (2004*a*), *i.e.*

Males: $W = 0.000948476 * CL^{2.8659}$

Females: $W = 0.000165818 * CL^{3.2244}$

where W is the wet weight of each individual (g) and CL is carapace length (mm).

4.2.2 Data analyses

Catch rates, which were calculated as the total number of crabs per trap lift, were log (+1) transformed to account for the heteroscedasticity in the raw data prior to being analysed using analysis of variance (ANOVA). The factors considered were depth category, region and season, as described in Section 3. The results of these analyses demonstrated that very significant differences existed between catch rates in the two regions that were considered (see Results), with extremely low numbers of crabs captured in the Esperance zone, *i.e.* east of 120º E. All subsequent analyses were therefore completed using only raw data from the Albany zone, *i.e.* west of 120º E.

Catch rates from individual traps set in the Albany zone were square root transformed and subjected to ANOVA, considering depth and season as factors. Arithmetic means and their 95% confidence intervals are presented for any significant factors. The catch rates of male and female *C. bicolor* were then calculated separately for each season and depth category.

Landed catch rates were calculated as the number of legal size (>103 mm CL) male and non-ovigerous female crabs caught per trap lift. These data were log (+1) transformed and then analysed as described above using ANOVA. Arithmetic means and their 95% confidence intervals are presented for the significant factors.

Catches per unit of effort (cpue), which were expressed as the landed weight of *C. bicolor* >103 mm CL per trap lift (kg) and not including ovigerous females, were log (+1) transformed before being analysed with ANOVA, considering depth and season as factors (as described in Section 3). Mean cpues and their 95% confidence intervals are presented for each factor.

4.2.3 Different trap sizes and bait saving devices

Additional catch data were collected by one of the professional participants using larger traps and bait saving devices (bait holders that exclude sea lice). These traps were 850 mm long, 750 mm wide and 850 mm high with a circular top entrance 170 mm in diameter and 200 mm deep and an escape gap measuring 60 mm by 300 mm and thus had a volume approximately five times that of the standard traps used for the project and described in Section 1. The bait saving devices were cylindrical in shape and covered with *ca*. 2.5 mm plastic mesh. The same baits were used as described in Section 1. These traps were set in strings of three and were lifted 124 times between January and March 2005 with a mean soak time of about seven days. Positions and depths were recorded for each line as was the total number and weight of Crystal Crab landed. Where possible, the number of returned crabs, i.e. undersize and ovigerous females was also recorded.

Since these traps were set in an area that had been previously fished during the research project with the standard Elvinco traps at similar depths (229 trap lifts in total during the same season one year earlier), these data were compared using ANOVA. Catches per unit of effort (cpue), which were expressed as the landed weight of *C. bicolor* >103 mm CL per trap lift (kg), were square root transformed before being analysed.

4.3 RESULTS

4.3.1 Catch rates

Catch rates showed no correlation with the number of days that the traps were allowed to fish, *i.e.* soak time (Figure 4.1). The range of catch rates after 2-4 days soak time was 0.2-2.3 crabs per trap lift and on one occasion where traps were allowed to fish for 54 days, a catch rate of *ca* 2 crabs per trap was recorded.

Analyses of variance demonstrated significant differences in the catch rates of *C. bicolor* between the two regions. Catch rates were much lower in the Esperance zone than the Albany zone with means of *ca* 0.1 and 1 crabs per trap lift, respectively (Figure 4.2). All subsequent analyses were therefore restricted to data from the Albany zone.

Catch rates within the Albany zone varied markedly with longitude, but the data showed no clear trend in abundance between the western and eastern areas of the Albany zone (Figure 4.2).

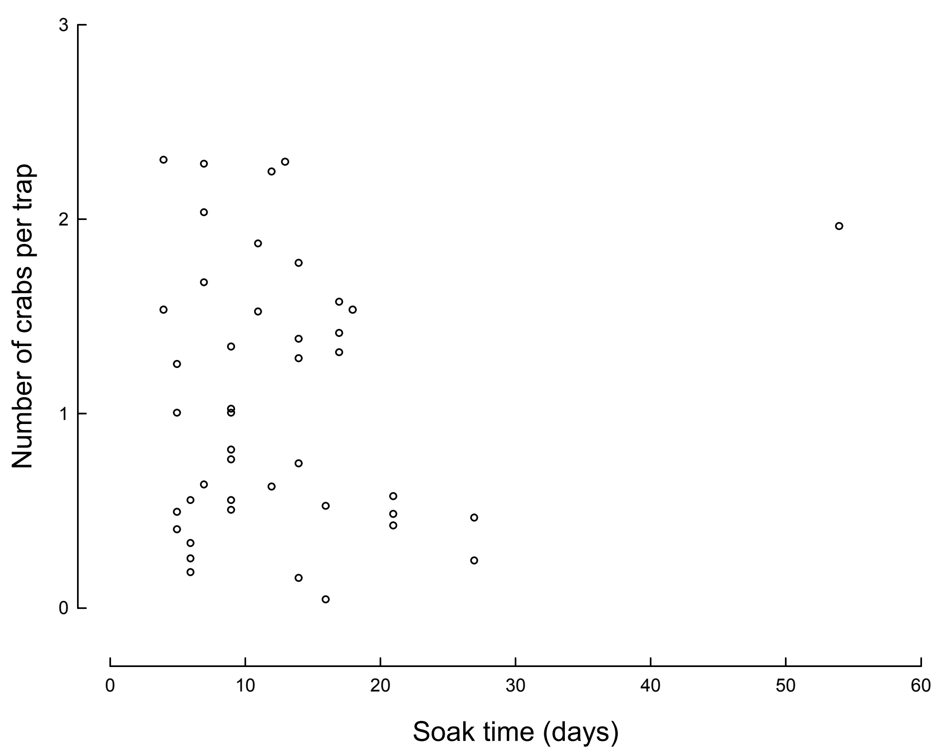

Figure 4.1. Catch rates, expressed as the mean number of *Chaceon bicolor* per trap lift after different soak times.

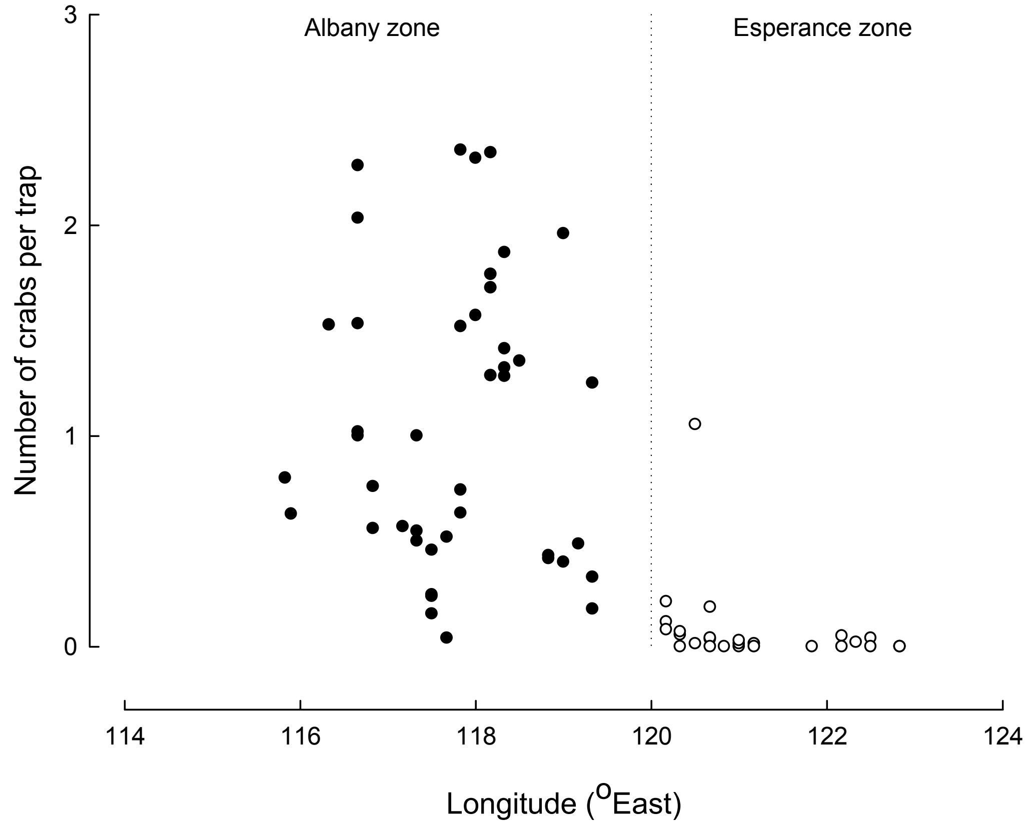

Figure 4.2. Catch rates, expressed as the average total number of *Chaceon bicolor* captured per trap lift in each line of traps, for the Albany zone (west of 120º E) and the Esperance zone (120-125º E).

Significant differences were demonstrated for the catch rates of *C. bicolor* in the Albany zone in different depths and seasons (Table 4.1). Catch rates were highest in traps set in water depths between 701 and 800 m (*ca* 1.6 crabs per trap lift) and lowest in water depths between 301 and 400 m (*ca* 0.5 crabs per trap lift) (Figure 4.3). Catch rates were similar in all other depths, *i.e.* 401-700 m and 801-900 m, ranging from 0.7 to 1.2 crabs per trap lift. Catch rates from traps set during the summer months were more than five times higher than those recorded during the winter months (*ca* 1.5 and 0.3 crabs per trap, respectively) (Figure 4.4). Traps set during the autumn and spring months returned similar catch rates of approximately 1.1 crabs per trap lift (Figure 4.4). The interaction between depth and season was also significant.

Table 4.1. Mean squares and significance levels for two-way ANOVAs of catch rates of *Chaceon bicolor* in the Albany zone expressed as the total number of crabs per trap lift. Depth categories were defined as 100 m intervals between 301 and 400 m, 401 and 500 m, 501 and 600 m, 601 and 700 m, 701 and 800 m and 801 and 900 m. $^{**}p < 0.01$, $^{***}p < 0.001$.

	df	Mean square
Depth	5	5.671***
Season	3	25.989***
Depth x Season	9	1.854***
Residual	2231	0.452

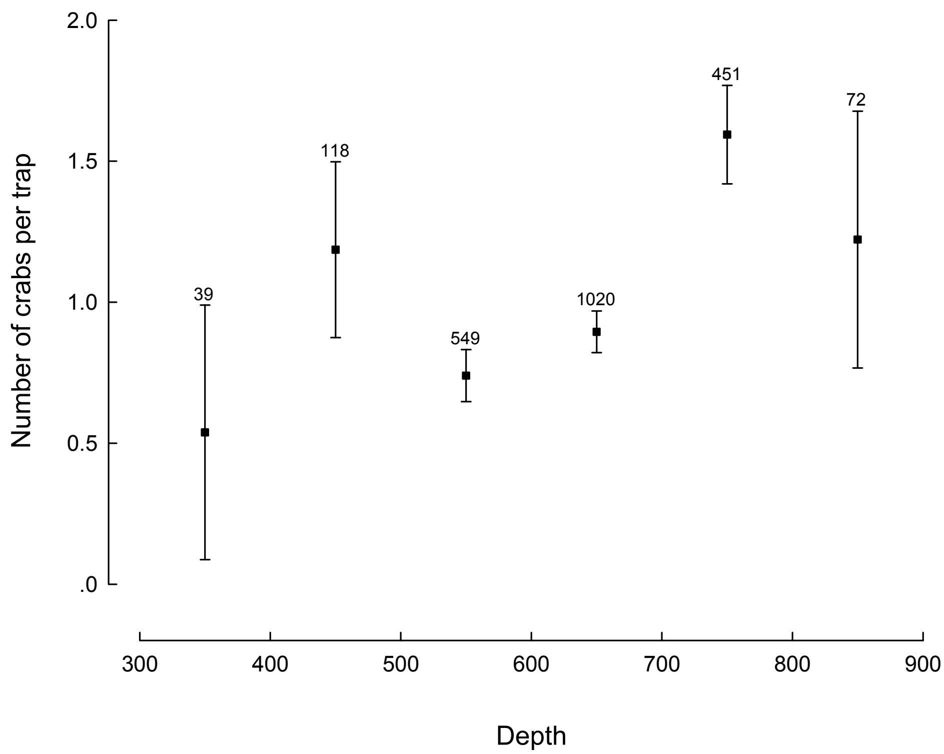

Figure 4.3. Catch rates, expressed as the average number of *Chaceon bicolor* captured per trap lift at different depths in the Albany zone and their 95% confidence intervals. Sample sizes are shown for each mean.

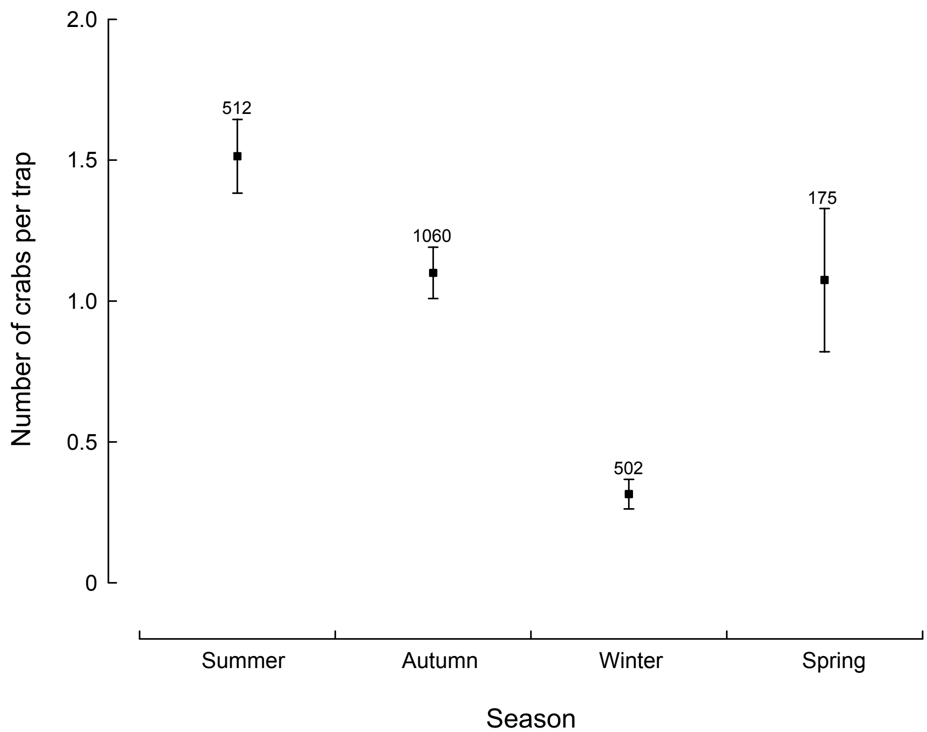

Figure 4.4. Catch rates, expressed as the average number of *Chaceon bicolor* captured per trap lift in different seasons in the Albany zone and their 95% confidence intervals. Sample sizes are shown for each mean.

Male *C. bicolor* were far more abundant than females in traps set between 501 and 800 m, with 1524 males captured at a catch rate of *ca* 0.9 crabs per trap lift compared to 268 females caught with a catch rate of *ca* 0.1 crabs per trap lift in those depths (Figure 4.5). In the deepest water sampled, *i.e.* 801-900 m, males were also slightly more abundant than females, while in the shallowest water sampled, *i.e.* 301-400 m, females were slightly more abundant than males (Figure 4.5). Catch rates of both male and female Crystal Crabs were similar between 401 and 500 m (Figure 4.5). The catch rates of male Crystal Crab were substantially higher than females in each season (Figure 4.6).

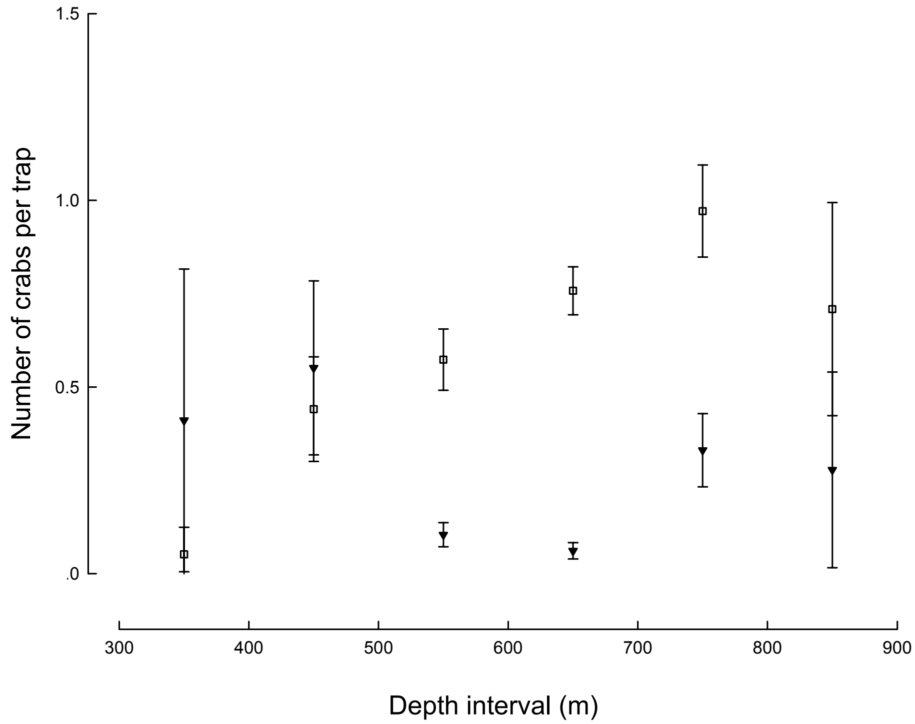

Figure 4.5. Catch rates, expressed as the average number of crabs captured per trap lift for male (squares) and female (triangles) *Chaceon bicolor* at different depths in the Albany zone and their 95% confidence intervals.

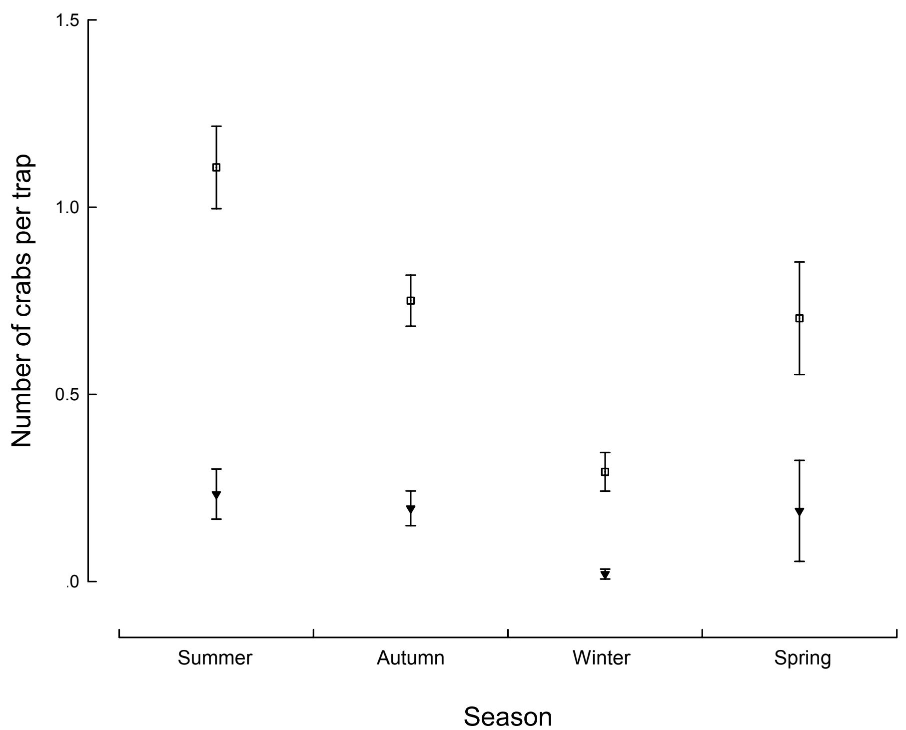

Figure 4.6. Catch rates, expressed as the average number of crabs captured per trap lift for male (squares) and female (triangles) *Chaceon bicolor* in different seasons in the Albany zone and their 95% confidence intervals.

Ovigerous female *C. bicolor* were never captured east of 120º E and catch rates were low in the area west of 120º E, with an average of approximately 0.01 ovigerous females per trap lift recorded. Notably, three berried females were recorded from one trap that was set in 701-800 m water depth during autumn. A total of 30 ovigerous female were captured which represented about 11% of all females caught (data not shown). Catch rates of ovigerous females were not analysed due to low sample sizes, although ovigerous females were recorded from depths between 401 and 800 m and in each season of the year.

4.3.2 Landed catch rates

Landed catch rates, expressed as the number of Crystal Crabs >103 mm CL and not including ovigerous females, followed similar trends to the total catch rates, being significantly different at different depths and in different seasons (Table 4.2). Mean landed catch rates were highest between 701 and 800 m and significantly greater than those at 301 to 400 m and 501 to 700 m, although similar to catch rates between 401 and 500m and between 801 and 900 m (Figure 4.7). The interaction between depth and season was also significant.

Table 4.2. Mean squares and significance levels for two-way ANOVAs of landed catch rates of *Chaceon bicolor* in the Albany zone expressed as the number of crabs >103 mm CL per trap lift. Depth categories were defined as 100 m intervals between 301 and 400 m, 401 and 500 m, 501 and 600 m, 601 and 700 m, 701 and 800 m and 801 and 900 m. $^{**}p < 0.01$, $^{***}p < 0.001$.

	df	Mean square
Depth	5	0.634***
Season	3	2.886***
Depth x Season	9	0.197***
Residual	2210	0.050

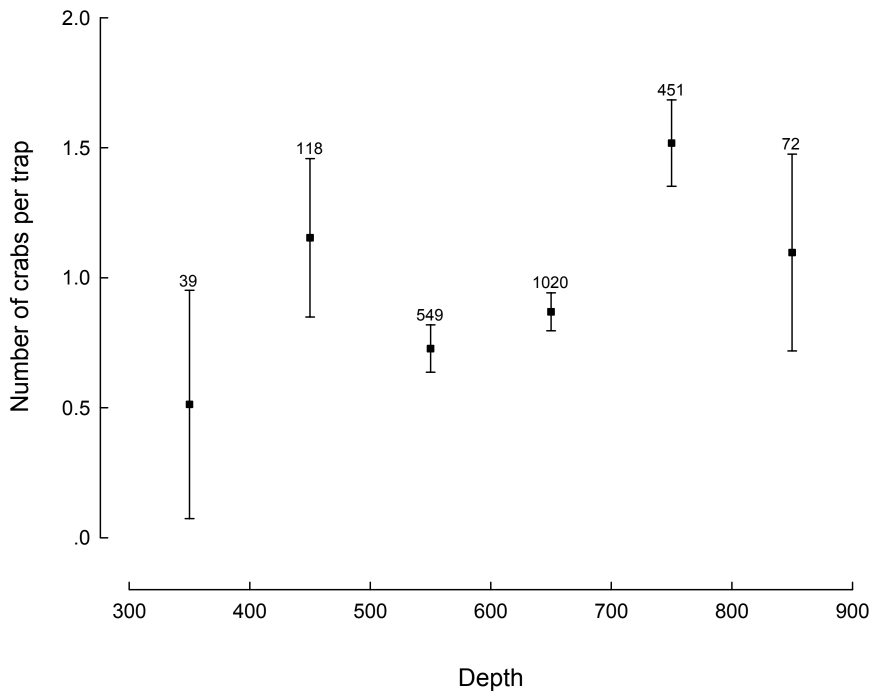

Figure 4.7. Landed catch rates, expressed as the average number of *Chaceon bicolor* >103 mm CL captured per trap lift at different depths in the Albany zone and their 95% confidence intervals. Sample sizes are shown for each mean.

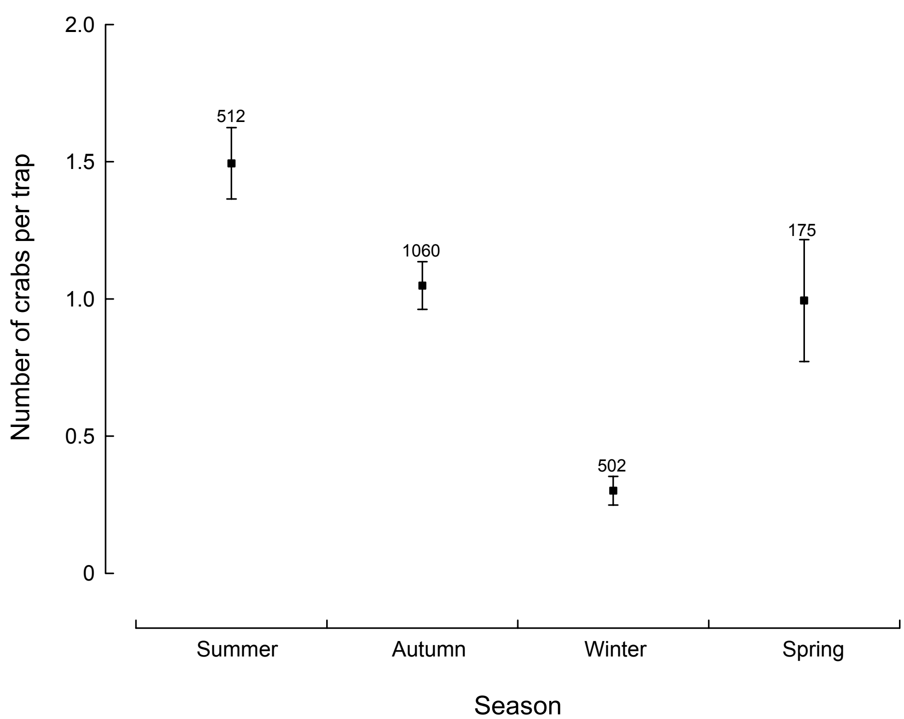

Figure 4.8. Landed catch rates, expressed as the average number of *Chaceon bicolor* >103 mm CL captured per trap lift in different seasons in the Albany zone and their 95% confidence intervals. Sample sizes are shown for each mean.

4.3.3 Catches per unit of effort

ANOVA demonstrated that there were significant differences in cpue of *C. bicolor* >103 mm CL and excluding ovigerous females between different depths and seasons (Table 4.3). Catches per unit of effort were greatest in depths between 401 and 500 m and 701 and 800m (Figure 4.9). The lowest cpue was recorded in the shallowest depth surveyed, *i.e.* 301 to 400 m. Catches per unit of effort were greatest in the summer months and least during winter (Figure 4.10). The interaction between depth and season was also significant.

Table 4.3. Mean squares and significance levels for two-way ANOVAs of catches per unit of effort of *Chaceon bicolor* in the Albany zone expressed as the weight of crabs (kg) >103 mm CL per trap lift. Depth categories were defined as 100 m intervals between 301 and 400 m, 401 and 500 m, 501 and 600 m, 601 and 700 m, 701 and 800 m and 801 and 900 m. $^{**}p < 0.01$, $^{***}p < 0.001$.

	df	Mean square
Depth	5	0.574***
Season	3	3.425***
Depth x Season	9	0.227***
Residual	2210	0.061

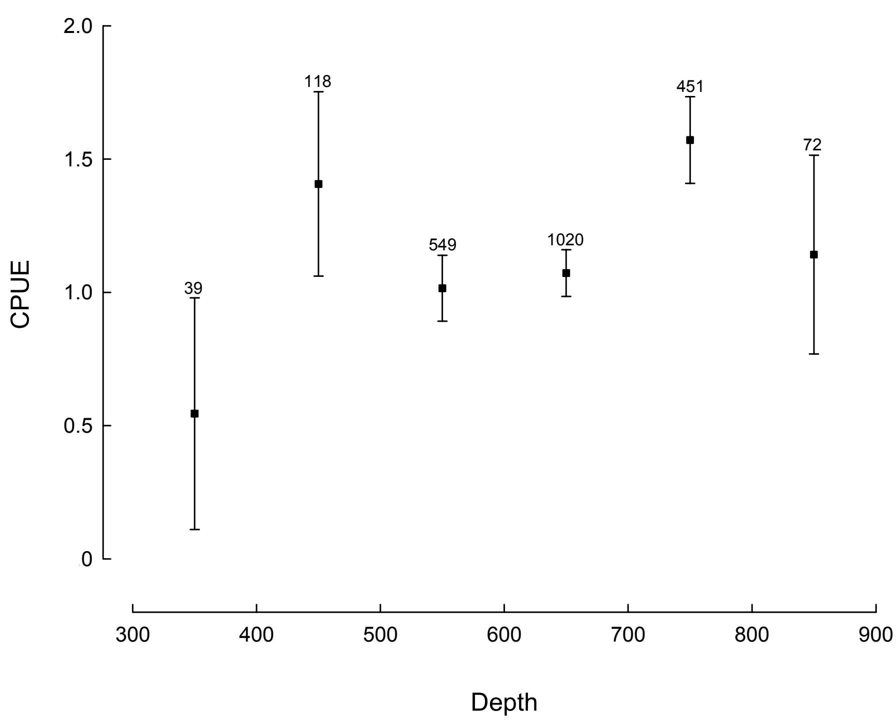

Figure 4.9. Catches per unit of effort, expressed as the average weight of *Chaceon bicolor* >103 mm CL captured per trap lift at different depths in the Albany zone and their 95% confidence intervals. Sample sizes are shown for each mean.

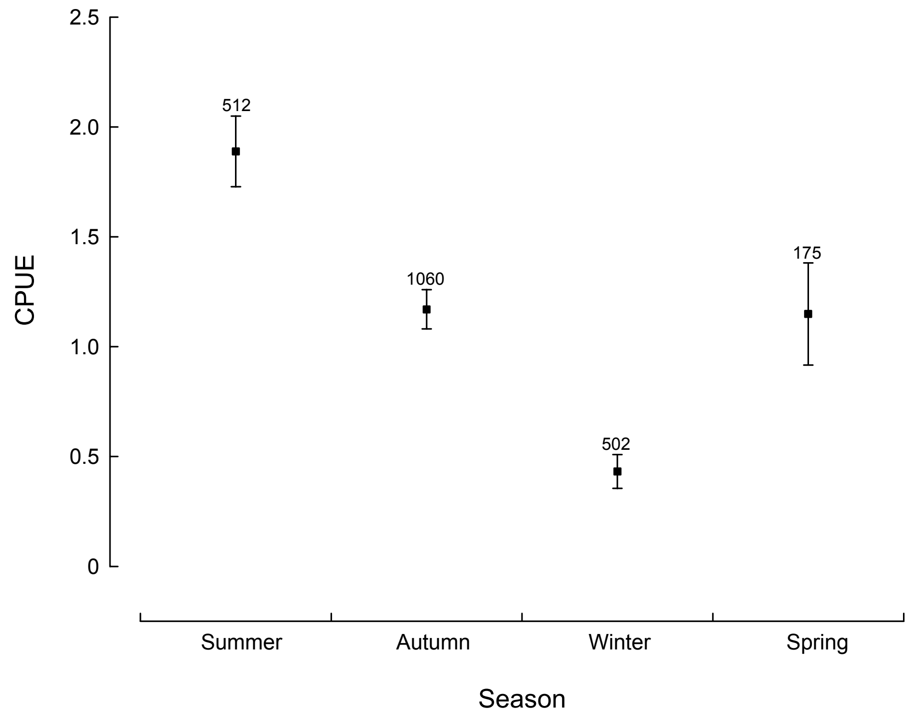

Figure 4.10. Catches per unit of effort, expressed as the average weight of *Chaceon bicolor* >103 mm CL captured per trap lift in different seasons in the Albany zone and their 95% confidence intervals. Sample sizes are shown for each mean.

Significant differences were demonstrated for the cpue of Crystal Crab using different sized traps at similar depths in the same area and season (Table 4.4). Thus, although we recognise potential temporal variability due to the different traps being set during summer in sequential years, the largest mean cpue was recorded in the larger traps (*ca* 5.5 kg per trap lift) and the smallest cpue in the smaller standard traps (*ca* 1.7 kg per trap lift).

Table 4.4. Mean squares and significance level for ANOVA of catches per unit of effort of *Chaceon bicolor* captured between 118º and 118º 30' E with standard and larger sized traps. See text for trap dimensions. $**p < 0.01$, $***p < 0.001$.

	df	Mean square
Trap type	1	2.121**
Residual	6	0.104

4.4 TAG AND RELEASE OF CHACEON BICOLOR

A total of 106 *C. bicolor* were tagged and released with 103 of those crabs captured and released west of approximately 118º E (Figure 4.11*a*). Release depths varied from 499 to 900 m (Figure 4.11*b*). The low numbers of Crystal Crabs that were captured and had CLs less than 103 mm (total 97) and/or were ovigerous females (total 30) with no missing limbs restricted the tag and release program. No recaptured crabs have been reported to date.

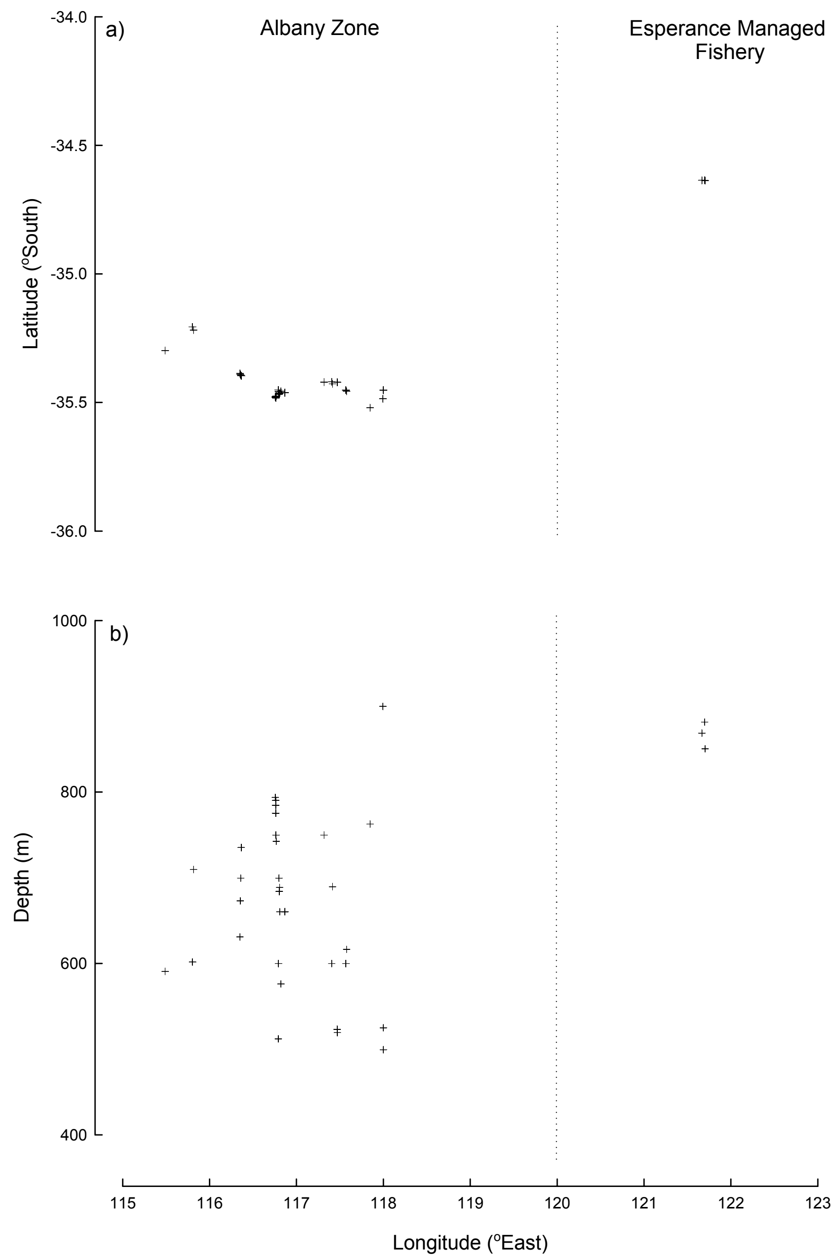

Figure 4.11. Release a) locations and b) depths of tagged *Chaceon bicolor* on the south coast of Western Australia.

4.5 DISCUSSION

The results of this study show that, although soak times were generally longer than anticipated, *i.e.* usually greater than two days (see section 2), no significant difference was observed in the mean catch rates of *C. bicolor* with different soak times. In fact, on one extreme occasion where traps were unable to be retrieved for 54 days due to a strongly flowing Leeuwin Current that held the marker floats below the water surface, a catch rate of about 2 crabs per trap was recorded. This was almost twice the overall mean catch rate recorded for the Albany zone. Since there was no bait left in those traps on retrieval (B. Chuwen, pers. obs), crabs were not attracted by bait after that length of time and therefore, it is possible that either the crabs could not get out of the traps once captured or that after such a prolonged fishing time, the traps provided habitat for individuals. Results reported for another deep sea crab species, *Paralithodes camtschaticus*, showed that this species was able to escape from purposefully discarded traps allowed to fish for prolonged periods of time, only to be replaced by different and larger individuals over time (Godøy *et al.* 2003), indicating that the traps were being used for shelter.

The very low catch rates that were recorded in the area east of 120º E, *i.e.* in the Esperance zone, may reflect a very low biomass of Crystal Crab in that region, indicating that 120º E is the approximate eastern extent of the commercial exploitable Crystal Crab stock on the south coast. However, the relative abundance of Crystal Crab did not decline progressively from west to east in the Albany Zone, which would be expected if the population of crabs extended essentially only as far as 120º E. Furthermore, it must be noted, that such unusually high numbers of sea lice (unidentified isopod species) were observed only in the area east of 120º E, at least as far as Esperance (*ca* 122º E) (pers. obs) that it is probable that baits in traps set in this area were decimated so quickly that Crystal Crabs were not attracted to the traps (fishers were restricted to using only standard type bait holders that do not exclude sea lice: see *General Materials and Methods*). This is highlighted by the fact that no bait remained in any of the bait holders, even after only two days soak time, and that the limited by-catch in this area was almost completely consumed by sea lice on retrieval of the traps (B. Chuwen, pers. obs). In view of these factors, it is not possible to determine the distribution and abundance of Crystal Crab east of 120º with the data collected in this study.

The results of this study have shown that the highest catch rates in the Albany zone were recorded during the summer months and the lowest catches recorded in winter, while catch rates during spring and autumn were similar. These results differ from those recorded for this species on the west coast of Western Australia where no distinct monthly or seasonal trends in catch rates were described (Smith *et al.* 2004*a*). These differences may reflect differences in oceanographic conditions between the two coasts and may indicate that a greater variation in such conditions occurs on the south coast in different seasons. It is relevant to note that, while the strength of the Leeuwin Current, which flows southward along the west coast and then eastwards along the south coast, is generally greatest during the winter months on the west coast, that current usually flows in that region throughout the year (Cresswell 1990, Cresswell and Peterson 1993). In contrast, the Leeuwin Current essentially only flows along the south coast following peak flows on the west coast, usually during winter months, a point consolidated by the strong flowing current observed during this study in the winter months (B. Chuwen, pers. obs). While the Leeuwin current is essentially restricted to the surface layer, *i.e.* above the thermocline (Cresswell 1990), it is important to note that the distribution of Crystal Crabs on the south coast extends into shallower water than described for that species on the west coast. Therefore, the Leeuwin Current may exert a greater influence over the water temperature and/or salinity experienced at those depths in this region, which may provide the basis for migration of this species either across different depths or to different regions of the south coast, thereby affecting their catchability at different times of the year.

The data collected in this study has also demonstrated that the catch rates of male *C. bicolor* were always greater than those of females, with an overall male to female ratio of *ca.* 4:1. While these data indicate that male crabs are much more abundant than females, other authors have attributed similar sex ratios of other deep sea crabs to behavioural traits, including male aggression and avoidance of traps by ovigerous females, rather than actual differences in the abundance of the different sexes (*e.g.* Miller 1990, Smith *et al.* 2004*a*). Similarly, the low percentage frequency of occurrence of ovigerous females captured on the south coast during this research may reflect actual low numbers of spawning females in this region, or again, may be due to trap avoidance and therefore non-capture of egg bearing females.

In the Albany zone, catch rates, *i.e.* number of crabs per trap lift, and landed catch rates, *i.e.* number of legal sized and non-ovigerous females, followed essentially the same trend, and thus it is reasonable to suggest that no particular depth or season would produce higher proportions of legal sized crabs than undersized and/or ovigerous individuals. Therefore, any regulations or restrictions to reduce the by-catch of undersize and/or ovigerous Crystal Crabs would require the use of methods other than seasonal closures or depth restrictions, such as escape gaps in traps to allow smaller individuals to escape as the traps are hoisted through the water column. Such escape gaps are currently used in the south coast crustacean fishery (Department of Fisheries, Western Australia, Regulations).

Catches per unit of effort (cpue) in the Albany zone followed the same trend as the catch rates described above, with the greatest cpue recorded from traps deployed in water depths ranging from 701 to 800 m (mean = approximately 1.6 kg per trap lift). However, as cpue between 401 and 900 m had a relatively small range from a minimum of *ca.* 1.1 kg per trap lift between 501 and 600 m, to the maxima between 701 and 800 m, it can be deduced that commercial quantities of Crystal Crab will be captured across the relatively large depth range between 401 and 900 m on the south coast of Western Australia. This range is considerably larger than that over which commercial quantities of this species are captured on the west coast, *i.e.* predominately between 500 and 800 m (pers. comm., Dr. R. Melville-Smith, Department of Fisheries WA), and may reflect a larger area of suitable habitat type within that depth range on the south coast. The significant interaction between depth and season for both catch rates and cpues may reflect a tendency for this species to migrate up and down the continental slope during the year.

This study has also demonstrated that the catchability of Crystal Crab, expressed as cpue, is dependant on the size of traps used. Traps that were three times the volume of the standard traps used, captured on average, three times the landed weight (*ca.* 5.5 kg per trap lift) of Crystal Crabs as compared to the smaller traps (*ca.* 1.7 kg per trap lift) when deployed in the same area (between 118º and 118º 30’ E), at similar depths and in the same season. Although bait saving devices were used in those larger traps, it is important to note that inspection of the bait canisters upon retrieval of the standard traps deployed in that area, *i.e.* not fitted with bait saving devices, revealed that bait was generally still present and that sea lice were not affecting the bait as was the case east of 120º E (B. Chuwen, pers. obs). It is therefore likely that trap size rather than the use of bait saving devices in this area where sea lice were not prolific, was the reason for the differences in the catching efficiency of the two trap types. These data demonstrate that restrictions in the types of fishing gears allowed by commercial fishers to target Crystal Crab will considerably affect the catches of this species and therefore the economic viability of the fishery. Such restrictions may, however, provide a means for managers to regulate the numbers of Crystal Crabs captured.

5.0 ASSESSMENT OF POTENTIAL YIELD OF CRYSTAL CRAB *CHACEON BICOLOR* FROM THE SOUTH COAST OF WESTERN AUSTRALIA

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5.1 SUMMARY

A research survey of the *Chaceon bicolor* stock on the south coast of Western Australia was carried out from December 2003 to October 2004. The data arising from this study were analysed to determine the expected annual catch taken using the same level of exploitation as that exerted by the commercial fishery for this species off the west coast of Western Australia. The catch estimate was obtained by multiplying the average annual catch for the west coast fishery by the ratio of the products of catch per unit of effort (cpue) and area occupied by *C. bicolor* on the south and west coasts. A further catch estimate was obtained by constraining the latter area to the average area on the west coast from which catches were obtained in 2001 to 2003. Low cpues to the east of 120° E led to the exclusion of this region from the analysis for the south coast. For the remaining survey data, no relationship was found between cpue and longitude or soak time but cpue change significantly with depth. The average cpue for the south coast was 1.16 (S.E. 0.11) kg.traplift^{-1}, compared with the cpue for the west coast commercial fishery of approximately 1.15 kg.traplift^{-1}. The area of *C. bicolor* habitat on the west coast was considerably greater than that on the south coast, *i.e.* 64,420 km^2 vs 8,082 km^2 based on depths from 450 to 1,220 m in which the species is assumed to be distributed, or 45,656 vs 5,272, 24,417 vs 2,529, or 41,083 vs 3,937 km^2 using depths from 300 to 900, 500 to 800, or 400 to 900 m, respectively. Due to the very large differences between these areas, the resulting estimates of equivalent south coast catch were low, *i.e.* ~20-26 tonnes. Constraining the calculation to the grid cells fished between 2001 and 2003 on the west coast, the areas of *C. bicolor* habitat on the west coast were 15,912, 14,056, 9,552 or 13,750 km^2 based on depths from 450 to 1220, 300 to 900, 500 to 800, or 400 to 900 m, respectively. Using these areas, the potential annual south coast catch is estimated to be ~56 to 108 tonnes. Thus, if the

catches obtained between 2001 and 2003 on the west coast are sustainable, the "equivalent" south coast catch might range from a conservative value of ~20-26 tonnes to a maximum of between ~56 and 108 tonnes.

5.2 INTRODUCTION

Research surveys were undertaken for Crystal Crab *Chaceon bicolor* off the south coast of Western Australia between December 2003 and October 2004. These surveys were carried out by commercial fishers in approximate accordance with a sampling regime defined by Richard Stevens and supervised by Ben Chuwen. Although the sampling regime required fishers to set traps along specified transects, fishers on some occasions deviated from this aspect of the sampling protocol by fishing in the depths and locations in which they expected catch rates to be relatively high and which would avoid tangling of gear (B. Chuwen, pers. comm.). Catch per unit of effort (cpue, $kg.traplift^{-1}$) was relatively low in the area east of 120° E. This has been attributed to the presence of large numbers of sea lice that reduced the effectiveness of traps due to the consumption of bait by sea lice and it has been suggested that the low catch per unit of effort does not reflect the true relative density of the stock in this region (B. Chuwen, pers. comm.).

The objective of this brief assessment was to use the survey data to determine the annual yield of Crystal Crabs that might be expected from waters off the south coast of Western Australia.

5.3 BACKGROUND

Smith *et al.* (2004) noted that *C. bicolor* is found in water depths from 450 to 1,220 m in both Australian and New Zealand waters, but is exploited only in Western Australia. There are no genetic studies of which I am aware, thus it is assumed that the Western Australian fishery exploits a single genetic stock of this species and that removals on the south coast may affect that part of the stock that is located on the west coast, and vice versa. However, as the contribution of each section of the stock to the assemblage of crabs within either location is unknown, it would be appropriate for alternative stock assessments to be undertaken both using the combined west and south coast data and treating the fishery as exploiting a single stock and also using the west and south coast data separately and treating the crabs in each location as separate "stocks".

At the outset, it should be noted that estimation of the sustainable annual yield of the stock of *C. bicolor* is not possible with the data that are currently available. The time series of catch and effort data for the west-coast fishery is not yet of sufficient length and precision to allow evaluations of the impact of catch removals on the abundance of the stock. Thus use of biomass dynamics models is not possible. Furthermore, there are currently no estimates of natural mortality for this species or of the fishing mortality of the "stock(s)" on either the west or south coasts of Western Australia. As with other deep sea crabs, however, it is likely that *C. bicolor* is long lived and thus has a low natural mortality and low productivity.

If data are insufficient to allow determination of the annual sustainable yield, how might an estimate of the potential annual yield of Crystal Crabs from the south coast of Western Australia be derived? In this study, it was assumed that the objective was to determine an allowable yield for the south coast based on a level of exploitation equivalent to that on the portion of the stock lying in the west coast region of the fishery. Thus, the annual commercial catches should be proportional to the biomass of legal-sized crabs within each of the regions. The latter was assumed to be proportional to the product of the catch per unit of effort of legal-sized crabs (kg.traplift^{-1}) and the area of the habitat in which the Crystal Crabs are located. It was assumed that the catchabilities of crabs in the west and south coast fisheries are the same.

5.4 METHODS

Biological data collected for both the males and females of *C. bicolor* and reported in Smith *et al.* (2004) were analysed to determine the parameters of the allometric relationships between the body mass of crabs and their carapace lengths.

The biological data that were collected subsequently during the south coast survey included details of the sex and carapace length (CL) of each crab caught in each trap, together with information on traps that had caught no crabs. The latitude and longitude of the location at which fishing of the line of traps commenced, the depth at this location and the soak time of the traps were recorded. The number of traps in the line and the total mass of legal-sized crabs that were ultimately landed by these traps was recorded. The body mass of each crab was calculated using the weight-length relationship derived for the corresponding sex.

Although females crabs caught before 30 May 2004 and crabs less than 107 mm CL (due to confusion regarding the actual minimum legal length, *i.e.* 103 mm CL) were not landed by the fishers, all crabs caught in the traps while an observer was present were measured. To confirm that the recorded landed weights were consistent with the details recorded for the individual crabs, estimates of the landed weight were derived from the biological data collected in the survey, by calculating for each line of traps the sum of the estimated body weights of crabs of sizes that were at or above the minimum legal length of 103 mm CL. The catch per unit of effort (cpue) for each line of traps was calculated by dividing the landed catch of legal-sized crabs by the number of traps in the line. Similarly, the estimated cpue was calculated using the estimated mass of legal-sized crabs in each line of traps. The catches per unit of effort derived from the two sets of landed weights were then compared by calculating the correlation coefficient and testing its significance.

The cpue data calculated from the landed catch of legal-sized crabs were then analysed using a stepwise multiple regression of catch per unit of effort versus latitude, longitude, depth and soak time. As latitude was the only independent variable that was found to be significant (see Results), cpue was plotted against latitude. The plot revealed a distinct cluster of low catches per unit of effort in the more northerly sites (*i.e.* to the north of 34° 45' S) within the surveyed region, which appeared to represent the data from east of 120° E. Survey data that were located to the west of 120° E were selected for further analysis. The relationships between cpue and latitude, longitude, depth and soak time for the selected data were investigated using stepwise multiple regression. The average cpue of these crabs in the region located to the west of 120° E. was calculated.

ETOPO5 5-minute gridded elevation data[1] from the National Geophysical Data Center, NOAA, were analysed to determine the surface area (km^2) of the spherical polygons defined by the corners of the 5-minute grid cells lying between depths of both 450 to 1220 m (corresponding to the

[1] Data Announcement 88-MGG-02, Digital relief of the Surface of the Earth. NOAA, National Geophysical Data Center, Boulder, Colorado, 1988.

depth range described by Smith *et al*., 2004) and 300 to 900 m (corresponding to the depth range surveyed in this study, see Results). The analysis was also undertaken using depth ranges of 500 to 800 m (as suggested by R. Melville-Smith in a pers. comm. to B. Chuwen) and 400 to 900 m, reflecting the fact that the starting depths recorded in the data used were the depths at the start of each transect rather than the average depth.

The west coast fishery for *C. bicolor* developed from a negligible catch in 1977 to reach an average annual catch of ~210 tonnes for the period 2001 to 2003 and producing peak catch rates of approximately 1.15 $kg.traplift^{-1}$ (Smith *et al.*, 2004).

Although no details of the spatial extent of the fishery on the west coast are reported by Smith *et al.* (2004), the comment is made that "Catches of *C. bicolor* were grouped into two regions, *i.e.* to the north and south of 28º 50'S (approximately Geraldton), which lies in the middle of the range of latitudes where sampling was undertaken". It has therefore been assumed that the area over which *C. bicolor* is distributed and over which the species is exploited by the west coast fishery falls in the specified depth range within the region from 22.5 to 34° 24' S and 110 to 117° E. Recognising the low catch rates to the east of 120° E, *C. bicolor* is assumed to be distributed on the south coast in the specified depth range between 34° 24' and 36° S and 110 to 120° E.

The area from which the west coast catch was drawn and lying within each of the two depth zones was also calculated using the geographical boundaries of each of the 10 × 10 minute grid cells for which fishing activity was reported in the data provided by fishers to the Western Australian Department of Fisheries. The average of the resulting areas for 2001 to 2003 was used in estimating the potential yield from the south coast.

Finally, the catch on the south coast that would be likely to result from an equivalent level of exploitation to that exerted by the west coast fishery was calculated by multiplying the average catch for the west coast for the years 2001 to 2003 by the ratio of the products of the cpues and areas of habitat for the south and west coasts.

5.5 RESULTS

The relationships between the body weights (g) and sizes (mm CL) of the individuals of *Chaceon bicolor* that were collected in the study described by Smith et al. (2004) were

Males: $W = 0.000948\,\mathrm{CL}^{2.866}$

Females: $W = 0.000166\,\mathrm{CL}^{3.224}$.

The correlation between the cpues based on the mass of legal-sized crabs that were landed and on the sum of the masses of the individual crabs with carapace sizes of 103 mm or greater was 0.94 ($P < 0.001$).

Only latitude was found to be statistically significant ($P < 0.001$) when the entire data set was subjected to stepwise regression (Figure 1). A distinct cluster of low values of cpue at latitudes between 34.5 and 34.75° S was evident when cpues were plotted against latitude (Figure 1). Excluding the data to the east of 120° E, produced a scatter of points that, with less contrast in latitude, suggested a far less strong relationship between cpue and latitude and removed the cluster of low values that had been present in the previous plot (Figure 2). The low values east of 120° E were consistent with the advice received from Ben Chuwen, who had attributed these to the reduced effectiveness of traps in this region due to greater consumption of bait by larger numbers of sea lice.

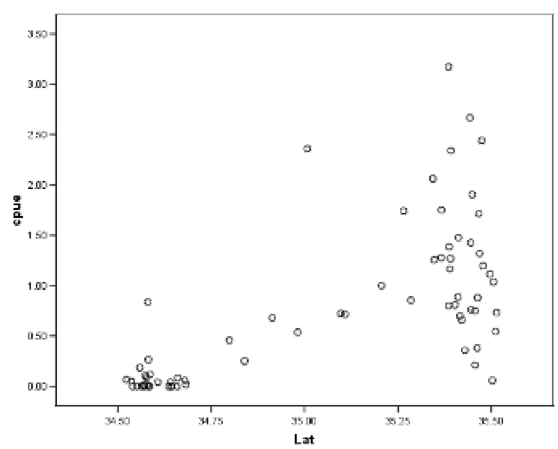

Figure 1. Relationship between catch per unit of effort of *Chaceon bicolor* (kg.traplift^{-1}) and latitude for all locations fished during the survey.

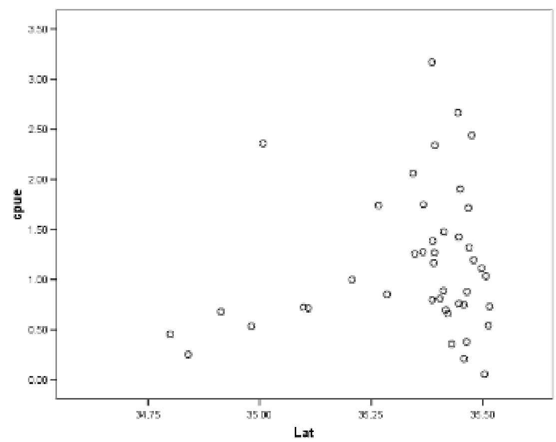

Figure 2. Relationship between catch per unit of effort (kg.traplift^{-1}) of *Chaceon bicolor* and latitude for locations to the west of 120° E.

As it appears likely that commercial fishers would focus future fishing on the area to the west of 120° E, subsequent analysis of the survey data was restricted to this area. A stepwise multiple linear regression of cpue on latitude, longitude, soak time and depth revealed that cpue was significantly influenced ($P < 0.01$) by depth (Figure 3). It should be noted that the depth recorded for each line in the data used for this analysis was the starting depth for the line, and this was invariably the depth of the near-shore end of the line of traps.

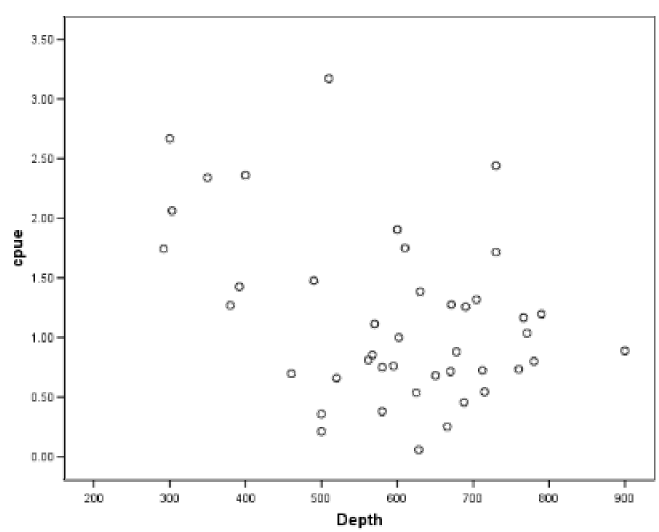

Figure 3. Catch per unit of effort (kg.traplift^{-1}) versus depth (m).

The mean cpue of individuals of *C. bicolor* in the area west of 120° E that were of legal size, *i.e.* ≥103 mm CL, was 1.16 (S.E. 0.11) $kg.traplift^{-1}$. It should be noted, however, that some of the female crabs included in this calculation may have been ovigerous.

On the west coast, the area in the depths from 450 to 1,220 m in which *C. bicolor* is assumed to be distributed covers 64,420 km^2, whereas, on the south coast, it covers only 8,082 km^2 (Figure 4). If the depths occupied by *C. bicolor* are assumed to range between 300 and 900 m, the areas of habitat on the west and south coasts are 45,656 and 5,272 km^2, respectively, between 500 and 800 m the areas are 24,417 and 2,529 km^2, respectively, and between 400 and 900 m are 41,083 and 3,937 km^2, respectively. The areas between 300 and 900 m, 450 and 1220 m, 500 and 800 m, and 400 and 900 m lying in the geographical grid cells that were fished on the west coast between 2001 and 2003 were 14,056, 15,912, 9,552 and 13,750 km^2, respectively.

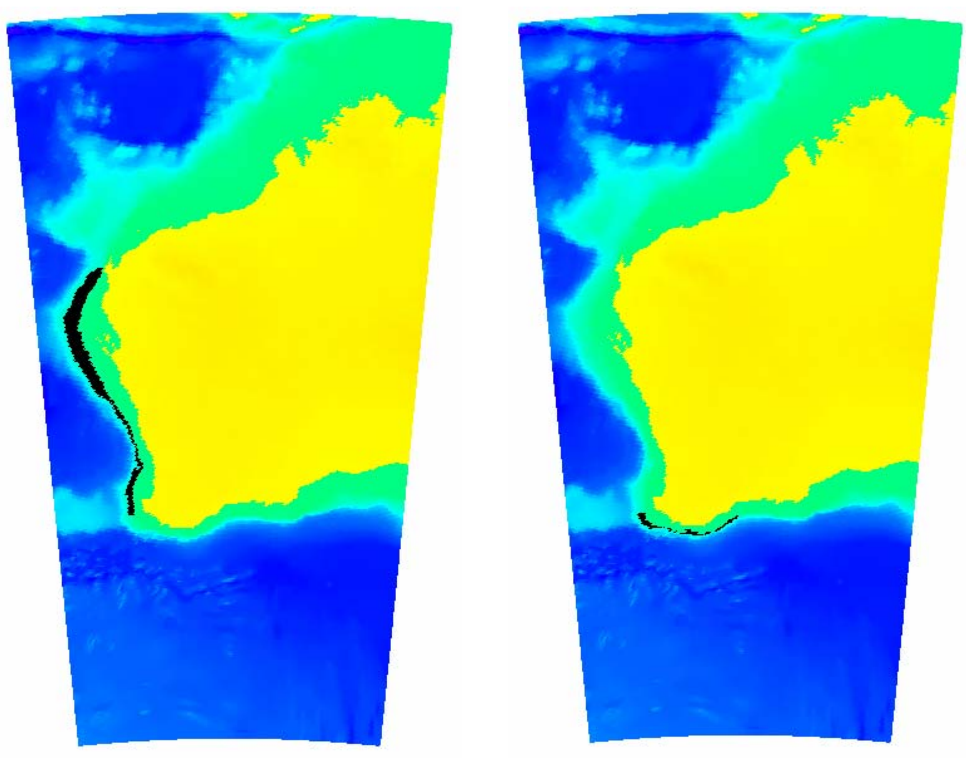

Figure 4. Maps showing the areas between depths of 450 and 1,220 m on the west and south coasts (shaded in black) used in calculating the areas occupied by *Chaceon bicolor*. Alber equal area projection.

Based on the ratio of the products of areas of habitat and cpues, the estimated catch on the south coast that could be obtained using the same rate of exploitation as that on the west coast is relatively small. Using the depth range from 450 to 1,220 m, the potential south coast catch is 26.6 (95% confidence interval (C.I.): 21.4 to 31.7) tonnes, whereas with the narrower depth range from 300 to 900 m, the catch becomes 24.5 (95% C.I.: 19.7 to 29.2) tonnes. Based on the depth ranges from 500 and 800 m, and from 400 and 900 m, the projected south coast catches are 21.9 (17.7 to 26.2) and 20.3 (16.4 to 24.2) tonnes, respectively. If the calculation is based on the average area between 300 and 900, 450 and 1220, 500 and 800, and 400 to 900 m depth in the grid cells fished on the west coast between 2001 and 2003, the estimate of the potential south coast yield is 107.6 (95% C.I.: 86.8 to 128.3), 79.4 (95% C.I.: 64.2 to 94.8), 56.1 (95% C.I.: 45.3 to 66.9), or 60.6 (95% C.I.: 49.0 to 72.3) tonnes, respectively.

5.6 DISCUSSION

The area of *C. bicolor* habitat on the south coast is much less than that on the west coast as the width of the shelf within the depths occupied by this species is much less on the south than the west coast. Although the average cpue of the survey catches on the south coast in the region west of 120° E was very similar to the average cpue experienced by the west coast commercial fishers, the abundance of crabs is likely to be much smaller than on the west coast as the cpue is distributed over a much smaller area of habitat. The area of *C. bicolor* habitat that was fished by the west coast fishery between 2001 and 2003 was approximately 24 to 30% of the corresponding habitat in the total area considered to be the range of the species on the west coast, *i.e.* from 34° 24′ S extending as far to the north as Exmouth Gulf.

The estimates of potential catch from the south coast reflect the uncertainty associated with alternative assumptions. If based on the area of *C. bicolor* habitat and the assumption that the west coast catch is drawn from the entire extent of the range, the south coast catch is estimated to be ~20 to 26 tonnes. However, if the west coast catch is considered to be drawn from only that habitat within the grid cells exploited by fishers during 2001-2003, the potential annual yield is ~56 to 108 tonnes.

It is useful to return again to the question of stock identity. If there is a single stock of *C. bicolor* and the fishery for this species is extended to the south coast, the stock will be exposed to an increase in exploitation. With the data that are available, it is not possible to determine whether the current level of exploitation is sustainable. If further exploitation is permitted, cpues for both the west and south coast fisheries should be monitored to ensure that they do not fall below specified critical levels.

5.7 ACKNOWLEDGEMENTS

Thanks are extended to Richard Stevens and Ben Chuwen for providing access to their survey data and for their helpful advice.

6.0 BENEFITS AND ADOPTION

The biological data collected during this research will assist industry members and fisheries managers to develop appropriate plans that will ensure that the emerging *Chaceon bicolor* fishery on the south coast of Western Australia develops in an environmentally and economically sustainable way. These data will also provide the basis for future stock assessment of this species in this region, *i.e.* provide baseline data from which the effect of harvesting on the relative abundances and size distributions of Crystal Crabs can be determined.

In order that these benefits be realised, the Department of Fisheries, Western Australia needs to accept and adopt the information and data provided herein. All data has been provided to the Department of Fisheries, Western Australia in a format compatible with the extant deep sea crab database, and will therefore be both easily accessible and comparable to data collected for this species on the west coast of the state

These data will also assist commercial fishers in selecting appropriate fishing gears and techniques and will provide valuable information that will assist them to determine appropriate levels of investment in fishing for Crystal Crabs on the south coast of Western Australia.

7.0 FURTHER DEVELOPMENT

Following approval and acceptance by the Fisheries Research and Development Corporation, this report will be supplied to the Department of Fisheries, Western Australia, the Department of Environment and Heritage, Murdoch University's Centre for Fish and Fisheries Research and all commercial crustacean fishers on the south coast of Western Australia. Brief reports outlining the major findings will be submitted to Western Fisheries and PROWEST magazines in order to disseminate the information and implications of the results to the wider public.

An advertised meeting will be held in Albany on the south coast of Western Australia to discuss these findings with all interested parties, including professional fishers and the general public. The results of this meeting will be reported to the Department of Fisheries, Western Australia, with a view to developing a fisheries management plan that is also acceptable to the

Federal Department of Environment and Heritage so that Crystal Crabs will receive exempt status for export.

8.0 PLANNED OUTCOMES

Prior to this project no data existed on the size distribution and relative abundance and distribution of Crystal Crab, *Chaceon bicolor* on the south coast of Western Australia. This study has thus provided quality data for this species in this region which will now place the managers of the southern crustacean fishery in a better position to develop the Crystal Crab fishery on the south coast of Western Australia to its optimal and sustainable harvest level.

Data collected on the relative abundance of this species have allowed comparisons to be made with the Crystal Crab fishery on the west coast allowing reasonable estimates of the total annual yield of this species from waters on the south coast to be made. Data collected on the size distribution of Crystal Crab in this region will allow further assessment of the state of the fishery in the future, by providing important baseline data with which to compare future results.

The results will also enable fishers to make reasonable and educated decisions concerning the most appropriate levels of investment into the fishery and the types of fishing gear and the time and water depth of deployment of gear that will optimise the economic yield of the fishery.

9.0 GENERAL CONCLUSIONS

Data have been collected that will assist in developing the Crystal Crab fishery on the south coast of Western Australia to its optimum sustainable yield. The main findings of this research project were:

- The estimated potential total yields for *Chaceon bicolor* from waters off the south coast of Western Australia range from a conservative 20-26 tonnes to a maximum yield of between 56 and 108 tonnes per annum. The estimates were based on calculations using different areas of suitable habitat for this species on the west coast. The conservative estimates were based on the entire suitable habitat on the west coast, whereas the maximum estimates were based on the area on the west coast from which catches of Crystal Crab have been taken between 2001 and 2003.

- Catch rates and catches per unit of effort (cpue) indicate that abundance of Crystal Crab east of 120º E is very low, however, very high numbers of sea lice in that area may have been responsible for those very low catch rates through decimation of the bait required to attract crabs into the traps. Since the area to the east of 120º E was not included in the calculations to determine the potential annual yield from the south coast, any *C. bicolor* that do inhabit that region would be additional to the estimated total annual catch presented in this study.
- The average cpue in the Albany zone was 1.16 kg per trap lift which is similar to that recorded for the west coast Crystal Crab fishery between 2001 and 2003, *i.e.* 1.15 kg per trap lift.
- Commercial quantities of Crystal Crabs were captured in the Albany zone, between 115º 20' E and 119º 20' E, in depths ranging from 401 to 900 m, with maximum cpue of 1.6 kg per trap lift recorded in depths between 801 and 900 m in that area. The highest catches and cpues were recorded during the summer months.
- Catch rates of male Crystal Crabs were on average four times greater than that of females, except in water between 301 and 400 m deep.
- Catches per unit of effort were greater in larger traps than smaller traps, with those cpues proportional to the volume of the traps used, *i.e.* traps that were five times greater in volume captured five times the amount of Crystal Crabs when fished at similar depths in the same area.
- The average carapace length (CL) of all captured male *C. bicolor* was significantly greater than that of females, with mean lengths of 136 and 115 mm, respectively, recorded, while the mean lengths of landed male and female crabs, *i.e.* > 103 mm CL, were 137 and 120 mm, respectively.
- The CL of *C. bicolor* was generally inversely proportional to depth, with the mean lengths of both sexes being greatest in depths between 301 and 500 m and least between 701 and 800 m.
- The mean CLs of male and female *C. bicolor* on the south coast are currently larger than those recorded on the west coast at 136 and119 mm, respectively for males and 115 and

106 mm, respectively for females. The maximum size of male Crystal Crabs captured on the south coast was also greater than the west coast, while that of females was similar.

- A total of 17 species other than Crystal Crab, representing five taxonomic categories were captured during the research survey, but the level of the catch was low. The greatest contributing taxonomic category was the Decapods, which were caught in less than 6% of traps set. King Crab (*P. gigas*) occurred in 3.5% of traps with fewer than six individuals captured per 100 traps deployed. Individual *P. gigas* below the minimum legal length (MLL) for capture accounted for two thirds of the total capture of that species. Since there is a significant overlap in the distributions of the commercially important King Crab and Crystal Crabs, management plans must take into account the capture of the former species while targeting *C. bicolor*.

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11.0 APPENDICES

11.1 APPENDIX 1: INTELLECTUAL PROPERTY

The value of the intellectual property will be 49% based on Part C7 of the FRDC project proposal.

11.2 APPENDIX 2: CAPTURE OF SPECIES OTHER THAN *CHACEON BICOLOR*

A total of 17 species other than Crystal Crab, representing five taxonomic categories were also captured during this research survey. The greatest contributing taxonomic category was the decapods, which were caught as in over 8% of traps set. Of the decapods, King Crab (*Pseudocarcinus gigas*) was the dominant species caught, occurring in 3.5% of traps with more than five individuals captured per 100 traps deployed. Individual *P. gigas* below the minimum legal length for capture accounted for two thirds of the total take of that species.

Table A2. Percentage frequency of occurrence and number of individuals of species other than *Chaceon bicolor* captured per 100 traps set in water depths greater than 300 m.

Taxonomic category	Species	Percentage frequency of occurrence	Number of individuals per 100 traps
Gastropoda		0.45	0.81
	Unidentified sp.	0.45	0.81
Echinodermata		0.78	0.95
	Asteroidae sp.	0.28	0.35
	Echinoidae sp.	0.50	0.60
Decapoda		5.24	7.86
	Pseudocarcinus gigas (total)	3.47	5.49
	P. gigas (<MLL)	2.34	4.21
	P. gigas (>MLL)	1.13	1.28
	Majidae sp.	0.68	0.76
	Diogenidae sp.	0.18	0.23
	Paralithodes sp.	0.03	0.10
	Nephropidae sp.	0.53	0.93
	Unidentified sp. 1	0.25	0.25
	Unidentified sp. 2	0.10	0.10
Chondricthei		0.93	0.93
	Squalidae sp.	0.25	0.25
	Cephaloscyllium sp.	0.55	0.55
	Cephaloscyllium fasciatum	0.05	0.05
	Etmopterus sp.	0.08	0.08
Teleostei		1.36	1.39
	Moridae sp.	1.31	1.34
	Genypterus blacodes	0.05	0.05

11.3 APPENDIX 3: STAFF

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