Stock Assessment Report to PIRSA Fisheries

Blue Crab (*Portunus pelagicus*) Fishery 2005/06

D.R. Currie, G.E. Hooper and T.M. Ward

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EXECUTIVE SUMMARY

1. This fishery assessment report updates the 2006 report and assesses the current status of the Blue Crab Fishery (BCF) in South Australia.

2. The Total Allowable Commercial Catch (TACC) has not been harvested since it was implemented in 1996/97. However, the difference between the total catch and the TACC has declined progressively over the last decade. In 2005/06, >99% of the TACC was harvested.

3. The current TACC (626.8 t) is >50% greater than the mean catch for the 10-year period preceding implementation (411 t; 1986/87 – 1995/96).

4. Total catch in 2005/06 was among the highest on record (619.3 t), and 0.83% higher than in 2004/05. Total effort increased from 500 boat days in 1983/84 to ~3,500 boat days in 1995/96, but has since declined to <2,000 boat days in 2005/06.

5. Fishery-independent data suggest that the abundance of male, female, legal and undersized crabs increased in Spencer Gulf (SG) in 2005/06 following three consecutive seasons of decline.

6. Crab abundance has increased in Gulf St. Vincent (GSV) since 2004/05, with catch rates of males, females, legal and undersized crabs higher in 2005/06 than in 2004/05.

7. Data were available to assess the fishery's performance against 9 of the 11 Performance Indicators (PIs). Five of these nine PIs were above the target reference point.

8. Evidence available suggests that crab stocks in both SG and GSV are being harvested within sustainable limits.

9. The most pressing research need for the BCF is a review of the PIs to provide a better framework to assess stock status. In particular, the reference points for relative exploitation rate, pre-recruit abundance (% undersized) and sex ratio need to be replaced with more informative measures.

10. The PIs for SG and GSV should include: total catch; commercial Catch Per Unit Effort (CPUE) from logbook data with effort in potlifts; commercial recruitment (CPUE of undersized crabs from pot sampling data); survey CPUE (potlifts); and survey recruitment (CPUE of undersized crabs from pot sampling data).

11. Ecological PIs and reference points could be established for SG and GSV using by-catch data collected during the fishery-independent surveys and pot-sampling program.

12. Development of suitable reference points for SG and GSV will require a revision of the methods used to analyse changes in the catch rates of undersized and adult crabs in commercial fishing and fishery-independent surveys.

13. The current assessment framework for the fishery also needs to be revised. SG and GSV are separate sub-populations with a limited gene flow and should be assessed separately, with specific reference points for all PIs in each gulf.

1 INTRODUCTION

This report is the fourth version of a "living" document that is updated annually as part of SARDI Aquatic Sciences ongoing fishery assessment program for the South Australian Blue Crab Fishery (BCF). This assessment reports on the BCF to 31 July 2006, summarises the information from previous reports and presents analyses of the information collected via commercial logbook returns and fishery independent surveys. No data or information on blue swimmer crabs from the West Coast region are included.

1.1 HISTORY OF THE FISHERY

1.1.1 Commercial Fishery

Blue swimmer crabs (*Portunus pelagicus*) were first taken as by-catch in prawn and marine scale-fish fisheries in the 1970's. In 1986, the sale of blue swimmer crabs, as by-catch from the prawn fishery was prohibited. The South Australian Government issued twelve experimental fishing permits for blue swimmer crabs in the early 1980's, four in the West Coast, six in Spencer Gulf (SG), and two in Gulf St. Vincent (GSV). The West Coast fishery declined in 1986 and the four licence holders surrendered their entitlements. In June 1996, interim management arrangements for the Blue Crab Fishery (BCF) were established. An initial management strategy was implemented along with a core research program to support the development and maintenance of a sustainable and viable fishery.

In 1997, PIRSA Fisheries proposed a 3-year development strategy for the BCF. During this period, the capacity for expansion of the fishery was to be determined through research and further fishing. A limited entry fishery was created with access based on historical catches.

The fishery is based on the capture of a single species, *Portunus pelagicus,* although other crab species may also be landed. The fishery is presently divided into three fishing zones (West Coast, Spencer Gulf and Gulf St. Vincent, Figure 1), with a single quota for SG and GSV combined.

The South Australian BCF has three major stakeholders: the commercial pot fishery, the commercial marine scale fishery (MSF) and the recreational fishery. In 2005/06, there were 8 crab pot fishers with licences, five in SG and three in GSV. Eleven MSF fishers, ten in GSV and one in SG, are allocated blue crab quota.

Commercial pot fishers generally haul their gear every 24 hours using specifically designed crab pots covered with netting. Commercial marine scale-fish fishers use either hoop or drop nets hauled every 20-30 minutes. Crabs can be stored live in tanks, iced down uncooked or cooked before being landed in port. Most of the commercial catch is marketed in Australia, primarily in the Sydney and Melbourne fish markets. In 2004/05 the commercial landed value of blue crabs in South Australia was $3.59 million (Knight *et al*, 2006).

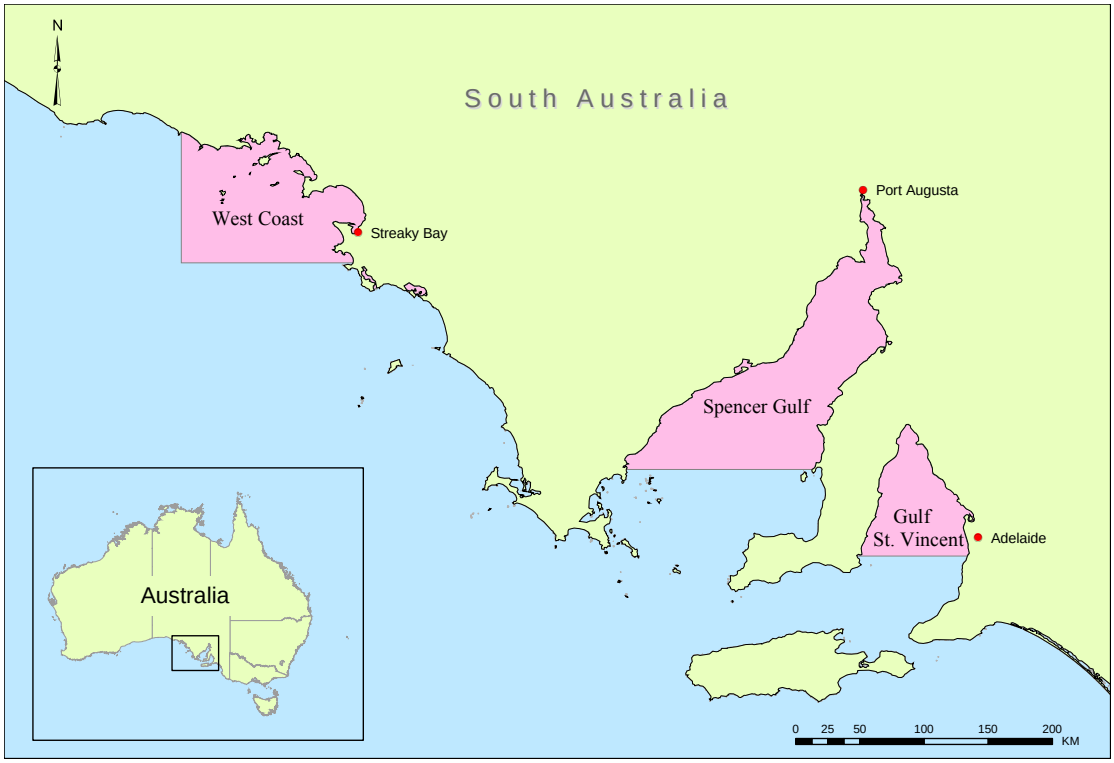


Figure 1. Map showing the locations of the three main blue crab fishing zones in South Australia.

Commercial quantities of blue crabs are also taken from bays on the west coast of South Australia (Figure 1), but are included as part of the MSF. In 2005/06, the landed catch from the West Coast fishery was 29.3 t from 474 boat days, with a catch per unit effort (CPUE) of 61.7 kg/day. This equates to a 12.0 t (69%) increase in catch, a 234 day (98%) increase in effort, and a 10.4 kg/day (14%) decrease in CPUE from the 2004/05 fishing season.

1.1.2 Recreational Fishery

There is no regular assessment of the recreational harvest of blue swimmer crabs in South Australia. McGlennon and Kinloch (1997) estimated a total catch of 161.2 t per year, of which 115.8 t was taken in GSV and 45.4 t in SG. Thus, the recreational catch was estimated to be 32.9% in GSV, 10.8% in SG and 20% of the overall TACC. This estimate does not include the recreational shore-based fishery, which is considered to be significant.

More recently, a National Recreational and Indigenous Fishing Survey (Henry and Lyle, 2003) was conducted between May 2000 and April 2001. The estimated annual catch taken by recreational fishers during this period for South Australia was 389.8 t. A further 31.7% of the total catch was released after capture (Anon, 2003). The release rate is based upon the crabs that were discarded under the legal size limit or that were caught when the bag limit was exceeded. This indicates that the recreational harvest was 37.5% of the total catch during 2000/2001.

1.2 MANAGEMENT

1.2.1 Management Tools

The fishery is managed under the *Fisheries Act 1982*, the *Fisheries (Scheme of Management - Blue Crab Fishery) Regulations 1998*, and the *Fisheries (Scheme of Management - Marine Scale Fisheries) Regulations 2006*. The minimum legal size is 110 mm in carapace width (measured at the anterior base of the first spine). No ovigerous females may be retained.

The commercial pot fishers fish exclusively for blue crabs, whereas the marine scale-fish fishers may also target other species pursuant to their MSF licences. The commercial fishery may only take crabs from the GSV and SG. The commercial fishery is further regulated by gear restrictions and seasonal closures from December to February in SG, and November to January in GSV.

In addition, output controls (catch quotas) were imposed on the BCF by means of a Total Allowable Commercial Catch (TACC). The TACC was distributed as quota to individual operators, with different levels being allocated for pot fishers and marine scale-fish fishers. The TACC was initially set by PIRSA at 520 t for the 1996/97 fishing season. Each year thereafter, the BCF Management Committee (BCFMC) has provided advice to the Director of Fisheries in recommending a TACC. In 2005/06, the TACC was 626.8 t.

The recreational fishery is subject to a daily bag limit of 40 blue crabs and sand crabs combined per person per day. When fishing from a boat, the personal bag limit applies up to a total of three people, after which a boat limit of 120 blue crabs and sand crabs combined per day applies.

1.2.2 Management Objectives

The primary objectives for the BCF are provided in the Management Plan and are:

- Ensure sustainable harvests from the blue crab resource.
- Ensure equitable allocation of the blue crab resource to the commercial and recreational sectors.
- Provide efficient and cost effective management of the fishery.
- Provide for secure access to the resource for each sector.
- Minimise the impact of blue crab fishing on the environment.
- Provide society with a return from the blue swimmer crab resource.

1.2.3 Management Strategies

To ensure a robust assessment of the fishery, performance is measured annually against the key fishery indicators defined in the management plan (Table 1).

1.2.4 Independent Research Review

Following the independent research review of the BCF by Scandol and Kennelly (2001), a set of indicators was developed as a management tool using catch and effort information recorded in commercial logbooks as well as data collected during fishery independent surveys (Table 2).

Table 1. Key performance indicators for the BCF

Indicator	Interim Target Reference	Interim Limit Reference
Catch	TACC	80% of TACC
Relative exploitation rate		
Gulf St Vincent (% of 1994 level)	50	100
Spencer Gulf (% of 1990 level)	40	80
Pre-recruit (as % under-size in June and July)		
Gulf St Vincent	10	5
Spencer Gulf	30	15
Sex Ratio (% female in June and July)	30	15

Table 2. Likely response of key indices to recruitment indicators for the BCF.

⬆ increase, ⬆⬆ clear increase, ⬇decrease, ⬇⬇clear decrease, ⭘ no signal							
	Size Structure		**CPUE**		**Sex Ratio**		**Catch**
	Pre-recruit index	Mean Size	Fishery	Survey	Males	Females	
Decrease in recruitment	⬇⬇	⬆⬆	⬇	⬇⬇	⬇	⬆	⭘
Constant recruitment	⭘	⭘	⭘	⭘	⭘	⭘	⭘
Increase in recruitment	⬆⬆	⬇	⬆	⬆⬆	⭘	⭘	⭘

1.3 BIOLOGY OF THE BLUE SWIMMER CRAB

1.3.1 Taxonomy

The blue swimmer crab (*Portunus pelagicus,* Linnaeus 1766) is a true crab (Brachyura) belonging to the family Portunidae.

1.3.2 Description

The blue swimmer crab has five pairs of legs. The first pair are chelae or claws, the following three pairs are walking legs where the last pair of legs are modified as swimming paddles. The carapace is rough in texture, broad and has a prominent projection/spine on each side. Blue swimmer crabs are active swimmers, but during inactivity they bury in the sediment, with only eyes, antennae and gill chamber openings uncovered. Males are blue and have larger claws than females, which are green-brown in colour (Figure 2). A detailed description of this species is provided by Stephenson (1972).

Figure 2. Male (top) and female (bottom) blue swimmer crabs *Portunus pelagicus* (L.).

1.3.3 Distribution

Portunus pelagicus is distributed throughout the coastal waters of the tropical regions of the western Indian Ocean and the Eastern Pacific (Kailola *et al*., 1993); they are adapted to a life in warmer waters. In the relatively colder, temperate parts of Australia, the life cycle has evolved to complete growth and reproduction during the warmer part of the year when water temperatures are elevated to those similar to the tropical regions. For the rest of the year, blue crabs withstand the relatively lower temperatures in the southern Australian environment by being less active.

P. pelagicus occurs in a wide range of algal and seagrass habitats and on both sandy and muddy substrata, from the intertidal zone to at least fifty metres of depth (Williams, 1982; Edgar, 1990). In coastal waters, smaller crabs are found in shallow waters, while adults are found in comparatively deeper waters. Juvenile crabs occur in mangrove creeks and mud flats for eight to twelve months by which time they attain a

size of 80 to 100 mm in carapace width. Within South Australia, there is a distinct seasonal pattern of adult crab movements into shallow inshore waters during the warmer months of September to April and to deeper offshore waters during the colder months of May to August (Smith, 1982).

1.3.4 Stock Structure

Using allozyme markers, Bryars and Adams (1999) determined that the populations of *P. pelagicus* within SG, GSV and the West Coast regions of South Australia, represented separate sub-populations with a limited gene flow. They also found that inter-regional larval dispersal is restricted, and each sub-population must be dependent on its own larval supply.

Chaplin *et al.* (2001), using microsatellite markers, found that the assemblages of *P. pelagicus* in different embayments in South Australia often constitute genetically different meta-populations. The level of migration between these populations is probably limited and the dynamics of a population, in a given embayment, is likely to be determined by local factors.

1.3.5 Reproductive Cycle

Male and female *P. pelagicus* generally reach sexual maturity at a size of 70 to 90 mm in carapace width, when they are approximately one year old. The male and female will form a pre-corpula for eight to ten days before ecdysis of the female. After female ecdysis, when the female is soft-shelled, copulation takes place over a six to eight hour period (Meagher, 1971).

The spawning season lasts for 3 to 4 months over the summer/autumn period. The duration of the growing season varies among individuals because those settling in early summer have a longer growing season than those settling in mid-to-late summer. In South Australian waters, crabs close to the minimum legal size (110 mm) are approximately 14 to 18 months old, sexually mature, and females have produced at least two batches of eggs within one season (Kumar *et al*., 2000, 2003).

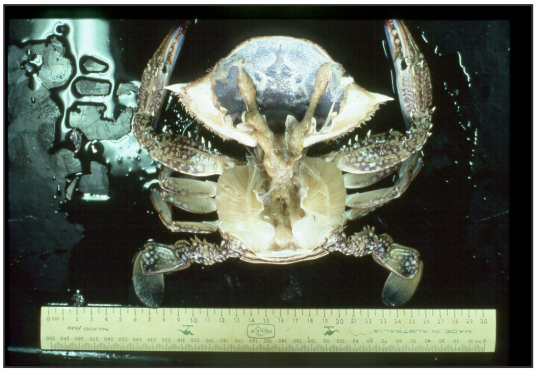
1.3.6 Ovarian Development

Development of the ovaries in females appears to be triggered by rising water temperatures in spring. During copulation, the spermatophore is transferred to the female spermatheca. The eggs are subsequently fertilised on extrusion (Smith, 1982). Van Engel (1958) found that the sperm in the spematheca of female *Callinectes sapidus* could remain viable for at least 12 months. This is likely to also be the case for *P. pelagicus*. Egg extrusion is independent of the timing of copulation.

The ovarian development can be classified by five visually distinguishable stages (see Sumpton *et al*., 1994 and Figure 3):

Stage 1(S1): Gonad immature, white or translucent
Stage 2(S2): Gonad maturing, light yellow/orange, not extending into hepatic region
Stage 3(S3): Gonad maturing, yellow/orange not extending into hepatic region
Stage 4(S4): Gonad mature, dark yellow/orange extending into hepatic region
Stage 5(S5): Ovigerus, female bearing fully matured eggs (pale to dark yellow eggs) externally.

The fourth stage of ovarian development was observed in late October to November in conjunction with rising seawater temperatures. Kumar *et al*. (2000) demonstrated that during November, more than 40% of crabs were in advanced Stage 4, and 80% caught were between Stages 3-4. Figure 4 shows the seasonal ovarian developmental stages in the blue swimmer crab.

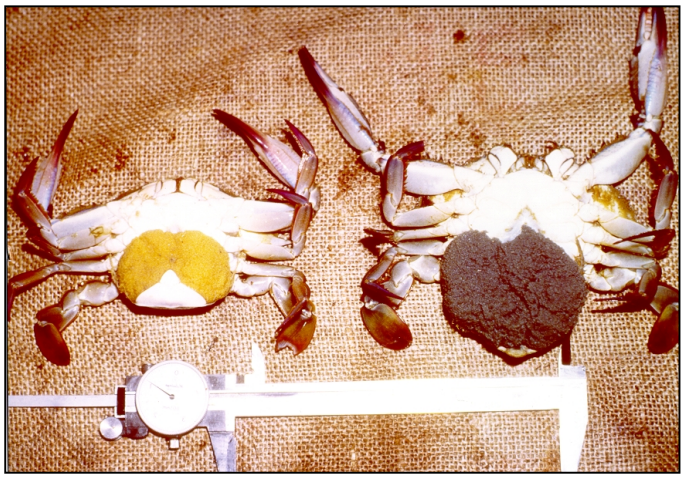


Stage 1

Stage 2

Stage 3

Stage 4



Stage 5

Figure 3. Ovarian stages of the blue swimmer crab (from Kumar *et al.*, 2000).

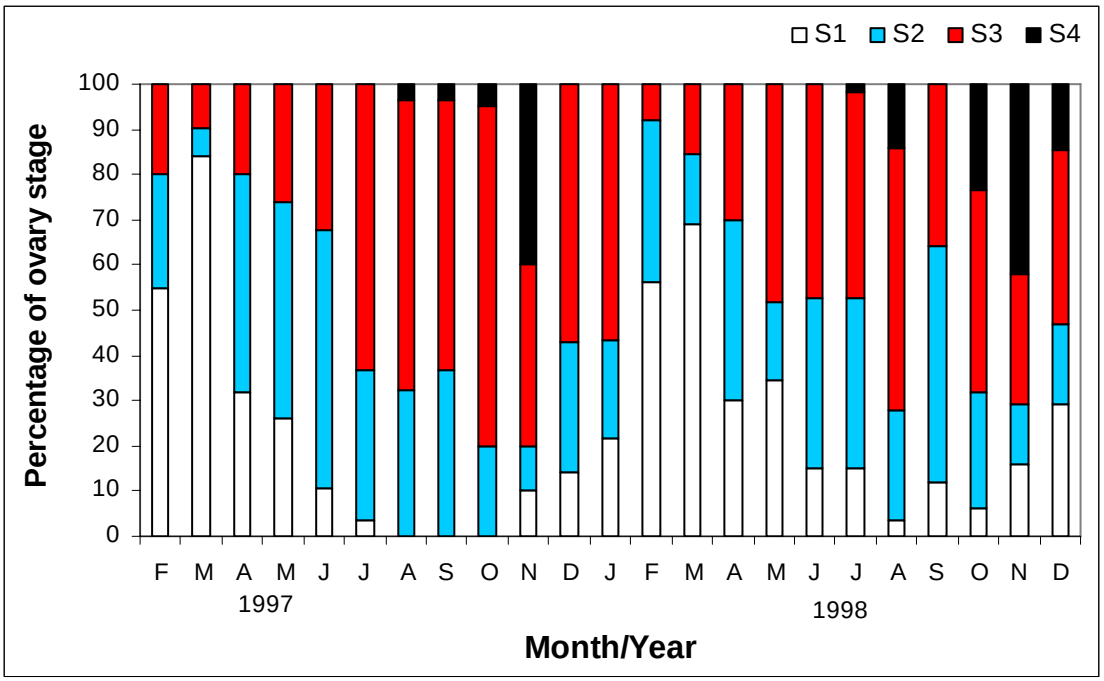


Figure 4. Ovarian development of the blue swimmer crab samples collected in South Australia during 1997 and 1998. Colour codes for the various reproductive stages shown above (from Kumar *et al.*, 2000).

1.3.7 Ovigerous Females

In tropical waters, female blue swimmer crabs are found to carry eggs throughout the year. However, seasonal variation in the number of egg-bearing females can be observed (see Kumar *et al.,* 2000). During embryonic development (Stage 5), the colour of the eggs changes from yellow to a dark grey (Figure 3).

In South Australian waters, egg-bearing females have been observed throughout the year, however in late spring there is a substantial increase in the proportion of berried females. Data from the commercial fishery logbooks during season 2001/2002 shows the proportion of berried females caught in GSV from July 1997 to June 2005 (Figure 5). In SG, a larger proportion of berried females appeared in the catch slightly later than in GSV. This pattern was consistent between years.

1.3.8 Fecundity

Fecundity is calculated as the number of eggs carried externally by the female. Kumar *et al.* (2003) found that the fecundity of female crabs is size-dependent and increases up to a carapace width of 134 mm and decreases thereafter. Fecundity increased by 83.9% with an increase of carapace width from 105 mm to 125 mm, implying that a single large female could produce as many eggs as two small females. Kumar *et al.* (2000) found that a female blue crab can produce between 650,000 to 1,760,000 eggs per spawning.

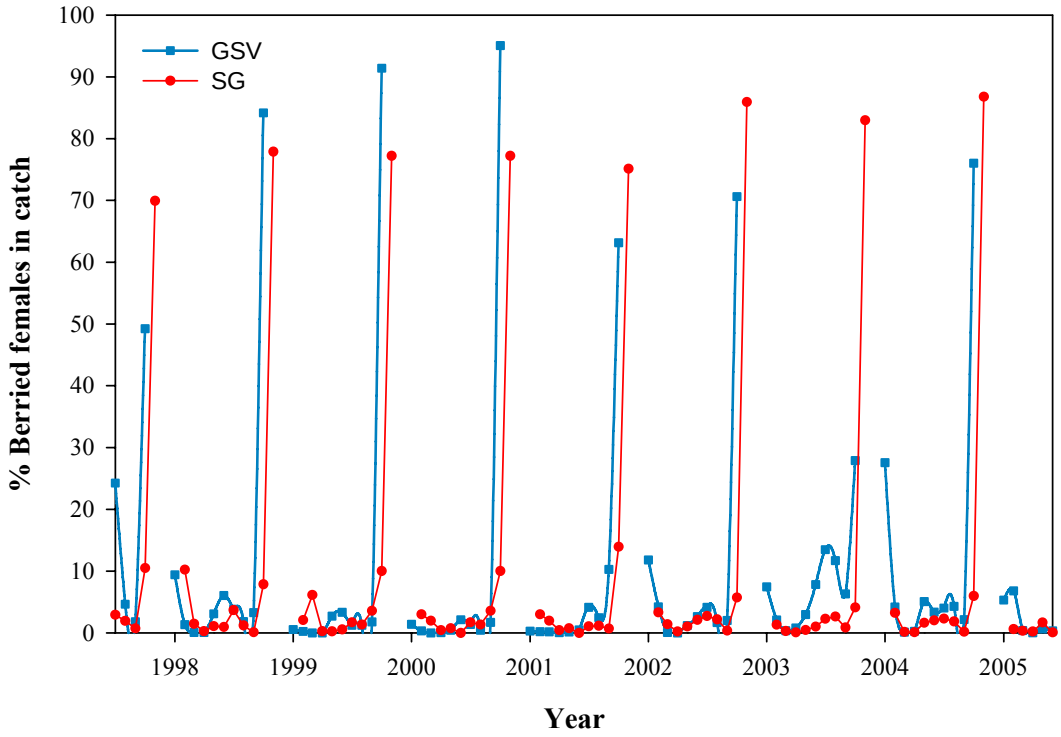


Figure 5. Relative abundance of berried females in commercial catches from 1997/98 to 2005/06. GSV=Gulf St Vincent; SG=Spencer Gulf.

1.3.9 Multiple Spawning

P. pelagicus can spawn more than one batch of eggs in a season. Eight to ten days after spawning the first batch of eggs, the female may ovulate and fertilise a second batch (Meagher, 1971). On examination of berried females, some carried developing oocytes at stages 2 and 3 in the ovary whilst also carrying an external egg mass (Kumar *et al*., 2003). While blue crabs are capable of producing more than one batch of eggs in a season, successive ovulations do not always occur (Meagher, 1971).

1.3.10 Recruitment

Recruitment to the fishery is defined as those crabs entering the fishery, which are susceptible to being caught by the fishing gear. Recruits have a carapace width (measured from the posterior base of the spine) of less than 110 mm. Recruitment to the fishery has been found to take place during the winter months of the year, i.e. June and July (Kumar *et al*., 2000).

1.3.11 Parasites

The parasites of some decapod crustaceans are known to cause sterilisation of their host, and can therefore have an important impact of the population of infested species (Gaddes and Sumpton, 2004). The barnacle *Sacculina granifera* is a known parasitic castrator of *P. pelagicus*, and can have a marked effect on gonad development and growth in Australian populations (Shields and Wood, 1993). Levels of parasitism and in South Australian blue crab populations have yet to be examined.

1.4 PREVIOUS RELATED RESEARCH

The first report on the South Australian blue crab fishery was published in 1987 by the South Australian Department of Fisheries (Grove-Jones, 1987). In 1994, the blue crab fishery was reviewed (Baker and Kumar, 1994). SARDI completed the first stock assessment report for the fishery in 1998, and has since provided annual reports (Kumar, *et al.,* 1998; Kumar, *et al.,* 1999a; Kumar *et al.,* 1999b; Boxshall, *et al.,* 2000; Boxshall, *et al.,* 2001; Hooper and Svane, 2003; Svane and Hooper, 2004; Currie and Hooper, 2006). The Proceedings of the First National Workshop on Blue Swimmer Crab were published in 1997 (Kumar *et al.,* 1997).

Initiated by the Fisheries Research and Development Corporation (FRDC), the Centre of Research on Ecological Impacts of Coastal Cities at the University of Sydney completed an independent review into the research needs of the fishery in February 2001. This report, which was done in consultation with stakeholders, includes comments on the sampling issues for Ecological Sustainable Development (ESD) outcomes, and provides a research review, short-term monitoring advice, and recommendations for a 5-year research program (Scandol and Kennelly, 2001).

A more recent FRDC report (Svane and Cheshire, 2005), reviewed the biology of blue crabs and the key biological determinants for the fishery. This report also provides information on the geographical patterns of post-settlement in juvenile crabs.

2 FISHERY STATISTICS

2.1 INTRODUCTION

SARDI maintains a comprehensive catch and effort database for the BCF using data collected from the compulsory fishing logbook system. To simplify reporting, each gulf is divided into a series of administrative fishery blocks (Appendix 1 and 2). Data are collected by block and include information on depth, effort, catch weight and catch abundance. The logbook system is also used to collect biological data, including the number of undersized crabs, berried crabs and the sex ratio of the catch. These data were first obtained in the 1996/97 fishing season, historical data was recorded into the GARFIS catch and effort database of the South Australian Fisheries Department from 1983/84.

The data presented in this report are necessarily limited to ensure the confidentiality for individual fishers (*Fisheries Act 1982*). This confidentiality clause prevents the publication of fishery data at scales less than 5 fishers, unless express written permission has been obtained.

Since the implementation of the TACC in the South Australian BCF in 1996/97, there has been a transfer of commercial effort from the MSF to the Pot fishery sectors. Figure 6 shows the number of licence holders in the fishery from 1996/97 to 2005/06, indicating an increase in the number of pot licences at the expense of a large number of MSF licences. Since 2002/03, numbers of licence holders in the Pot fishery have remained unchanged (8), while MSF licence holders have dropped by more than 25% from 15 to 11.

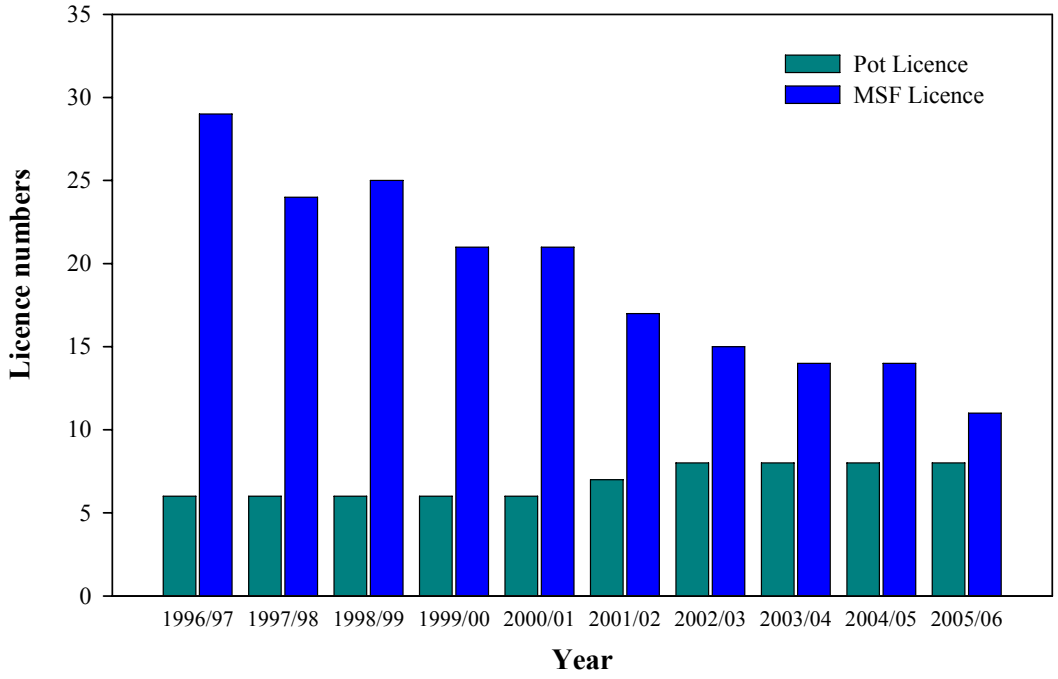


Figure 6. Number of licence holders for both commercial sectors (Pot, MSF) of the blue crab fishery.

2.2 TOTAL CATCH AND EFFORT

2.2.1 Historical Patterns

2.2.1.1 Catch

Blue crabs were first recorded as landed catch in the GARFIS records for 1983/84, when 26.9 t of crabs were harvested from 530 boat days (Figures 7 and 8). At this time, the majority of the fishing fleet consisted of MSF licence holders. Over the following twelve years catches progressively increased and reached a historical high of 651.26 t in 1995/96. The introduction of quotas in the following season, promoted a marked 29% reduction in catch with 462.39 t being taken during 1996/97. Since then catches have gradually increased each season.

In 2005/06, the TACC for the BCF was 626.8 t, the same TACC as for the previous five fishing seasons. The landed catch in 2005/06 from both commercial sectors was 619.3 t (98.81% of the TACC), with 96.94% taken by the pot fishery and 3.06% by the MSF. The total catch represented a 0.83% increase in catch from 2004/05. The TACC has not been harvested since implementation (1996/97), but in recent years catches have been close to target levels (Figure 7).

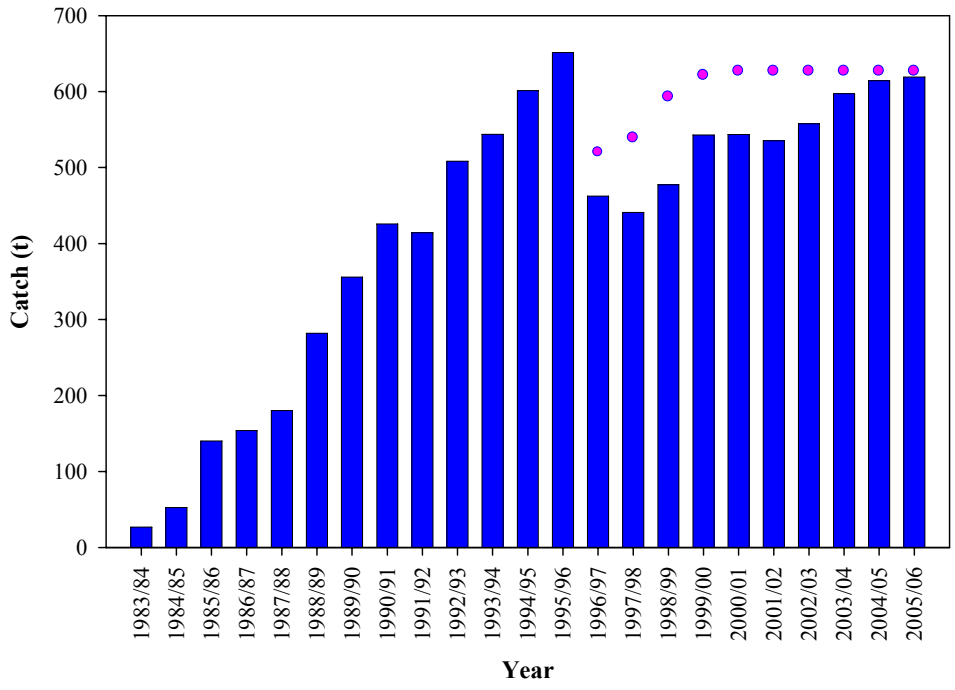


Figure 7. Total commercial catch (vertical bars) and TACC (pink dots) for the BCF from 1983/84 to 2005/06.

2.2.1.2 Effort

Figure 8 shows the effort (boat days) in the BCF since 1983/84. In 1996/97, effort was 2,213 boat days, rising to a maximum (post TACC) of 2,458 boat days in 1999/00. Since then effort has decreased, and in 2005/06 effort was 1,852 days (142 days lower than the 1994 boat days recorded during 2004/05).

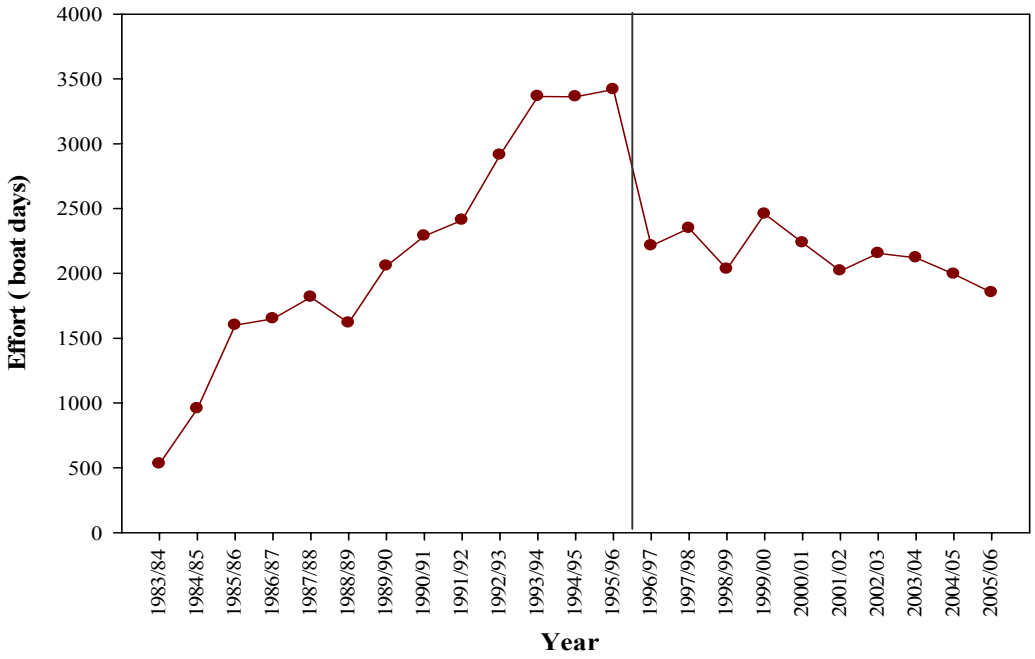


Figure 8. Total commercial effort (red line) for the BCF from 1983/84 to 2005/06. The introduction of TACC is indicated by a vertical line.

2.3 CATCH, EFFORT AND CPUE IN THE POT FISHERY SECTOR

2.3.1 Annual Patterns

2.3.1.1 Catch

The pot fishery in 2005/06 was allocated 603.19 t of the TACC (source: PIRSA Fisheries) of which 600.35 t was landed, a 2.77% increase compared to 2004/05, and the highest total catch (99.53% of the TACC) since the implementation of quota in 1996/97. The catch in this sector has steadily increased since 1997/98 when 397.12 t was landed (Figure 9).

2.3.1.2 Effort

During the first 6 years following the implementation of quota, effort (boat days) remained relatively constant with an average of 1,517 days fished (Figure 9). In 2002/03, two new pot fishing licences were issued and effort increased. Between 2004/05 and 2005/06, effort decreased from 1,757 to 1,742 boat days.

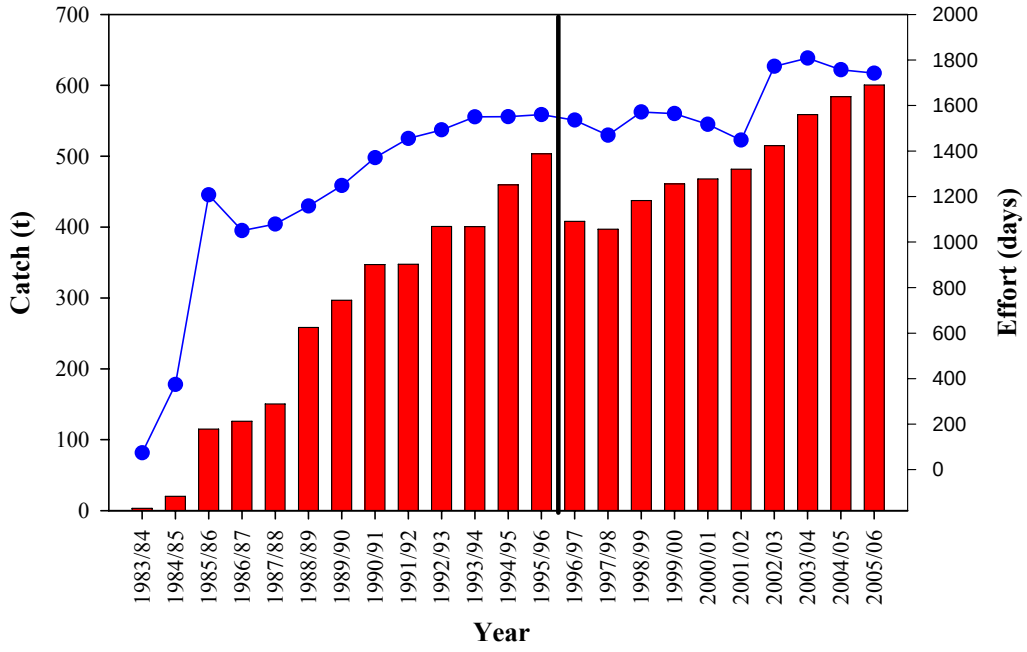


Figure 9. Historical crab catch (red vertical bars) and fishing effort (blue line) for the commercial pot fishery from 1983/84 to 2005/06. The black vertical line indicates the time when quota was implemented.

The number of potlifts in 1997/98 was 151,899. Since then, potting effort has gradually increased and in 2003/04 there were 201,979 potlifts. By exception, effort declined in 2004/05 to 187,706 potlifts. Potting effort has subsequently increased and in 2005/06 reached record high levels of 210,360 potlifts.

2.3.1.3 $CPUE_L$

The catch rate for the pot fishery was determined as catch per pot lift:

$$CPUE_L = \frac{Catch(kg)}{No.\ Potlifts}$$

Figure 10 provides a time-series of $CPUE_L$ since the introduction of quota. This shows that since 1996/97, $CPUE_L$ has varied little (range: 2.53 - 3.08 kg/potlift). In the most recent fishing season (2005/06), $CPUE_L$ was 2.85 kg/potlift. This equates to a 5.9% decrease on the 2004/05 catch rate of 3.03 kg/potlift.

Figure 10. Estimated CPUE$_L$ (kg/potlift) in the commercial pot fishery since 1997/98.

2.3.2 Seasonal Patterns

2.3.2.1 Catch

Fishing is conducted throughout the year except during the closed season in GSV (1st November - 15th January) and SG (22nd December - 19th February). Since 2004/05, the BCFMC has approved modifications in the SG closed season to take advantage of expected higher market prices in the lead up to Christmas.

Catches are highly seasonal and are typically highest at the start of autumn (ie March) and lowest around the start of winter (ie June) (Figure 11). In March 2006, a combined weight of 79.67 t of blue crab was landed by the SG and GSV fisheries (more than 3 times greater than the 22.46 t landed during June of the same year).

2.3.2.2 Effort

Monthly potting effort has varied markedly in each fishing season since the introduction of quota (Figure 11). Despite the large variation, a consistent seasonal trend in effort is evident. Notably, fishing effort is high during autumn (March-May) and spring (September/October), but invariably lower during early winter (June) immediately prior to the commencement of the new quota season.

2.3.2.3 CPUE$_L$

Catch per unit lift also varies markedly between months in any given year, but again shows a consistent seasonal pattern (Figure 12). CPUE$_L$ is typically highest during February/March, after the summer closure, but gradually declines as the season progresses with the lowest values usually being recorded at the start of winter (June). CPUE$_L$ normally increases again during August/September then declines over the remaining months of the fishing season. Since 1997/98, CPUE$_L$ has generally ranged between 2-5 kg per potlift. In 2005/06, the CPUE$_L$ was lowest in October (1.9 kg per potlift) and highest in February (4.3 kg per potlift).

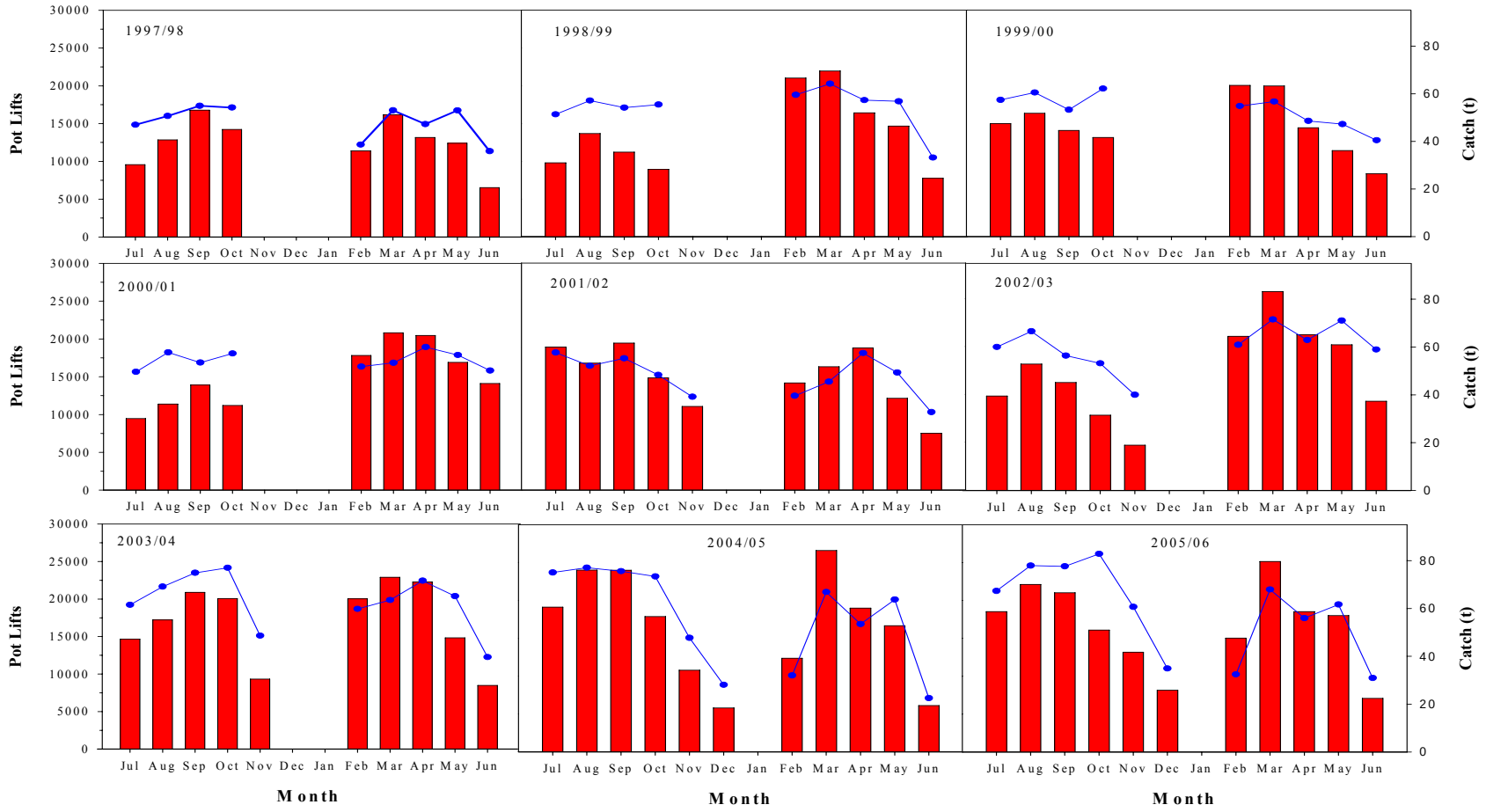


Figure 11. Monthly catch (vertical bars) and effort (blue line) for the commercial pot fishery 1997/98-2005/06. Data for November (prior to 2001) and January have been omitted for confidentiality reasons.

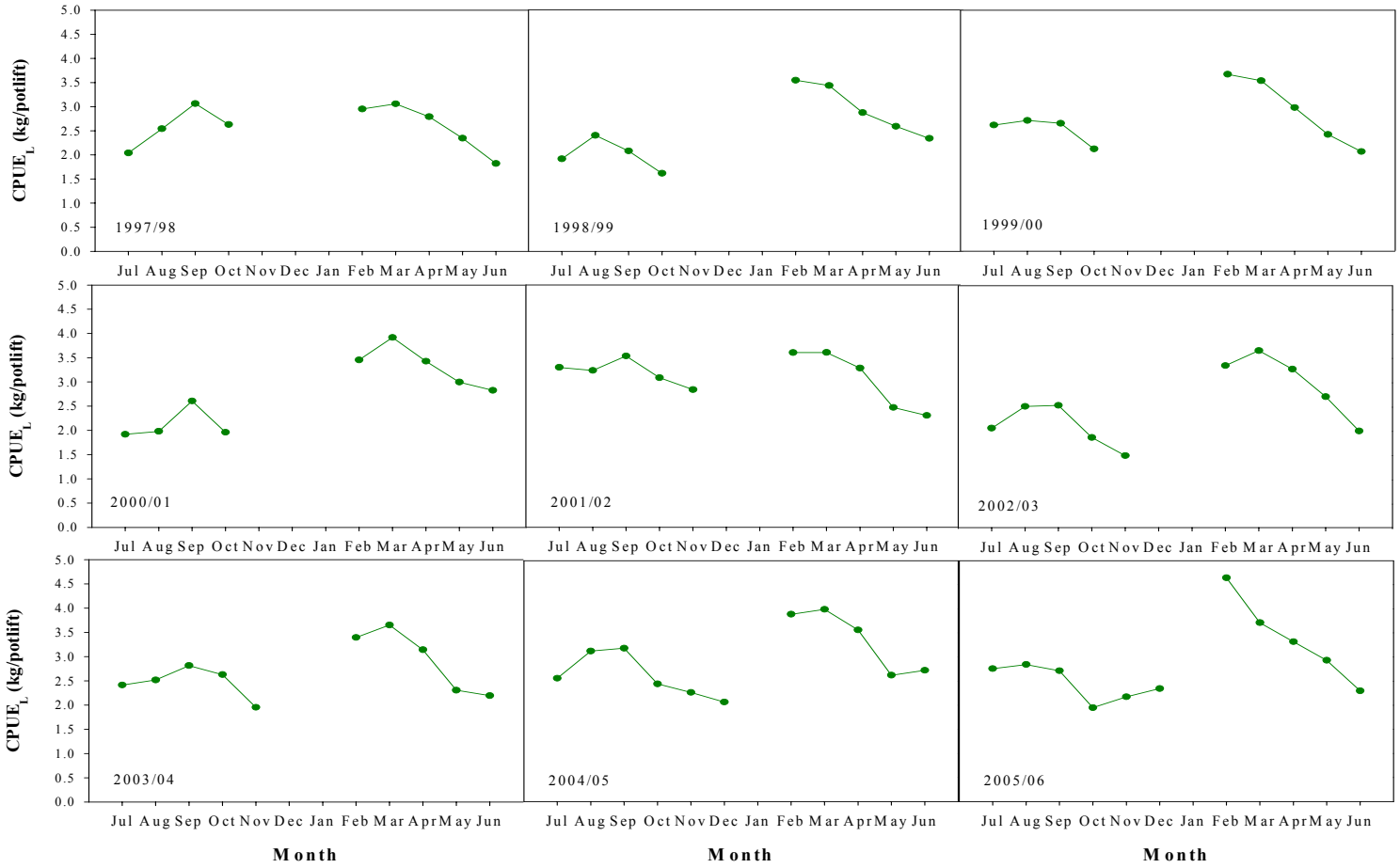


Figure 12. Monthly $CPUE_L$ for the commercial pot fishery 1997/98 to 2005/06. January data have been omitted for reasons of confidentiality.

2.4 CATCH, EFFORT AND CPUE IN THE MARINE SCALEFISH SECTOR

2.4.1 Annual Patterns

2.4.1.1 Catch

In 2005/06, the MSF sector was allocated 23.62 t of the TACC (source PIRSA Fisheries), a reduction of 6.46 t from the previous season. This sector harvested 18.98 t of crabs in 2005/06, representing 80.34% of the TACC. Crab catches by the MSF sector have fluctuated considerably since the implementation of the TACC in 1996/97 (18-79 t), and since 1999/00 catches have progressively declined (Figure 13).

2.4.1.2 Effort

Temporal trends in fishing effort for the MSF (boat days) have broadly mirrored catch (Figure 13). For example, during the period 1993/94-1995/96, when the annual catches were at record high levels annual effort peaked at >1800 boat days/year. Similarly, when low levels of catch were recorded, effort was also low. Since 1999/00, fishing effort in the MSF has been reduced by >85%. Such declines in effort can be largely attributed to recent reductions in the number of licensed fishers in the MSF.

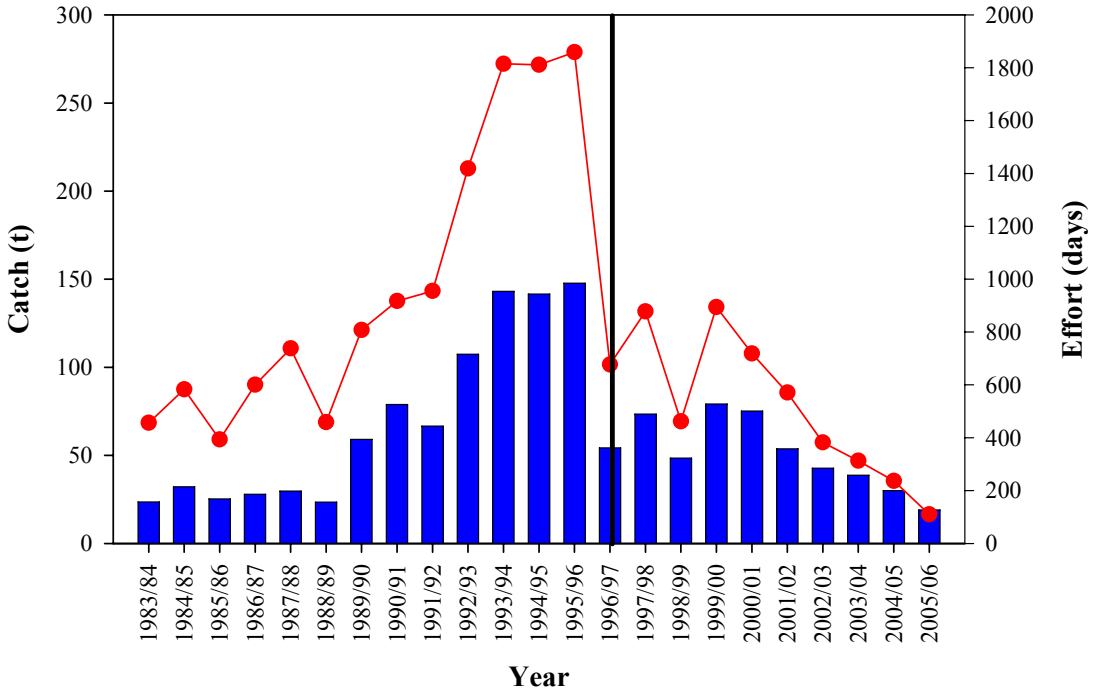


Figure 13. Annual crab catch (columns) and fishing effort (red line) for marine scale fishery from 1983/84 to 2005/06. Vertical black line indicates the year when the TACC was implemented.

2.4.1.3 $CPUE_D$

The catch rate for the MSF sector was determined as catch per boat day, as no information is available on the number of netlifts undertaken by this sector:

$$CPUE_D = \frac{Catch(kg)}{No.\ Boatdays}$$

A summary of $CPUE_D$ from 1983/84 to 2005/06 is provided in Figure 14. This indicates that $CPUE_D$ has gradually increased since 1983/84, and additionally shows that $CPUE_D$ reached record high levels during the most recent fishing season (2005/06). Catch rates for the 2005/06 season (172.52 kg/boat day) were approximately 36% higher than they were in the previous season (2004/05; 126.76 kg/boat day).

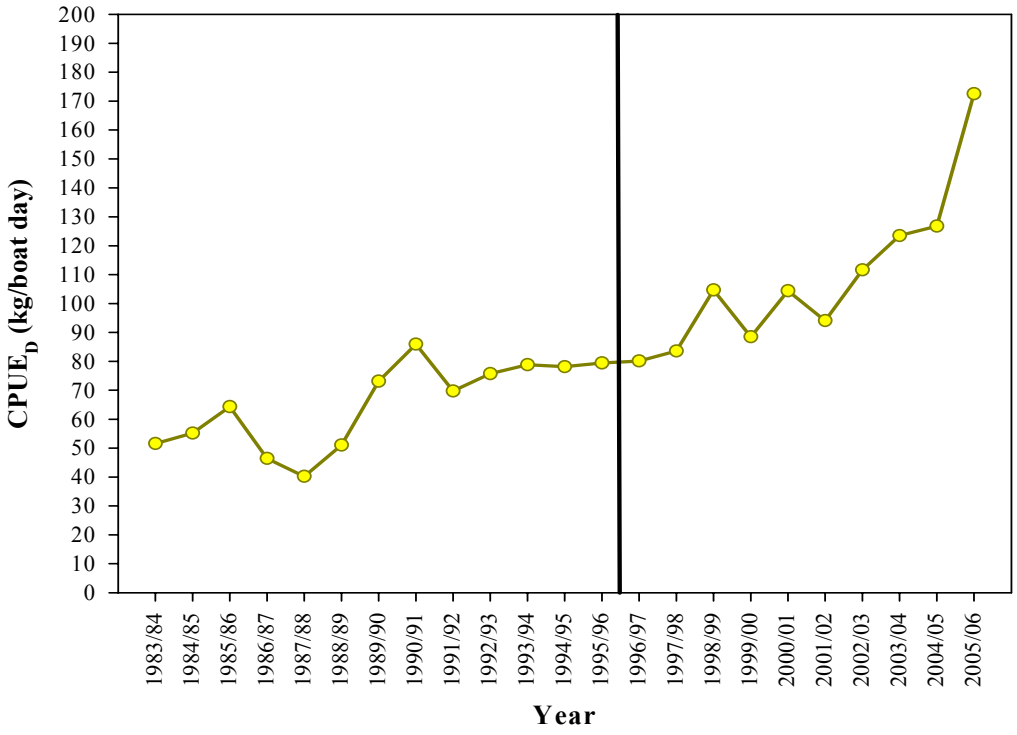


Figure 14. Estimated $CPUE_D$ in the marine scale fishery since 1983/84. Vertical black line indicates the year when TACC was introduced.

2.4.1.4 Catch by Gear type

The majority of the catch in 2005/06 was taken with either hoop nets or drop nets (99.68%). A small proportion was captured using a sinking mixed-mesh haul-net (0.18%), while the residual catch (0.13%) was harvested using a floating gar-mesh haul-net. These results were similar to those recorded during the preceding season (2004/05), when hoop/drop nets captured 99.71% of the catch, gill nets captured 0.27% of the catch and 0.02% were taken using sinking mixed-mesh haul-nets.

2.4.2 Seasonal Patterns

2.4.2.1 Catch

The monthly catch from July 2001 to June 2006 for the MSF sector is shown in Figure 15. These graphs show that the largest part of the catch in the MSF fishery was consistently landed at the end of the summer during the months of February and March. In 2005/06, 14.06 t of crab (74% of the total seasonal catch) was taken during these 2 months. This represented a 19% decline on the catch taken during the same two months in the previous year (19.51 t).

2.4.2.2 Effort

Seasonal patterns in fishing effort in the MSF closely follow patterns in catch (Figure 15). As for catch, fishing effort was highest during the months of February and March. In 2005/06, effort peaked at 39 boat days/month during March but declined to 3 boat days/month during June.

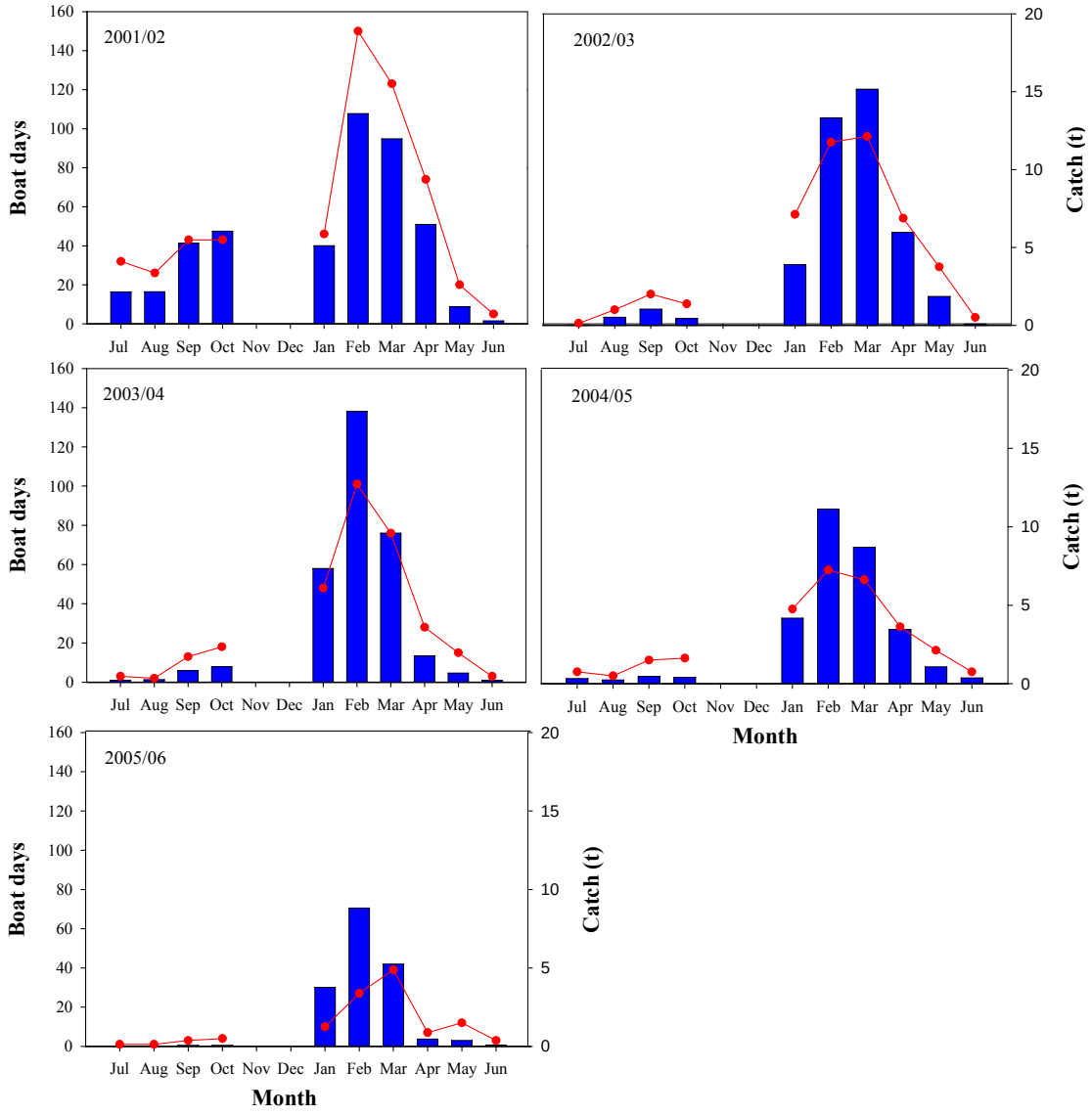


Figure 15. Monthly crab catch (blue columns) and fishing effort (red line) for the marine scale fishery from 2001/02 to 2005/06.

2.4.2.3 $CPUE_D$

Seasonal patterns in $CPUE_D$ are well defined over the period 2001/02 to 2005/06 (Figure 16). Specifically, $CPUE_D$ was highest during summer and early autumn, but gradually declined in the months leading up to and after this period. During 2005/06, catch rates reached record high values in January (376 kg/boat day). High catch rates (>130 kg/day) were also recorded during the months of February and March of the same year, but catch rates outside this period were low.

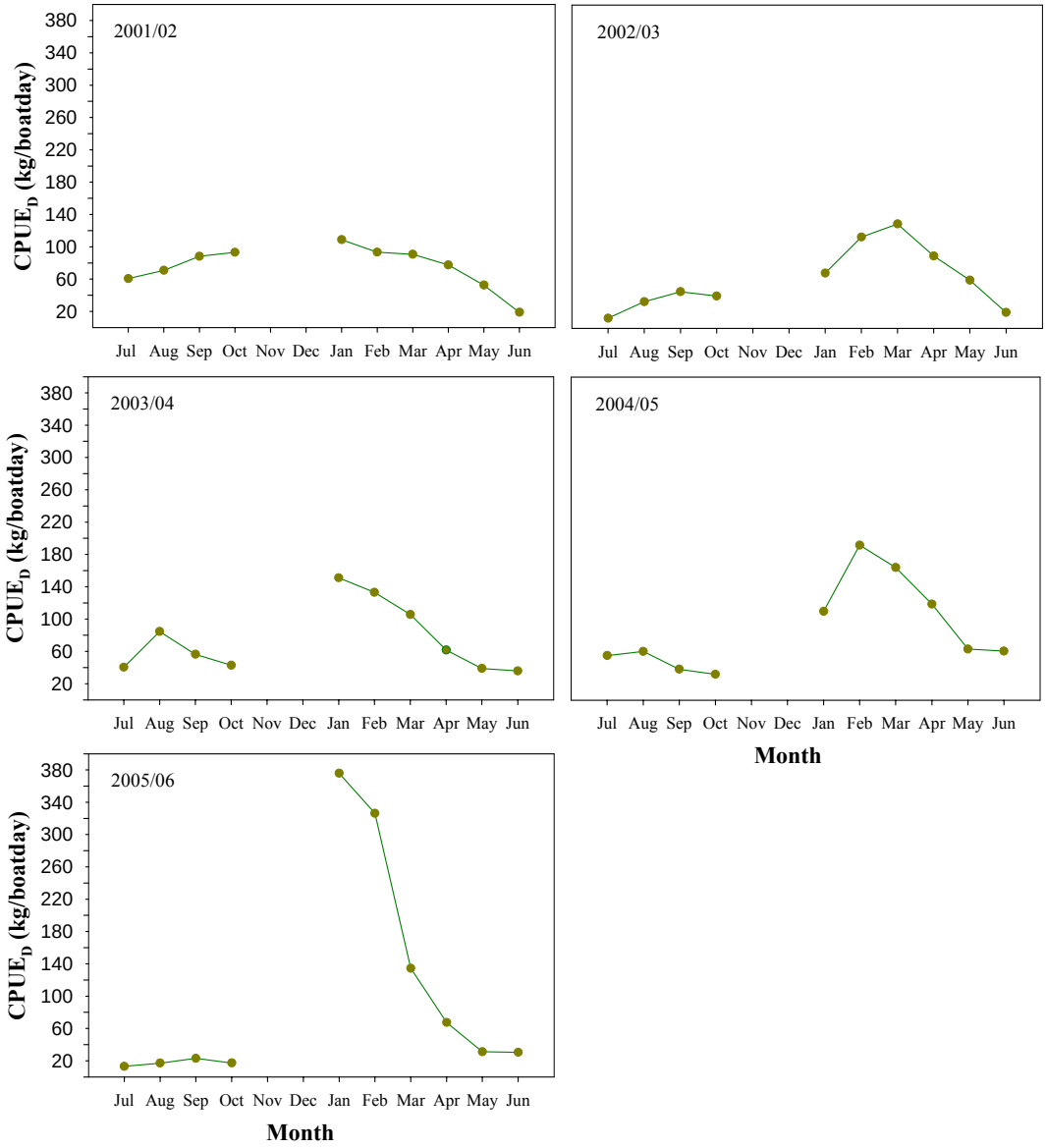


Figure 16. Monthly blue crab catch per unit effort ($CPUE_D$) for the marine scale fishery from 2001/02 to 2005/06.

3 FISHERY INDEPENDENT SURVEYS

3.1 INTRODUCTION

Fishery-independent surveys for the BCF have been conducted on an annual basis during June/July since 2002 (July 2002, July 2003, July 2004, June/July 2005, June 2006). The primary aim of the survey is to collect data on the spatial abundance and size composition of blue crabs in SG and GSV during winter, when juvenile crabs recruit to the fishery. This section of the report provides an assessment of spatial and temporal trends in crab size and abundance among the five surveys.

3.2 METHODS

3.2.1 Sampling

The survey area covered waters with depths ranging from 3 m to 22 m northwards of Adelaide in the GSV and northwards from Warbuton in the SG (Figure 17).

Commercial fishermen determined the sampling sites based on their fishing experience and their historical catch and effort data. From these recommendations, four sites were selected in each fishing block to be surveyed. In SG, the survey blocks were 3, 4, 6, 7, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 30, 31, 33, 36, 37, 42 (total 27 blocks) with 1080 pot lifts. In GSV, the survey blocks were 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 23, 26, 27, 33, 34, 35, 89 (total 23 blocks) with 920 pot lifts. For ease of interpretation and consistency with previous reports (Svane and Hooper, 2004; Currie and Hooper, 2006), the data from each block were grouped into three areas for each gulf. In SG, blocks 1-12 constitute the "North" area, blocks 13-26 the "Centre" area, and the remaining blocks the "South" area. In GSV, blocks 1-11 plus 37, 38, 39 and 89 constitute the "North" area, blocks 12-21 plus 36, 40 and 41 comprise the "Centre" area, and the remaining blocks the "South" area.

At each site, commercial crab pots and research pots were set and hauled on a daily basis. Commercial pots (Figure 18) have a diameter of 1.2-1.4 m, a height of 50 cm, and are covered with a 90 mm mesh. Research pots (Figure 19), used specifically for surveys, have a diameter of 1.4 m, a height of 50 cm, and a smaller mesh covering of 55 mm.

At each survey site, five sets of gear were deployed along a line, each comprising one commercial and one research pot. Each pot was separated by 40 m of rope and each set of gear spaced 150 m apart. Pots were baited with fresh Australian salmon or striped trumpeter, and were hauled at dawn.

A global positioning system (GPS) was used to locate the gear, and depth sounder readings were recorded for each site. Blue crabs were measured using Vernier callipers (carapace width), and details of their sex (male or female) and their condition (dead, soft, berried) recorded. The abundance of any by-catch species collected during the survey was also recorded.

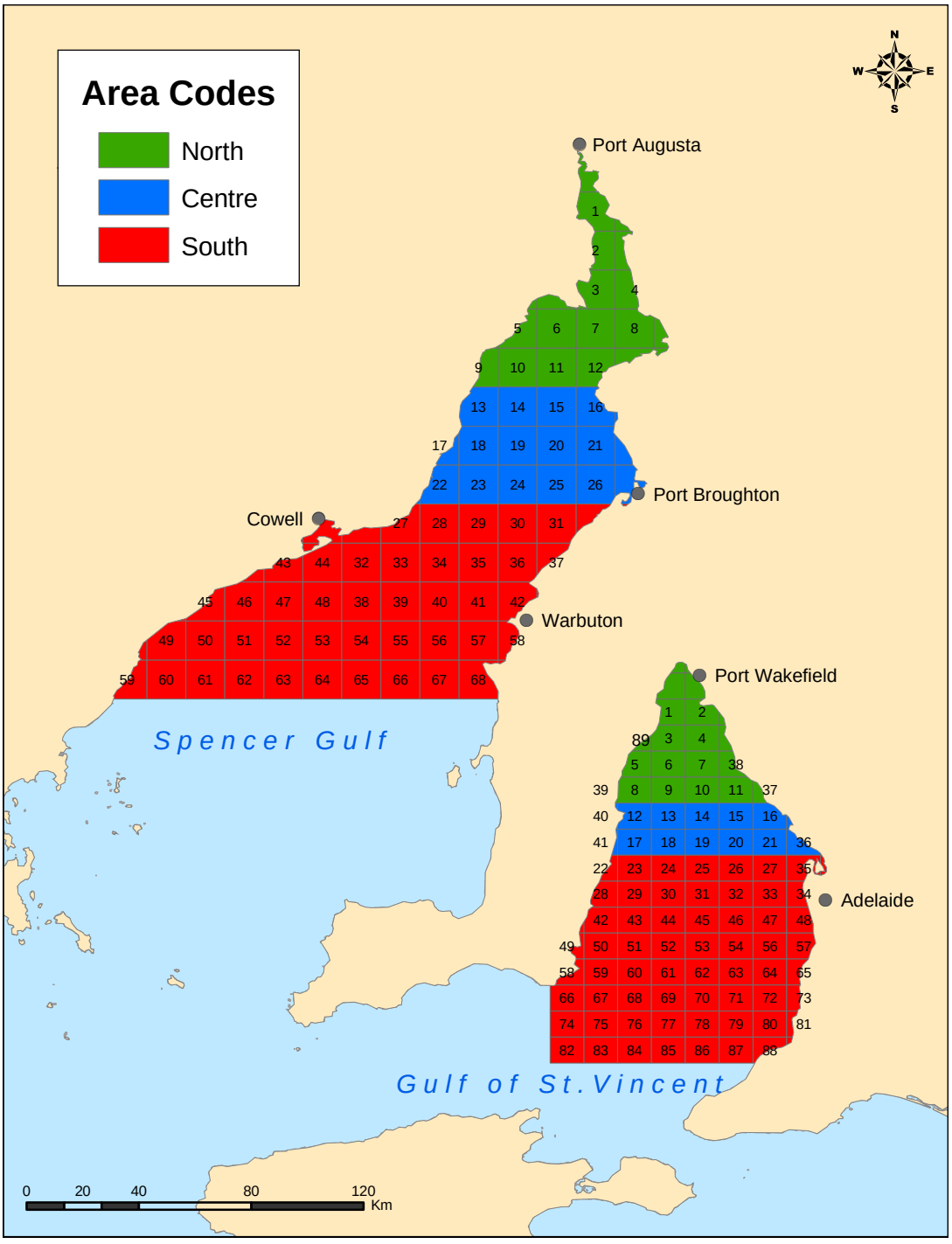


Figure 17. Commercial fishing blocks for the blue crab fishery in Spencer Gulf and Gulf St. Vincent. Each Gulf is sub-divided here into three areas (North, Centre, South) for comparative analyses.

Figure 18. Commercial crab pot used by the fishery with a mesh size of 90 mm.

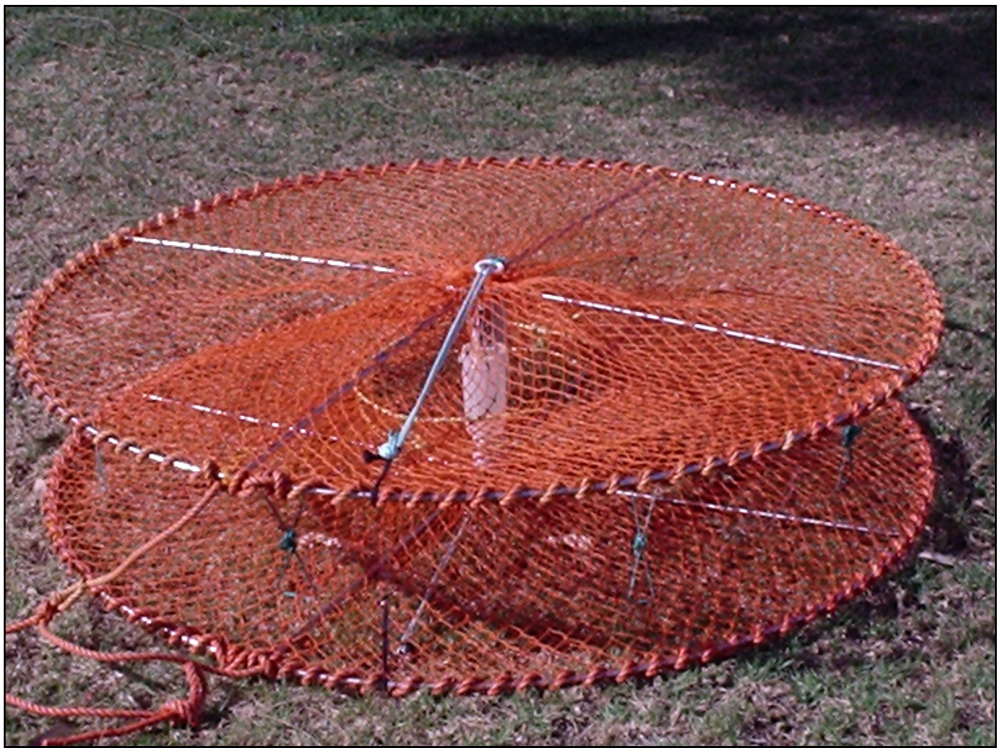


Figure 19. Research crab pot with a mesh size of 55 mm.

3.2.2 Statistical Analysis

The purpose of the statistical analyses was to compare the abundance, size and sex distributions between years and areas, and therein provide information relevant to ongoing assessment of blue crab stocks and the allocation of annual quotas. Two-way fixed factor analyses of variance (ANOVA) was used to test for differences in crab number and size (mm CW) between survey years (2002, 2003, 2004, 2005, 2006) and areas (North, Centre, South) in each gulf (SG, GSV) separately. Homogeneity of variance was examined using Cochran's test and heterogeneity removed by $\log_{10}(n+1)$ and $1/(n+1)$ transformations. Equality of variance was not always achievable, however ANOVA is generally considered robust in relation to this requirement. Post-hoc Student-Newman-Keuls (SNK) multiple comparison tests were employed to identify those areas and sampling years that differed significantly. Power analyses were also undertaken to determine the statistical power associated with each test performed. For the purposes of these analyses, the probability of committing a Type I error was set at 5% ($\alpha = 0.05$). A geographic information system (GIS) was additionally employed to characterise and display spatial and temporal trends in catch.

3.3 RESULTS

3.3.1 Recruitment and Sex Distribution

The proportion and numbers of undersized crabs (<110 mm) caught during the five fishery-independent surveys are shown in Table 3. As expected, the research pots, due to their smaller mesh size, caught larger numbers of undersized (recruits) crabs than commercial pots. Despite such differences, temporal trends in the proportion of undersized crabs taken in research pots have broadly paralleled undersized catches from commercial pots since the start of the survey. In the GSV, the proportion of undersized crabs taken appears to have declined and subsequently recovered over the period 2002 to 2006. Over the same period, the proportion of undersized crabs taken in the SG has progressively declined, suggesting that the numbers of recruits entering into the SG fishery has gradually declined since 2002. By comparison, the proportion of females has progressively increased in the GSV since 2002, but remained relatively unchanged in the SG.

Table 3. Proportion (%) and numbers of undersized (<110 mm) crabs and the total percentages of females caught in both pot types in the survey samples. C=commercial pot, R=research pot.

Gulf	Var.	2002		2003		2004		2005		2006	
		C	R	C	R	C	R	C	R	C	R
GSV	%	48.8	62.5	14.8	34.1	12	21.2	49.8	62.4	46.5	68.8
	No.	444	657	226	661	101	133	853	1516	1279	3263
	%♀	23.3	28.8	29.4	38	38.9	47.7	37.2	43.6	39.9	45.2
SG	%	36.1	51.8	29.4	49.5	20.5	31.6	14.5	30.3	11.5	29.3
	No.	1318	2509	1016	2225	828	1255	370	1034	382	1420
	%♀	25	31.2	22.2	30.4	26.9	34.4	32.3	39.2	24.9	30.5

3.3.2 Abundance of Crabs in Spencer Gulf

3.3.2.1 Effects of Year and Area

The effects of year and area on the number of crabs caught per pot is summarised in Table 4a. As year, area and the interaction term (year*area) are all significant, post-hoc multiple comparisons were conducted for each main effect (Table 4b), and a plot of marginal means constructed to examine the interaction (Figure 20). The post-hoc test on sampling year shows that crab catches in Spencer Gulf have declined and subsequently recovered since the commencement of the study (with catches in 2006 being the highest recorded since 2002). A post-hoc SNK test also discriminates the three latitudinal sampling areas, and confirms a broad-scale decline in the number of crabs caught between the North and South of Spencer Gulf (ie North>Centre>South; Appendix 3a). Because this spatial pattern was not consistent during 2002, a significant interaction term was also recorded.

Table 4a. Results of two-way ANOVA on differences in the abundance of blue crabs in three areas of Spencer Gulf (North, Centre, South) during five sampling years (2002, 2003, 2004, 2005, 2006).

Source	df	MS	F	Sig.	Power (α=0.05)
Year	4	3350.670	64.710	<0.001	1.000
Area	2	12214.630	235.894	<0.001	1.000
Year * Area	8	480.922	9.288	<0.001	1.000
Error	5041	51.780			

Table 4b. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Spencer Gulf (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset		
Dependent	Source	N	1	2	3
i) Year	2005	1080	5.52		
	2004	1080		7.42	
	2003	1058		7.51	
	2006	1080		7.56	
	2002	758			11.21
	Sig.		1	0.906	1
ii) Area	South	1392	4.02		
	Centre	2126		7.72	
	North	1538			10.77
	Sig.		1.000	1.000	1.000

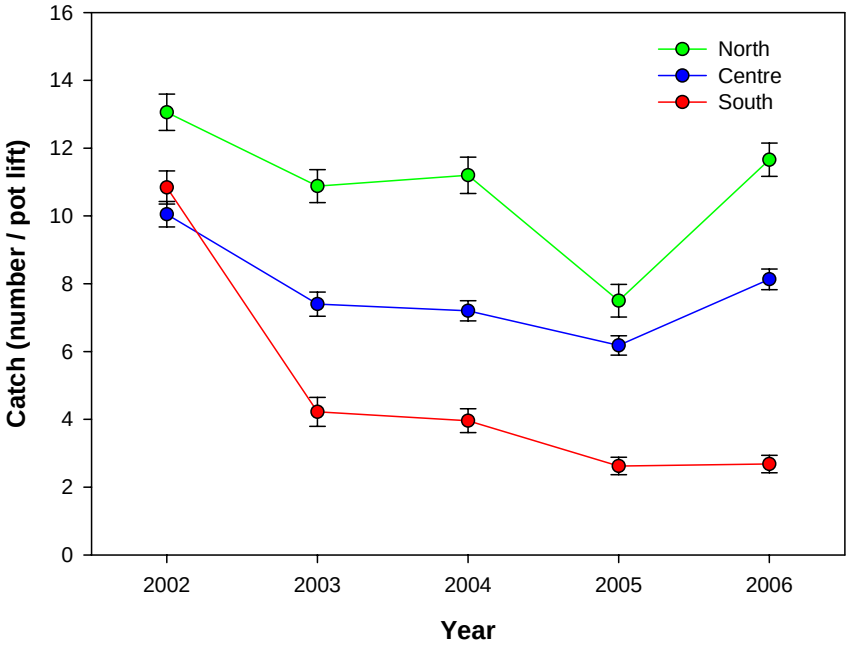


Figure 20. Mean numbers of crabs caught per pot in Spencer Gulf as a function of year and area. Values are mean ± standard error.

3.3.2.2 Effects of Pot Type

The number of crabs caught per pot type as a function of year and area is shown in Figures 21 and 22. ANOVA tests conducted independently for commercial and research pots provide similar outcomes (Table 5a) with significant ($p<0.001$) year, area and year*area interactions being recorded. Research pots consistently capture higher numbers of crabs than commercial pots (overall mean = 8.53 ± 0.17 *vs.* 6.73 ± 0.14 respectively), but trends in catches over time are remarkably similar between gear types. Crab catches for commercial and research pots have both declined from record high values in 2002 to record low values in 2005, but catches from both these gear types have recently increased over the period up to 2006 (Tables 5b and 5c). Consistent regional differences in catch are also evident in both the commercial and research pot data, with progressively lower numbers of crabs being caught from North to South (Tables 5a and 5b).

Table 5a. Results of two-way ANOVA on differences in the abundance of blue crabs in commercial and research pots in three areas of Spencer Gulf (North, Centre, South) during five sampling years (2002, 2003, 2004, 2005, 2006).

Dependent	Source	df	MS	F	Sig.	Power (α=0.05)
Commercial	Year	4	1469.327	36.290	<0.001	1.000
	Area	2	3323.102	82.076	<0.001	1.000
	Year * Area	8	310.290	7.664	<0.001	1.000
	Error	2513	40.488			
Research	Year	4	2245.510	37.477	<0.001	1.000
	Area	2	9809.547	163.718	<0.001	1.000
	Year * Area	8	320.616	5.351	<0.001	0.999
	Error	2513	59.918			

Table 5b. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of blue crabs taken in commercial pots during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Spencer Gulf (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset			
Dependent	Source	N	1	2	3	4
i) Year	2005	540	4.73			
	2006	540		6.14		
	2003	529		6.51		
	2004	540			7.49	
	2002	379				9.64
	Sig.		1.000	0.365	1.000	1.000
ii) Area	South	696	3.77			
	Centre	1063		7.02		
	North	769			9.00	
	Sig.		1.000	1.000	1.000	

Table 5c. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of blue crabs taken in research pots during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Spencer Gulf (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset			
Dependent	Source	N	1	2	3	4
i) Year	2005	540	6.31			
	2004	540		7.36		
	2003	529			8.51	
	2006	540			8.97	
	2002	379				12.77
	Sig.		1.000	1.000	0.348	1.000
ii) Area	South	696	4.26			
	Centre	1063		8.43		
	North	769			12.54	
	Sig.		1.000	1.000	1.000	

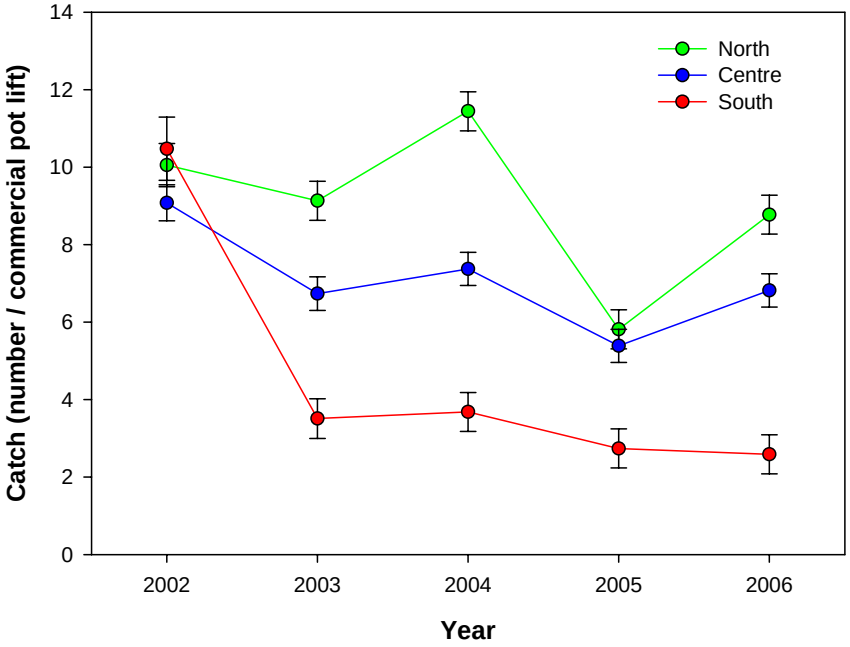


Figure 21. Mean numbers of crabs caught in commercial pots in Spencer Gulf as a function of year and area. Values are mean ± standard error.

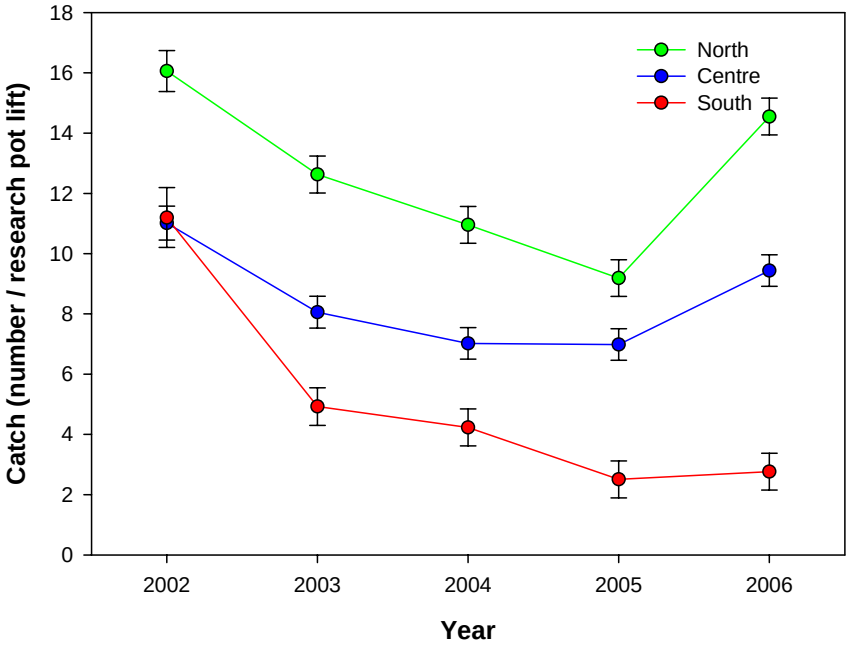


Figure 22. Mean numbers of crabs caught per research pot in Spencer Gulf as a function of year and area. Values are mean ± standard error.

3.3.2.3 Effects of Sex

Two-way ANOVA tests for differences in the number of females and males caught per pot lift as a function of year and area are summarised in Table 6a. These tests confirm the presence of significant ($p<0.001$) differences in the number of males and females caught over time and between different areas of Spencer Gulf. These differences are graphically summarised in Figures 23 and 24, and more formally presented in Tables 6b and 6c. These data show that numbers of both males and females have declined significantly over the period 2002 to 2005, but have most recently increased over the period 2005 to 2006. They also show that significantly higher numbers of males and females are represented in the North of the gulf each year, than in the Centre or South. A separate ANOVA (one-way) further shows that significantly ($F_{1,10110} = 1141.0$, $p<0.001$) higher numbers of males than females are represented in each years survey catch from Spencer Gulf (♂ = 5.36 ± 0.08, ♀ = 2.27 ± 0.05).

Table 6a. Results of two-way ANOVA on differences in the abundance of female and male blue crabs in three areas of Spencer Gulf (North, Centre, South) during five sampling years (2002, 2003, 2004, 2005, 2006).

Dependent	Source	df	MS	F	Sig.	Power (α=0.05)
Female	Year	4	141.874	13.755	<0.001	0.998
	Area	2	1682.418	163.118	<0.001	1.000
	Year * Area	8	120.795	11.712	<0.001	1.000
	Error	5041	10.314			
Male	Year	4	2233.041	85.672	<0.001	1.000
	Area	2	5024.633	192.773	<0.001	1.000
	Year * Area	8	346.195	13.282	<0.001	1.000
	Error	5041	26.065			

Table 6b. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of female blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Spencer Gulf (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset		
Dependent	Source	N	1	2	3
i) Year	2005	1080	1.999		
	2003	1058	2.019		
	2006	1080	2.131		
	2004	1080	2.273		
	2002	758		3.198	
	Sig.		0.228	1.000	
ii) Area	South	1392	1.225		
	Centre	2126		2.052	
	North	1538			3.517
	Sig.		1.000	1.000	1.000

Table 6c. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of male blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Spencer Gulf (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset		
Dependent	**Source**	**N**	**1**	**2**	**3**
i) Year	2005	1080	3.519		
	2004	1080		5.149	
	2006	1080		5.428	
	2003	1058		5.492	
	2002	758			8.008
	Sig.		1.000	0.292	1.000
ii) Area	South	1392	2.791		
	Centre	2126		5.672	
	North	1538			7.257
	Sig.		1.000	1.000	1.000

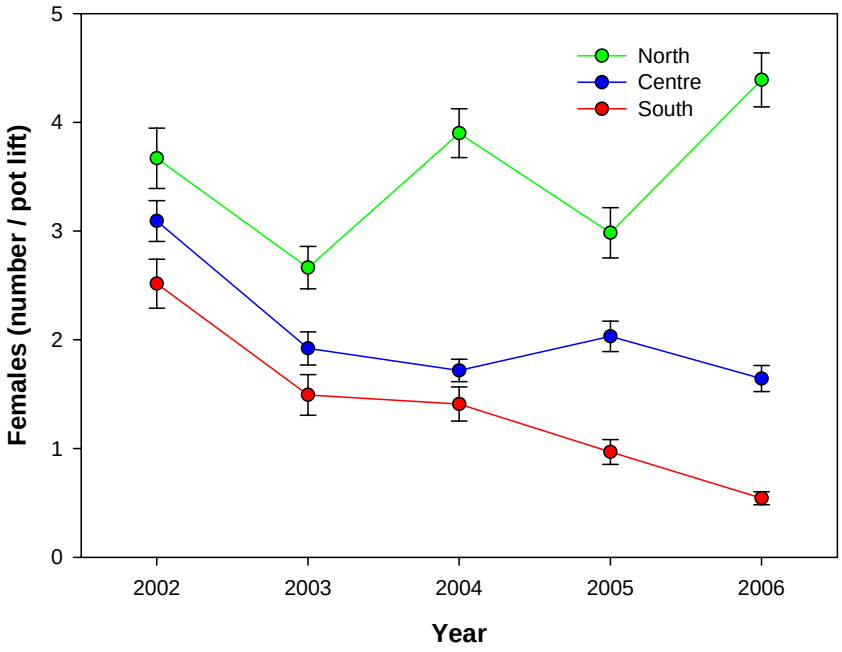


Figure 23. Mean numbers of female crabs caught per pot in Spencer Gulf as a function of year and area. Values are mean ± standard error.

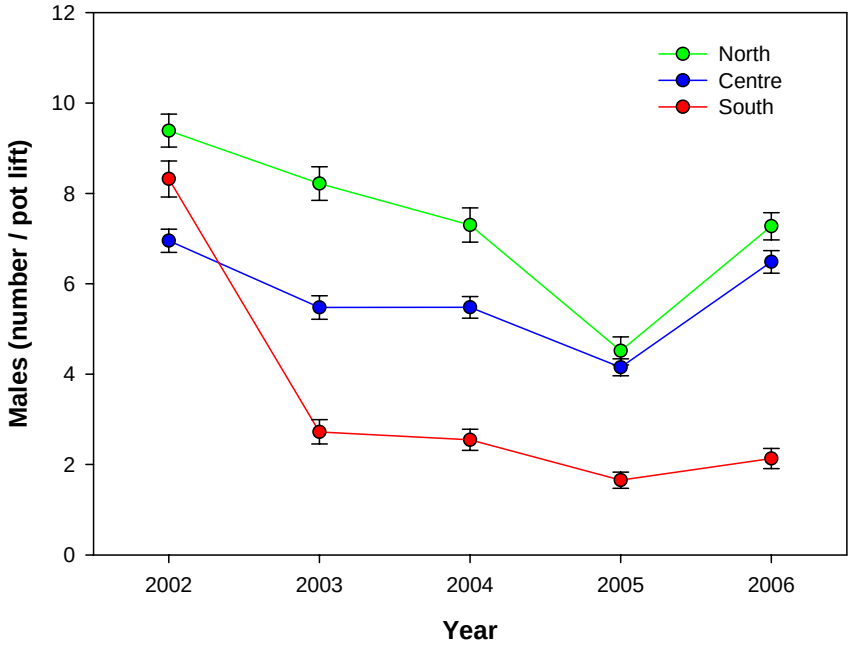


Figure 24. Mean numbers of male crabs caught per pot in Spencer Gulf as a function of year and area. Values are mean ± standard error.

3.3.2.4 Effect of Size

The numbers of legal (>110 mm) and undersized (<110 mm) crabs caught per pot is shown in Figures 25 and 26, respectively. ANOVA tests (Table 7a) and associated post-hoc SNK tests (Tables 7b and 7c) confirm several obvious trends in these figures. In particular, they validate significant ($p<0.001$) declines in the numbers of both legal and undersized crabs between the North and South of the Gulf (which are consistent with general patterns in total abundance described above). Additionally, they show general declines in both legal and undersized crabs over the period 2002 to 2005, followed by abrupt and significant increases in legal and undersized crabs over the period 2005 to 2006. Patterns in catch were not consistent between areas over time, and this resulted in significant interactions. These interactions were most pronounced for legal sized crabs as a result of unusually high catches in the southern area of the gulf in 2002. Temporal trends in undersized crab catches were much more consistent between areas. By exception, numbers of undersized crabs caught in pots in the northern region of the gulf increased markedly during 2006 and largely accounted for the significant interaction term for this group of crabs.

Because comparisons of marginal means indicate a tendency towards higher catches of legal rather than undersized crabs, a formal statistical test was undertaken to examine this. Results of this one-way ANOVA ($F_{1,10110} = 800.5$, $p<0.001$) confirm that significantly more legal sized crabs than undersized crabs were caught (Legal = 5.19 ± 0.08, Undersized = 2.44 ± 0.05).

Table 7a. Results of two-way ANOVA on differences in the abundance of legal and undersized blue crabs in three areas of Spencer Gulf (North, Centre, South) during five sampling years (2002, 2003, 2004, 2005, 2006).

Dependent	Source	df	MS	F	Sig.	Power (α=0.05)
Legal	Year	4	791.683	26.360	<0.001	0.999
	Area	2	3632.968	120.965	<0.001	1.000
	Year * Area	8	504.432	16.796	<0.001	1.000
	Error	5041	30.033			
Undersized	Year	4	1520.110	133.474	<0.001	1.000
	Area	2	2543.522	223.335	<0.001	1.000
	Year * Area	8	96.226	8.449	<0.001	0.999
	Error	5041	11.389			

Table 7b. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of legal-sized blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Spencer Gulf (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset		
Dependent	Source	N	1	2	3
i) Year	2005	1080	4.219		
	2003	1058	4.448		
	2004	1080		5.494	
	2006	1080		5.891	5.891
	2002	758			6.157
	Sig.		0.351	0.107	0.279
ii) Area	South	1392	3.055		
	Centre	2126		5.337	
	North	1538			6.909
	Sig.		1.000	1.000	1.000

Table 7c. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of undersized blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Spencer Gulf (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset			
Dependent	Source	N	1	2	3	4
i) Year	2005	1080	1.300			
	2006	1080		1.669		
	2004	1080		1.929		
	2003	1058			3.063	
	2002	758				5.049
	Sig.		1.000	0.086	1.000	1.000
ii) Area	South	1392	0.961			
	Centre	2126		2.387		
	North	1538			3.865	
	Sig.		1.000	1.000	1.000	

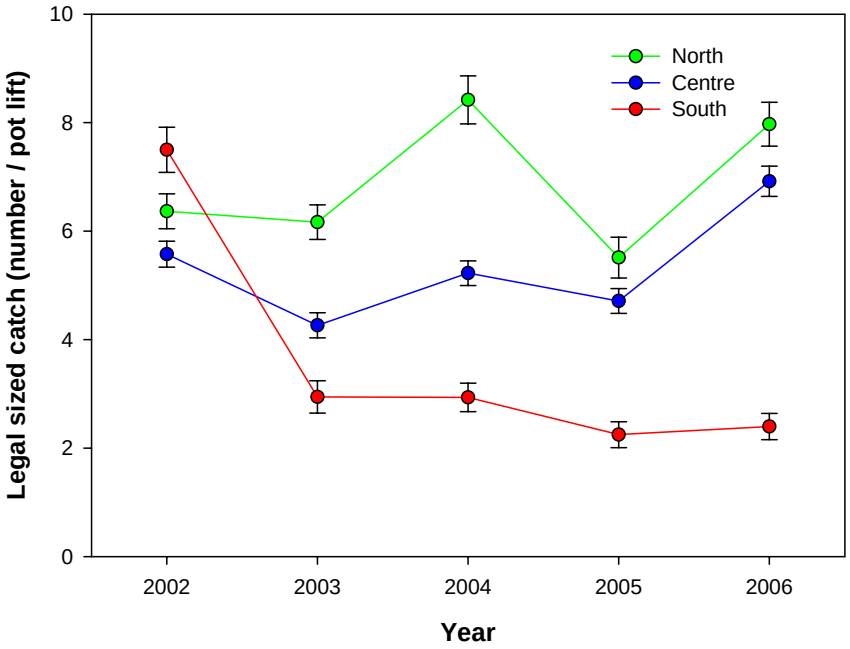


Figure 25. Mean numbers of legal crabs (>110 mm) caught per pot in Spencer Gulf as a function of year and area. Values are mean ± standard error.

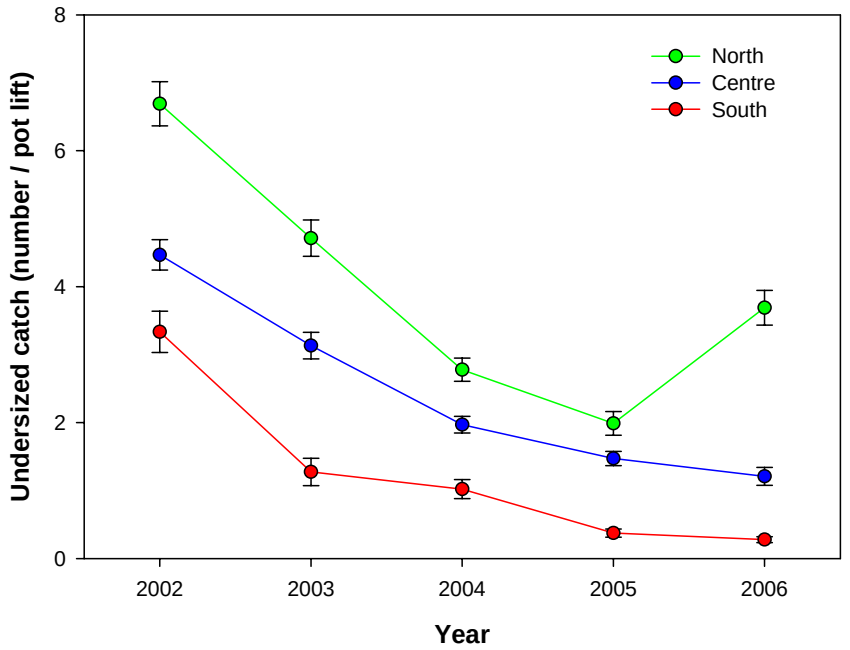


Figure 26. Mean numbers of undersized crabs (<110 mm) caught per pot in Spencer Gulf as a function of year and area. Values are mean ± standard error.

3.3.3 Abundance of Crabs in Gulf St Vincent

3.3.3.1 Effects of Year and Area

The effects of year and area on the number of crabs caught per pot is summarised in Table 8a. As year, area and the interaction term (year*area) are all significant, post-hoc multiple comparisons were conducted for each main effect (Table 8b), and a plot of marginal means constructed to examine the interaction. (Figure 27). The post-hoc SNK test on sampling year shows that collective crab catches were significantly higher in 2006 than in all previous years surveyed (ie 2006>2005>2003=2002>2004). A post-hoc SNK test also discriminated the three nominal sampling areas, however contrary to trends in Spencer Gulf, catches in Gulf St. Vincent were greatest in the southern zone and declined significantly towards the North (ie South>Centre>North; Appendix 3b). Because this spatial pattern was not consistent during 2002, a significant interaction term was also recorded.

Table 8a. Results of two-way ANOVA on differences in the abundance of blue crabs in three areas of Gulf St. Vincent (North, Centre, South) during five sampling years (2002, 2003, 2004, 2005, 2006).

Source	df	MS	F	Sig.	Power (α=0.05)
Year	4	5471.280	69.693	<0.001	1.000
Area	2	7716.713	98.295	<0.001	1.000
Year * Area	8	1257.489	16.018	<0.001	1.000
Error	4157	78.506			

Table 8b. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Gulf St. Vincent (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset			
Dependent	**Source**	**N**	**1**	**2**	**3**	**4**
i) Year	2004	920	1.59			
	2002	538		3.64		
	2003	914		3.79		
	2005	880			4.71	
	2006	920				8.14
	Sig.		1.000	0.733	1.000	1.000
ii) Area	North	1444	1.95			
	Centre	1668		4.49		
	South	1060			7.77	
	Sig.		1.000	1.000	1.000	

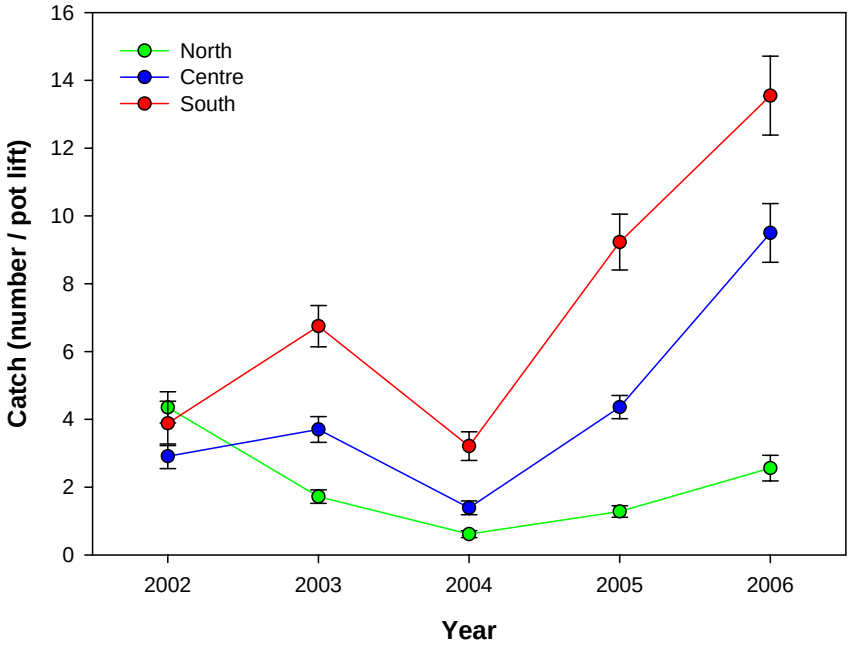


Figure 27. Mean numbers of crabs caught per pot in Gulf St. Vincent as a function of year and area. Values are mean ± standard error.

3.3.3.2 Effects of Pot Type

Two-way ANOVA tests for differences in the number of crabs caught by commercial and research pots as a function of year and area are summarised in Table 9a. These tests show that the catches of both commercial and research pots vary significantly ($p<0.001$) over time and also between different areas of Gulf St. Vincent. These differences are graphically summarised in Figures 28 and 29, and more formally presented in Tables 9b and 9c. Despite large interannular variations in catch, the summary data demonstrate that catches for both commercial and research pots has progressively increased over recent years, and gone from record low values in 2004 to record high values in 2006. Consistent patterns in catch for the two gear types are also evident by area. Both research and commercial pots captured significantly higher numbers of crabs in the southern area of the gulf, and significantly lower numbers in the northern area (ie South>Centre>North).

Due to similarities in the marginal mean plots of commercial and research catches it is not readily apparent if the catch rates of the two gear types differ in Gulf St. Vincent. A formal statistical test was applied to examine this. Results of this one-way ANOVA ($F_{1,4172} = 2216.6$, $p<0.001$) show that catches from research pots are significantly higher than commercial pots (Research = 5.17 ± 0.25, Commercial = 3.71 ± 0.16).

Table 9a. Results of two-way ANOVA on differences in the abundance of blue crabs in commercial and research pots in three areas of Gulf St. Vincent (North, Centre, South) during five sampling years (2002, 2003, 2004, 2005, 2006).

Dependent	Source	df	MS	F	Sig.	Power (α=0.05)
Commercial	Year	4	1139.669	25.024	<0.001	1.000
	Area	2	2664.263	58.500	<0.001	1.000
	Year * Area	8	366.669	8.051	<0.001	1.000
	Error	2071	45.543			
Research	Year	4	5023.380	46.351	<0.001	1.000
	Area	2	5299.082	48.895	<0.001	1.000
	Year * Area	8	1118.315	10.319	<0.001	1.000
	Error	2071	108.377			

Table 9b. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of blue crabs taken from commercial pots during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Gulf St. Vincent (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset		
Dependent	Source	N	1	2	3
i) Year	2004	460	1.83		
	2003	457		3.35	
	2002	269		3.38	
	2005	440		3.89	
	2006	460			5.98
	Sig.		1.000	0.497	1.000
ii) Area	North	722	1.72		
	Centre	834		3.62	
	South	530			6.57
	Sig.		1.000	1.000	1.000

Table 9c. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of blue crabs taken from research pots during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Gulf St. Vincent (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset		
Dependent	Source	N	1	2	3
i) Year	2004	460	1.36		
	2002	269		3.91	
	2003	457		4.24	
	2005	440		5.52	
	2006	460			10.31
	Sig.		1.000	0.073	1.000
ii) Area	North	722	2.17		
	Centre	834		5.35	
	South	530			8.96
	Sig.		1.000	1.000	1.000

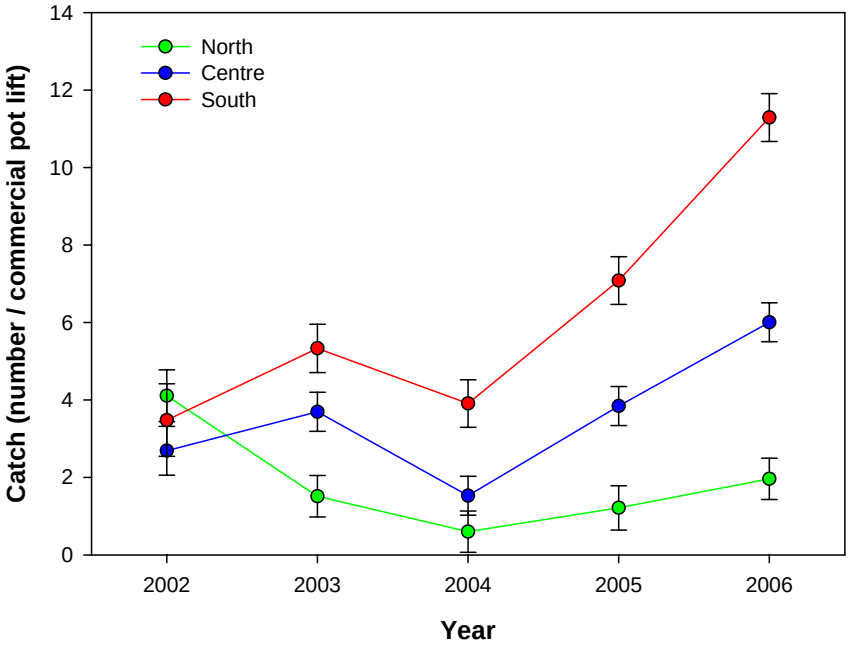


Figure 28. Mean numbers of crabs per commercial pot caught in Gulf St. Vincent as a function of year and area. Values are mean ± standard error.

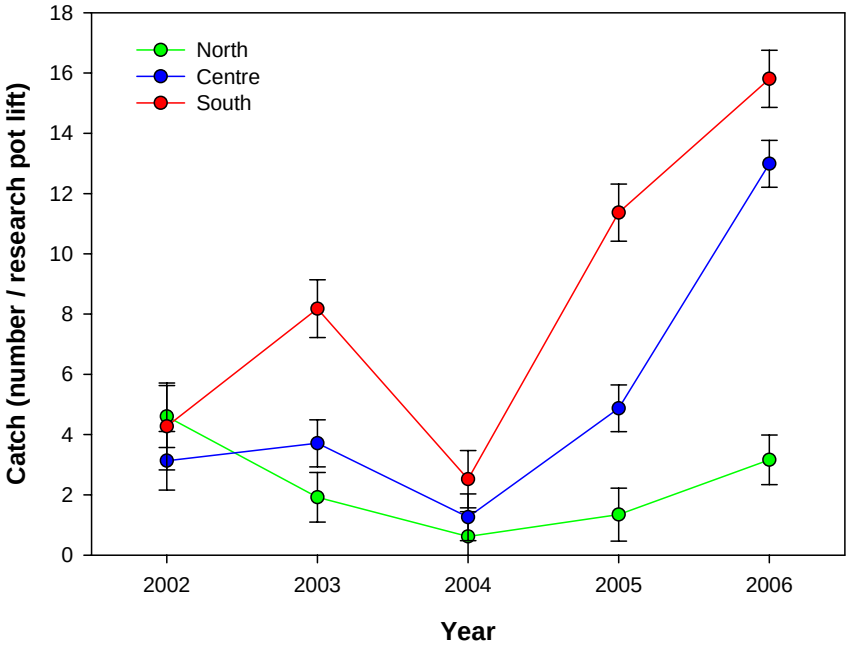


Figure 29. Mean numbers of crabs per research pot caught in Gulf St. Vincent as a function of year and area. Values are mean ± standard error.

3.3.3.3 Effects of Sex

Two-way ANOVA tests for differences in the number of females and males caught per pot lift as a function of year and area are summarised in Table 10a. These tests confirm the presence of significant ($p<0.001$) differences in the number of males and females caught over time and between different areas of Gulf St. Vincent. These differences are graphically summarised in Figures 30 and 31, and more formally presented in Tables 10b and 10c. These data demonstrate that numbers of males and females caught in pots in Gulf St. Vincent have broadly followed consistent trends over recent years. In particular, these data show that small declines in the populations of both sexes over the period 2002 to 2004 have been followed by large increases in male and females numbers over the period 2004 to 2006. Spatial patterns in catch are also consistent between genders, and both males and females are significantly ($p<0.001$) more abundant in pots fished within the southern area of the gulf rather than the central and northern areas (South>Centre>North). A separate ANOVA (one-way) further shows that significantly ($F_{1,8342} = 68.3$, $p<0.001$) higher numbers of males than females are represented in each years survey catch from Gulf St. Vincent (♂ = 2.70 ± 0.09, ♀ = 1.74 ± 0.08).

Table 10a. Results of two-way ANOVA on differences in the abundance of female and male blue crabs in three areas of Gulf St. Vincent (North, Centre, South) during five sampling years (2002, 2003, 2004, 2005, 2006).

Dependent	Source	df	MS	F	Sig.	Power (α=0.05)
Female	Year	4	1280.896	60.671	<0.001	1.000
	Area	2	2764.022	130.922	<0.001	1.000
	Year * Area	8	347.518	16.461	<0.001	1.000
	Error	4157	21.112			
Male	Year	4	1551.190	54.506	<0.001	1.000
	Area	2	1542.839	54.213	<0.001	1.000
	Year * Area	8	374.983	13.176	<0.001	0.998
	Error	4157	28.459			

Table 10b. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of female blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Gulf St. Vincent (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset			
Dependent	Source	N	1	2	3	4
i) Year	2004	920	0.680			
	2002	538	0.957	0.957		
	2003	914		1.298		
	2005	880			1.928	
	2006	920				3.522
	Sig.		0.229	0.139	1.000	1.000
ii) Area	North	1444	0.550			
	Centre	1668		1.365		
	South	1060			3.957	
	Sig.		1.000	1.000	1.000	

Table 10c. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of male blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Gulf St. Vincent (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset		
Dependent	**Source**	**N**	**1**	**2**	**3**
i) Year	2004	920	0.914		
	2003	914		2.497	
	2002	538		2.686	
	2005	880		2.777	
	2006	920			4.621
	Sig.		1.000	0.545	1.000
ii) Area	North	1444	1.396		
	Centre	1668		3.122	
	South	1060			3.811
	Sig.		1.000	1.000	1.000

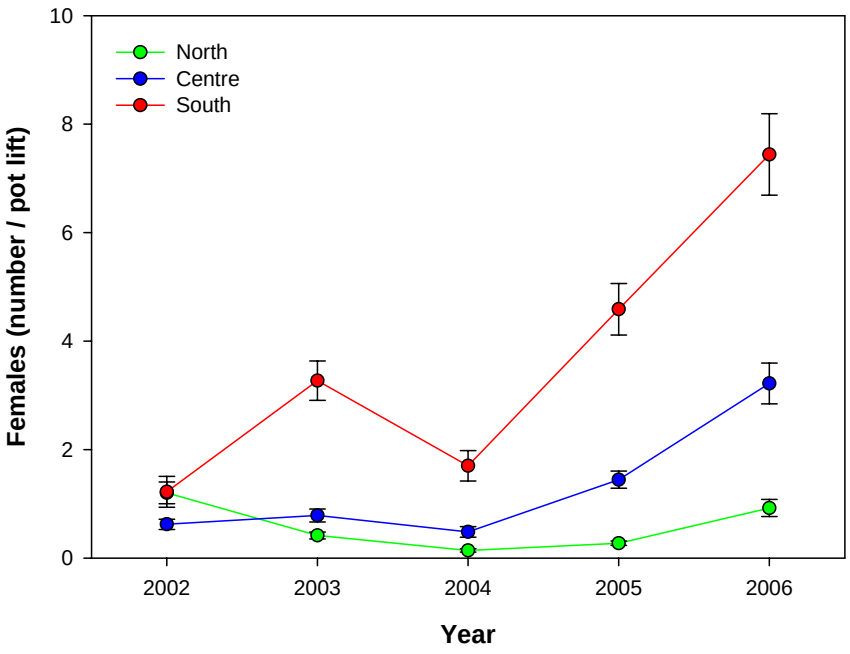


Figure 30. Mean numbers of female crabs caught per pot in Gulf St. Vincent as a function of year and area. Values are mean ± standard error.

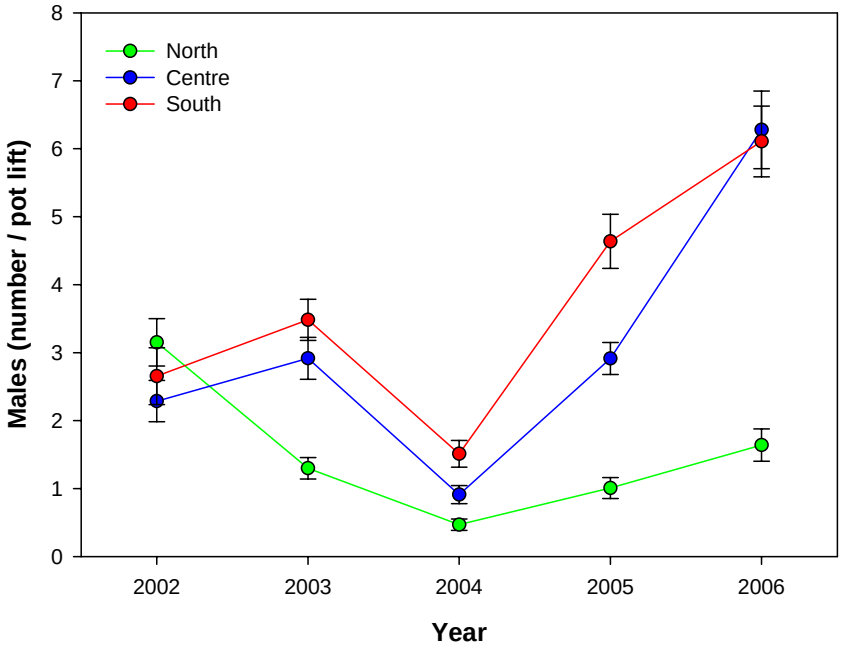


Figure 31. Mean numbers of male crabs caught per pot in Gulf St. Vincent as a function of year and area. Values are mean ± standard error.

3.3.3.4 Effect of Size

Two-way ANOVA tests for differences in the number of legal and undersized crabs caught per pot lift as a function of year and area are summarised in Table 11a. These tests confirm the presence of significant ($p<0.001$) differences in the number of legal and undersized crabs caught over time and between different areas of Gulf St. Vincent. These differences are graphically summarised in Figures 32 and 33, and more formally presented in Tables 11b and 11c. Like the gender data presented above, catch data grouped by size fluctuate considerably over time. Nevertheless, it is clear that numbers of both legal and undersized crabs in Spencer Gulf have broadly declined and subsequently recovered over the five-year period of the survey. Most notably, catches of both legal and undersized catches were the lowest recorded during 2004, and highest on record during 2006. Areal patterns in abundance, are by comparison, much more consistent, and show that significantly higher numbers of both legal and undersized crabs are represented in the South of the gulf each year, than in the Centre or North.

Due to apparent overlaps in the mean abundance plots, it is not clear if catches of legal and undersized crabs differ in Gulf St. Vincent. A formal statistical test was undertaken to examine this. Results of this one-way ANOVA ($F_{1,8342} = 8.1$, $p=0.602$) show that the numbers of legal and undersized crabs caught do not differ significantly (Legal = 2.25 ± 0.07, Undersized = 2.19 ± 0.09).

Table 11a. Results of two-way ANOVA on differences in the abundance of legal and undersized blue crabs in three areas of Gulf St. Vincent (North, Centre, South) during five sampling years (2002, 2003, 2004, 2005, 2006).

Dependent	Source	df	MS	F	Sig.	Power (α=0.05)
Legal	Year	4	567.214	30.992	<0.001	1.000
	Area	2	2729.660	149.143	<0.001	1.000
	Year * Area	8	132.993	7.266	<0.001	0.999
	Error	4157	18.302			
Undersized	Year	4	3138.677	90.986	<0.001	1.000
	Area	2	1281.444	37.147	<0.001	0.999
	Year * Area	8	670.111	19.426	<0.001	1.000
	Error	4157	34.496			

Table 11b. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of legal-sized blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Gulf St. Vincent (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset		
Dependent	Source	N	1	2	3
i) Year	2004	920	1.340		
	2002	538	1.597	1.597	
	2005	880		2.014	
	2003	914			2.824
	2006	920			3.205
	Sig.		0.231	0.052	0.075
ii) Area	North	1444	0.883		
	Centre	1668		2.183	
	South	1060			4.224
	Sig.		1.000	1.000	1.000

Table 11c. Results of post-hoc multiple comparison test (SNK) for differences in the abundance of undersized blue crabs taken during i) five sampling years (2002, 2003, 2004, 2005, 2006) in ii) three areas of Gulf St. Vincent (North, Centre, South). Homogeneous groups of means (crabs/potlift) that do not differ significantly are identified here as discrete subsets.

			Subset				
Dependent	Source	N	1	2	3	4	5
i) Year	2004	920	0.254				
	2003	914		0.970			
	2002	538			2.046		
	2005	880				2.692	
	2006	920					4.937
	Sig.		1.000	1.000	1.000	1.000	1.000
ii) Area	North	1444	1.063				
	Centre	1668		2.303			
	South	1060			3.544		
	Sig.		1.000	1.000	1.000		

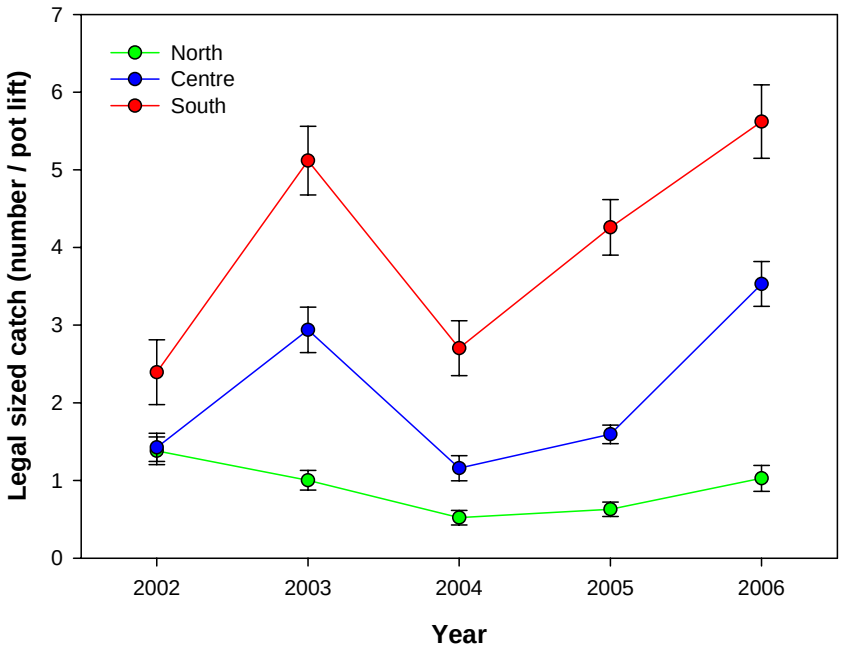


Figure 32. Mean numbers of legal sized crabs (>110mm) caught per pot in Gulf St. Vincent as a function of year and area. Values are mean ± standard error.

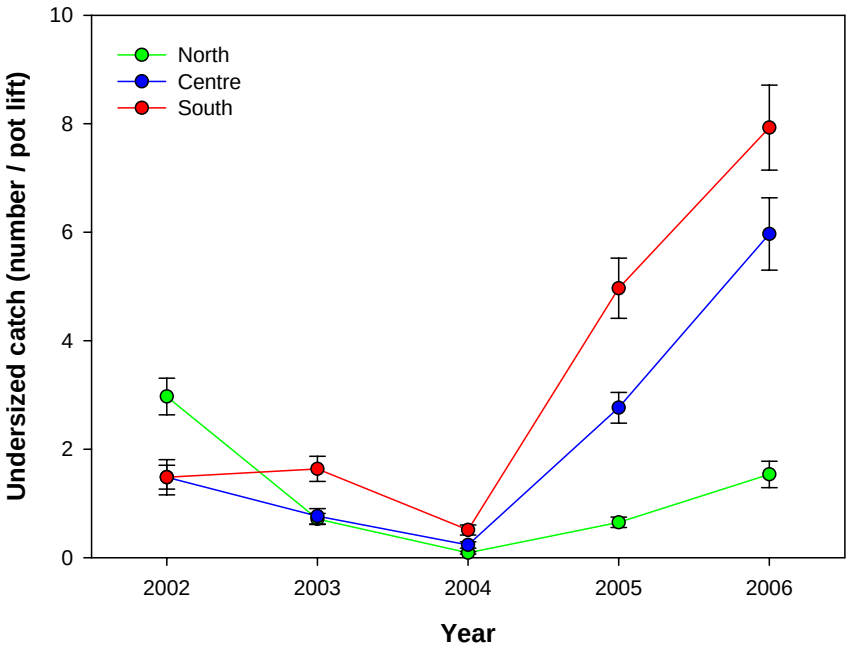


Figure 33. Mean numbers of under sized crabs (<110mm) caught per pot in Gulf St. Vincent as a function of year and area. Values are mean ± standard error.

3.3.4 Size Distributions

3.3.4.1 Effects of Gulf and Sex

A significant effect of region, year and sex was found but with significant interactions (Table 12, $p<0.001$). The interactions are caused by interference from the shift in the size distributions between gulfs, years and genders. Crabs of both sexes were significantly larger in Gulf St. Vincent than Spencer Gulf during 2003 and 2004, however the reverse occurred during 2002, 2005 and 2006 (when crabs of both sexes in Gulf St. Vincent were significantly smaller than those in Spencer Gulf) (Figure 34). On closer examination it is apparent that these differences are due to differential recruitment in the two gulfs.

Table 12. Results of factorial ANOVA on differences in the abundance of blue crabs in three areas of Gulf St. Vincent (North, Centre, South) during five sampling years (2002, 2003, 2004, 2005, 2006).

Source	df	MS	F	Sig.	Power (α=0.05)
Region	1	48215.238	275.713	<0.001	1.000
Year	4	39596.693	226.429	<0.001	1.000
Sex	1	53881.927	308.118	<0.001	1.000
Region * Year	4	103213.880	590.217	<0.001	1.000
Region * Sex	1	7340.551	41.976	<0.001	0.999
Year * Sex	4	792.463	4.532	<0.001	0.945
Region * Year * Sex	4	4559.264	26.072	<0.001	0.999
Error	57088	174.875			

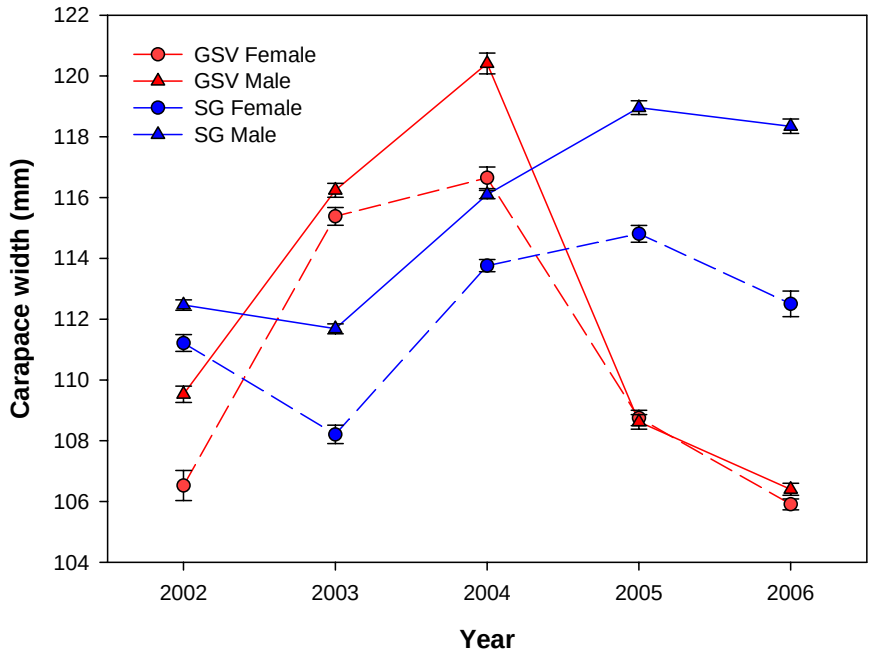


Figure 34. Mean size of male and female crabs caught in Gulf St. Vincent and Spencer Gulf as a function of year. Values are mean ± standard error.

3.3.4.2 Effects of Year, Females SG

Figure 35 shows the accumulative size frequencies for female crabs caught in commercial and research pots combined during the five surveys in July 2002, 2003, 2004, 2005 and 2006 in Spencer Gulf. A one-way ANOVA test ($F_{1,11471}$ = 68.1, $p<0.001$) showed that all years were significantly different. Associated post-hoc SNK tests showed that the mean female crab size (mm CW) was largest in 2005 followed by 2004, 2006, 2002 and 2003 (ie 2005=114.81±0.27; 2004=113.76±0.26; 2006=112.50±0.42; 2002=111.21±0.26; 2003=108.21±0.27).

3.3.4.3 Effects of Year, Males SG

Figure 36 shows the accumulative size frequencies for male crabs caught in commercial and research pots combined during the five surveys in July 2002, 2003, 2004, 2005 and 2006 in Spencer Gulf. A one-way ANOVA test ($F_{1,27100}$ = 303.7, $p<0.001$) showed that all years were significantly different. Results of associated post-hoc SNK tests were similar to those produced for females. These showed that the mean male crab size (mm CW) was largest in 2005 followed by 2006, 2004, 2002 and 2003 (ie 2005=118.96±0.20; 2006=118.35±0.24; 2004=116.10±0.17; 2002=112.47±0.26; 2003=111.64±0.16).

3.3.4.4 Effects of Year, Females GSV

Figure 37 shows the accumulative size frequencies for female crabs caught in commercial and research pots combined during the four surveys in July 2002, 2003, 2004, 2005 and 2006 in Gulf St. Vincent. A one-way ANOVA test ($F_{1,7295}$ = 282.6, $p<0.001$) showed that all years were significantly different. Associated post-hoc SNK tests showed that the mean female crab size (mm CW) was largest in 2004 followed by 2003, 2005, 2002 and 2006 (ie 2004=116.65±0.41; 2003=115.38±0.30; 2005=108.75±0.25; 2002=106.52±0.46; 2006=105.91±0.18).

3.3.4.5 Effects of Year, Males GSV

Figure 38 shows the accumulative size frequencies for male crabs caught in commercial and research pots combined during the four surveys in July 2002, 2003, 2004, 2005 and 2006 in Gulf St. Vincent. A one-way ANOVA test ($F_{1,11258}$ = 436.8, $p<0.001$) showed that all years were significantly different, however the rank order of years was not consistent with that of females. In contrast with females, the mean male crab size (mm CW) was largest in 2004 followed by 2003, 2002, 2005 and 2006 (ie 2004=120.41±0.38; 2003=116.24±0.23; 2002=109.53±0.29; 2005=108.62±0.22; 2006=106.40±0.20).

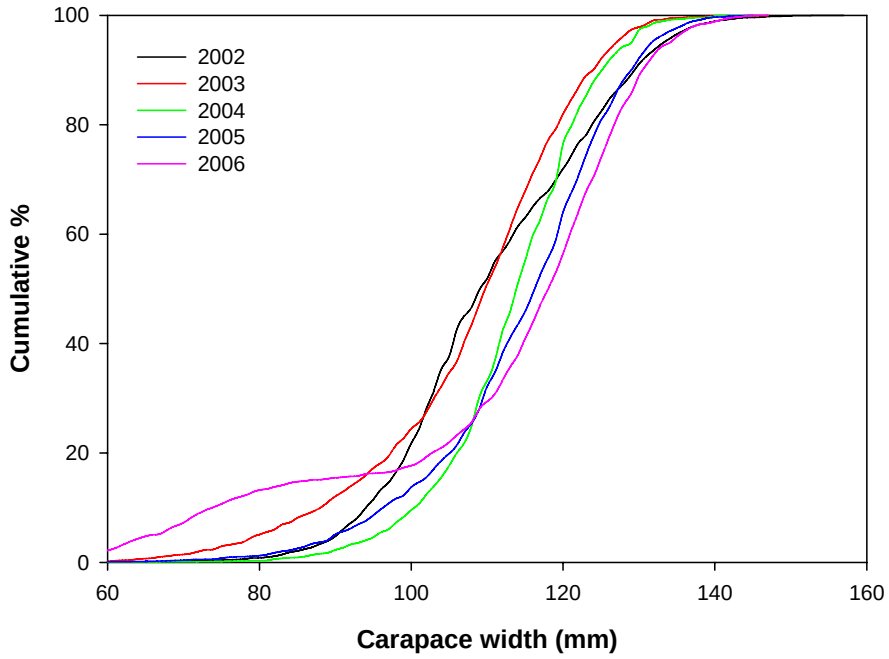


Figure 35. The cumulative size distributions of female blue crabs caught in Spencer Gulf in both commercial and research pots during the surveys in July 2002, 2003, 2004, 2005 and 2006.

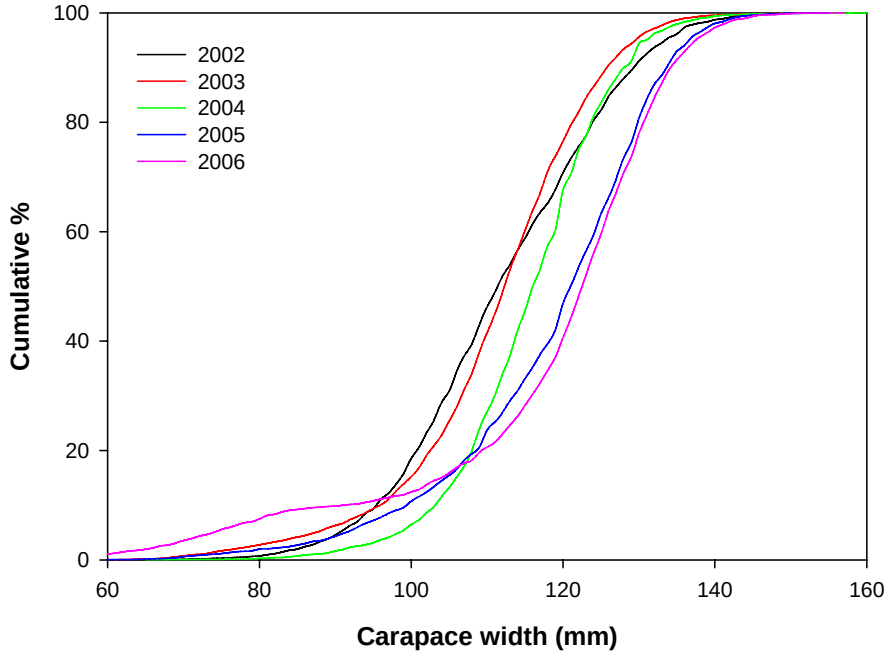


Figure 36. The cumulative size distributions of male blue crabs caught in Spencer Gulf in both commercial and research pots during the surveys in July 2002, 2003, 2004, 2005 and 2006.

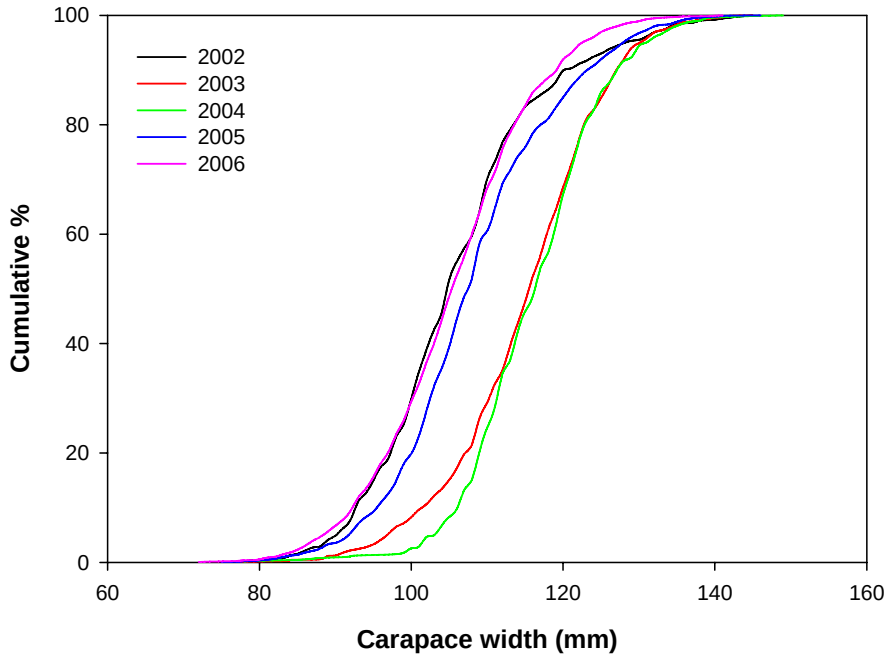


Figure 37. The cumulative size distributions of female blue crabs caught in Gulf St Vincent in both commercial and research pots during the surveys in July 2002, 2003, 2004, 2005 and 2006.

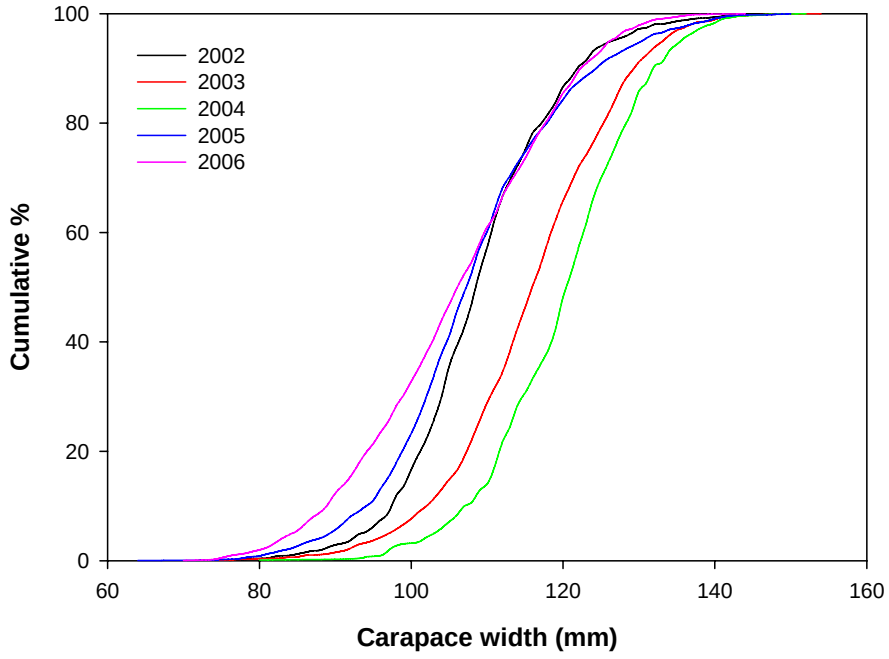


Figure 38. The cumulative size distributions of male blue crabs caught in Gulf St Vincent in both commercial and research pots during the surveys in July 2002, 2003, 2004, 2005 and 2006.

3.4 BY-CATCH

Information on by-catch was collected from the fishery independent surveys in 2002, 2003, 2004, 2005 and 2006. By-catch is defined as those species that are captured in pots or drop nets as incidental catch while targeting blue swimmer crabs (Roosenburg *et al.,* 1997; Saila, 1983).

A total of 52 by-catch species and 36,638 individuals were recorded during the 5 surveys (Tables 13a and 13b). This included 29 species of fish, 9 crustaceans, 10 molluscs, 3 echinoderms and 1 tunicate. Thirty-three of 52 by-catch species were captured in both gulfs. Eight species were taken exclusively from the SG, while a further 11 species were exclusively collected from the GSV.

The rock crab *Nectocarcinus integrifrons* was the most abundant by-catch species collected, and comprised 89% of the total by-catch in the SG, and 80% of the total catch in the GSV. This species was also extremely widespread, and occurred in 65% of pots lifted in the GSV and 32% of pots lifted in the SG. Other common species collected included the spider crab *Leptomithrax gaimardii* (8% of the combined GSV and SG by-catch), and the common leatherjacket *Acanthaluteres spilomelanurus* (4% of the combined GSV and SG by-catch). Most other species were infrequently captured and individually contributed to less than 2% of the total by-catch taken from both gulfs. These same relatively rare species also had restricted distributions and individually occurred in less than 3% of pots fished throughout either the GSV or SG.

3.4.1 Community Structure

Regional, inter-annual and pot type differences in by-catch were examined using Bray-Curtis (B-C) dissimilarity measures (Bray and Curtis, 1957). This measure was chosen as it is not affected by joint absences and has consistently performed well in preserving 'ecological distance' in a variety of simulations on different types of data (Field *et al*., 1982; Faith *et al*., 1987). Spatial patterns in B-C dissimilarity were mapped using a non-metric multi-dimensional scaling (MDS) algorithm, and regional, inter-annual and potting type differences tested using the ANOSIM routine of Clarke and Gorley (2001). By-catch data for the 2002 survey were excluded from this analysis as relatively fewer pots were sampled during 2002 than in all other years; their inclusion would have resulted in an unbalanced design, and biased estimates of both faunal abundance and diversity.

The MDS ordination (Figure 39) maps spatial and temporal differences in the composition of by-catch taken from each gulf (Spencer Gulf and Gulf St. Vincent) during each independent survey (2003, 2004, 2005, 2006). The stress coefficient of 0.06 indicates that the ordination is not unduly distorted and a good representation of the input dissimilarities in two dimensions (Clarke, 1993). Four distinct and cohesive groupings are evident in the ordination. These indicate marked differences in the composition of catch both between the two gulfs (Spencer, Gulf St Vincent) and between the two types of fishing pots employed in the survey (Commercial, Research). Additionally, tight clustering of yearly symbols within each grouping indicates that inter-annual differences in by-catch are much smaller than those associated with either region or gear type.

Table 13a. Total abundance and frequency of occurrence (% in brackets) of species taken as by-catch during fishery-independent pot surveys in Spencer Gulf.

Spencer Gulf		**2002**		**2003**		**2004**		**2005**		**2006**		
C = Crustacean, F = Fish, E = Echinoderm, M=Mollusc		Lifts = 758		Lifts = 1058		Lifts = 1080		Lifts = 1080		Lifts = 1080		
Common name	**Scientific name**	**No.s**	**Freq**	**No.s**	**Freq**	**No.s**	**Freq**	**No.s**	**Freq**	**No.s**	**Freq**	**Total**
Rock crab (C)	*Nectocarcinus integrifrons*	1035(94.95)	204(26.9)	1749(93.38)	394(37.2)	2122(89.23)	400(37)	1283(80.49)	333(30.8)	2066(87.84)	287(26.6)	8255
Spider crab (C)	*Leptomithrax gaimardii*	3(0.28)	3(0.4)	24(1.28)	21(2)	116(4.88)	57(5.3)	111(6.96)	74(6.9)	42(1.79)	29(2.7)	296
Leatherjacket (F)	*Acanthaluteres spilomelanurus*	13(1.19)	11(1.5)	27(1.44)	19(1.8)	33(1.39)	(0)	57(3.58)	(0)	57(2.42)	44(4.1)	187
Pt Jackson (F)	*Heterodontus portusjacksoni*	3(0.28)	2(0.3)	13(0.69)	10(.9)	7(0.29)	6(0.6)	36(2.26)	28(2.6)	27(2.26)	24(2.2)	86
Cuttlefish (M)	*Sepia apama*	2(0.18)	2(0.3)	3(0.16)	3(.3)	23(0.97)	22(2)	8(0.5)	6(0.6)	27(1.15)	26(2.4)	63
Red Mullet (F)	*Upeneichthys vlamingii*	7(0.64)	7(0.9)	9(0.48)	8(.8)	6(0.25)	5(0.5)	17(1.07)	12(1.1)	18(0.77)	15(1.4)	57
Fiddler (F)	*Trygonorhina fasciata*	4(0.37)	4(0.5)	12(0.64)	12(1.1)	9(0.38)	9(0.8)	7(0.44)	7(.06)	20(0.44)	20(1.9)	52
Cardinal Fish (F)	*Vincentia conspersa*	0(0)	0(0)	11(0.59)	8(.8)	9(0.38)	9(0.8)	11(0.69)	9(0.8)	18(0..76)	13(1.2)	49
Western King Prawn (C)	*Melicertus latisculatus*	4(0.37)	4(0.5)	1(0.05)	1(.12)	8(0.34)	7(0.6)	19(1.19)	15(1.4)	4(0.17)	4(0.4)	36
Trumpeter (F)	*Pelates sexlineatus*	0(0)	0(0)	3(0.16)	3(.3)	7(0.29)	6(0.6)	2(0.13)	2(.2)	19(0.13)	7(0.7)	31
Beche De Mer (E)	*Stichopus mollis*	4(0.37)	3(0.4)	2(0.11)	2(0.2)	13(0.55)	9(0.8)	3(0.19)	3(0..3)	6(0.26)	6(0.6)	28
Puffer Fish (F)	*Torguigener pleurogramma*	1(0.09)	1(0.1)	1(0.05)	1(.12)	4(0.17)	4(0.4)	3(0.19)	3(0..3)	11(0.47)	10(.9)	20
Balmain Bug (C)	*Ibacus peronii*	5(0.46)	4(0.5)	2(0.11)	2(0.2)	4(0.17)	4(0.4)	4(0.25)	4(0.4)	2(0.09)	2(0.2)	17
Sea urchin (E)	*Heliocidaris erythrogramma*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.06)	1(0.1)	13(0.55)	11(1.0)	14
Snapper (F)	*Pagrus auratus*	4(0.37)	4(0.5)	0(0)	0(0)	0(0)	0(0)	9(0.56)	4(0.4)	0(0)	0(0)	13
Soldier Fish (F)	*Gymnapistes marmoratus*	1(0.09)	1(0.1)	2(0.11)	2(0.2)	1(0.04)	1(0.1)	3(0.19)	3(0..3)	2(0.09)	1(0.1)	9
Wobbegong (F)	*Orectolobus ornatus*	0(0)	0(0)	0(0)	0(0)	1(0.04)	1(0.1)	3(0.19)	3(0..3)	5(0.19)	5(0.5)	9
Seaweed crab (C)	*Naxiaa spp.*	0(0)	0(0)	0(0)	0(0)	7(0.29)	7(0.6)	0(0)	0(0)	0(0)	0(0)	7
Sand crab (C)	*Ovalipes australiensis*	0(0)	0(0)	3(0.16)	2(0.2)	0(0)	0(0)	2(0.13)	1(0.1)	1(0.04)	1(0.1)	6
Rock ling (F)	*Genypterus tigerinus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	5(0.31)	5(0.5)	1(0.04)	1(0.1)	6
Skate (F)	*Raja whitleyi*	0(0)	0(0)	5(0.27)	5(0.5)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	5
Cowfish (F)	*Aracana aurita*	2(0.18)	2(0.3)	0(0)	0(0)	2(0.08)	2(0.2)	0(0)	0(0)	1(0.04)	1(0.1)	5
Flathead (F)	*Platycephalus bassensis*	0(0)	0(0)	0(0)	0(0)	1(0.04)	1(0.1)	1(0.06)	1(0.1)	3(0.09)	3(0.3)	5
Stingray (F)	*Dasyyatis brevicordata*	0(0)	0(0)	0(0)	0(0)	1(0.04)	1(0.1)	1(0.06)	1(0.1)	2(0.06)	1(0.1)	4
Numb Fish (F)	*Hypnos monopterygium*	2(0.18)	2(0.3)	0(0)	0(0)	0(0)	0(0)	1(0.06)	1(0.1)	0(0)	0(0)	3
Gummy shark (F)	*Mustelus antarcticus*	0(0)	0(0)	1(0.05)	1(.12)	0(0)	0(0)	1(0.06)	1(0.1)	1(0.06)	1(0.1)	3
Starfish (E)	*Pateriella brevispina*	0(0)	0(0)	1(0.05)	1(.12)	1(0.04)	1(0.1)	0(0)	0(0)	1(0.04)	1(0.1)	3
Gurnard Perch (F)	*Neosebastes nigropunctatus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.06)	1(0.1)	2(0.06)	1(0.1)	3
Dog Whelk (M)	*Pleuroploca austalasia*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.06)	1(0.1)	2(0.09)	2(0.2)	3
Porcupine Fish (F)	*Diodon nicthemerus*	0(0)	0(0)	1(0.05)	1(.12)	1(0.04)	1(0.1)	0(0)	0(0)	0(0)	0(0)	2
Scallop (M)	*Pecten fumatus*	0(0)	0(0)	0(0)	0(0)	1(0.04)	1(0.1)	1(0.06)	1(0.1)	0(0)	0(0)	2
Whiting (F)	*Sillaginodes punctata*	0(0)	0(0)	2(0.11)	2(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2
Sponge crab (C)	*Dromidiopsis australiensis*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.06)	1(0.1)	0(0)	0(0)	1
Flounder (F)	*Ammotretus rostratus*	0(0)	0(0)	1(0.05)	1(.12)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1
Weedy Whiting (F)	*Haletta semifasciata*	0(0)	0(0)	0(0)	0(0)	1(0.04)	1(0.1)	0(0)	0(0)	0(0)	0(0)	1
Octopus (M)	*Octopus maorum*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.06)	1(0.1)	0(0)	0(0)	1
Turban shell (M)	*Turbo torquatus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.06)	1(0.1)	0(0)	0(0)	1
Bait crab (C)	*Liocarcinus corrugatus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.04)	1(0.1)	1
Squid (M)	*Sepioteuthis australis*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.04)	1(0.1)	1
Abalone (M)	*Haliotis roei*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.04)	1(0)	1
Conch (M)	*unidentified*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.04)	1(0.1)	1

Table 13b. Total abundance and frequency of occurrence (% in brackets) of species taken as by-catch during fishery-independent pot surveys in Gulf St.Vincent.

Gulf St Vincent		**2002**		**2003**		**2004**		**2005**		**2006**		
C = Crustacean, F = Fish, E = Echinoderm, M=Mollusc		Lifts = 538		Lifts = 914		Lifts = 920		Lifts = 880		Lifts = 920		
Common name	**Scientific name**	**No.s**	**Freq**	**No.s**	**Freq**	**No.s**	**Freq**	**No.s**	**Freq**	**No.s**	**Freq**	**Total**
Rock crab (C)	*Nectocarcinus integrifrons*	1922(80.93)	340(63.2)	3994(84.07)	553(60.5)	6648(84.99)	733(79.7)	5844(80.22)	574(65.2)	3442(67.37)	521(56.6)	21850
Spider crab (C)	*Leptomithrax gaimardii*	352(14.82)	134(24.9)	307(6.46)	167(18.3)	440(5.63)	256(27.8)	657(9.02)	262(29.8)	903(17.67)	338(36.7)	2659
Leatherjacket (F)	*Acanthaluteres spilomelanurus*	46(1.94)	22(4.1)	83(1.75)	49(5.4)	368(4.7)	116(12.6)	442(6.07)	122(13.9)	433(8.48)	128(13.9)	1372
Sand crab (C)	*Ovalipes australiensis*	21(0.88)	11(2)	110(2.32)	22(2.4)	227(2.9)	50(5.4)	75(1.03)	23(2.6)	63(1.23)	18(2)	496
Red Mullet (F)	*Upeneichthys vlamingii*	18(0.76)	8(1.5)	134(2.82)	71(7.8)	32(0.41)	19(2.1)	96(1.32)	39(4.4)	22(0.43)	15(1.6)	302
Puffer Fish (F)	*Torguigener pleurogramma*	0(0)	0(0)	1(0.02)	1(0.1)	6(0.08)	4(0.4)	15(0.21)	11(1.3)	95(1.86)	42(4.6)	117
Fiddler (F)	*Trygonorhina fasciata*	4(0.17)	4(.7)	31(0.65)	30(3.3)	16(0.2)	15(1.6)	24(0.33)	23(2.6)	5(0.1)	5(0.5)	80
Cuttlefish (M)	*Sepia apama*	3(0.13)	3(0.6)	12(0.25)	12(1.3)	7(0.09)	6(0.7)	42(0.58)	31(3.5)	12(0.23)	12(1.3)	76
Flathead (F)	*Platycephalus bassensis*	1(0.04)	1(0.2)	6(0.13)	6(0.7)	23(0.29)	19(2.1)	9(0.12)	9(1)	32(0.63)	14(1.5)	71
Pt Jackson (F)	*Heterodontus portusjacksoni*	0(0)	0(0)	7(0.15)	7(0.8)	5(0.06)	5(0.5)	3(0.04)	3(0.3)	38(0.74)	29(3.2)	53
Cardinal Fish (F)	*Vincentia conspersa*	0(0)	0(0)	22(0.46)	16(1.8)	4(0.05)	4(0.4)	14(0.19)	12(1.4)	5(0.1)	5(0.5)	45
Rock ling (F)	*Genypterus tigerinus*	0(0)	0(0)	5(0.11)	5(0.5)	8(0.1)	7(0.8)	11(0.15)	11(1.3)	14(0.27)	13(1.4)	38
Starfish (E)	*Pateriella brevispina*	0(0)	0(0)	4(0.08)	4(0.4)	12(0.15)	8(0.9)	6(0.08)	6(0.7)	7(0.14)	7(0.8)	29
Balmain Bug (C)	*Ibacus peronii*	0(0)	0(0)	1(0.02)	1(0.1)	8(0.1)	8(0.9)	7(0.1)	7(0.8)	11(0.22)	6(0.6)	27
Soldier Fish (F)	*Gymnapistes marmoratus*	2(0.08)	2(0.4)	18(0.38)	18(2)	2(0.03)	2(0.2)	1(0.01)	1(0.1)	4(0.08)	4(0.4)	27
Beche De Mer (E)	*Stichopus mollis*	1(0.04)	1(0.2)	6(0.13)	6(0.7)	5(0.06)	5(0.5)	8(0.11)	8(0.9)	5(0.1)	5(0.5)	25
Trumpeter (F)	*Pelates sexlineatus*	1(0.04)	1(0.2)	0(0)	0(0)	0(0)	0(0)	7(0.1)	4(0.4)	4(0.08)	3(0.3)	12
Skate (F)	*Raja whitleyi*	0(0)	0(0)	2(0.04)	2(0.2)	0(0)	0(0)	5(0.07)	5(0.5)	2(0.04)	2(0.2)	9
Sea urchin (E)	*Heliocidaris erythrogramma*	0(0)	0(0)	3(0.06)	3(0.3)	2(0.03)	2(0.2)	0(0)	0(0)	4(0.08)	4(0.4)	9
Snapper (F)	*Pagrus auratus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2(0.03)	2(0.2)	4(0.08)	2(0.2)	6
Scallop (M)	*Pecten fumatus*	2(0.08)	2(0.4)	0(0)	0(0)	1(0.01)	1(0.1)	1(0.01)	1(0.1)	1(0.02)	1(0.1)	5
Hermit Crab (C)	*Pagguristies frontalis*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	4(0.05)	4(0.4)	0(0)	0(0)	4
Catfish (F)	*Cnidoglanis macrocephalus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	4(0.05)	4(0.4)	0(0)	0(0)	4
Top Shell (M)	*Calliostoma sp.*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	3(0.06)	3(0.3)	3
Seven Gill shark (F)	*Notoynchus cepedianus*	0(0)	0(0)	1(0.02)	1(0.1)	0(0)	0(0)	2(0.03)	2(0.2)	0(0)	0(0)	3
Turban Shell (M)	*Turbo torquatus*	0(0)	0(0)	0(0)	0(0)	3(0.04)	2(0.2)	0(0)	0(0)	0(0)	0(0)	3
Tunicate (A)	*unidentified*	0(0)	0(0)	0(0)	0(0)	2(0.03)	2(0.2)	0(0)	0(0)	0(0)	0(0)	2
Conch (M)	*unidentified*	0(0)	0(0)	0(0)	0(0)	2(0.03)	2(0.2)	0(0)	0(0)	0(0)	0(0)	2
Weedy Whiting (F)	*Haletta semifasciata*	1(0.04)	1(0.2)	1(0.02)	1(0.1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2
Squid (M)	*Sepioteuthis australis*	0(0)	0(0)	1(0.02)	1(0.1)	1(0.01)	1(0.1)	0(0)	0(0)	0(0)	0(0)	2
Shovelnose ray (F)	*Aptychotrema vincentiana*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2(0.03)	2(0.2)	0(0)	0(0)	2
Crested Weedfish (F)	*Cristiceps australis*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.01)	1(0.1)	0(0)	0(0)	1
Cowfish (F)	*Aracana aurita*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.01)	1(0.1)	0(0)	0(0)	1
Gurnard Perch (F)	*Neosebastes nigropunctatus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.02)	1(0.1)	1
Flounder (F)	*Ammotretus rostratus*	1(0.04)	1(0.2)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1
Stinkfish (F)	*Foetoreepus calauropomus*	0(0)	0(0)	1(0.02)	1(0.1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1
Whiting (F)	*Sillaginodes punctata*	0(0)	0(0)	0(0)	0(0)	1(0.01)	1(0.1)	0(0)	0(0)	0(0)	0(0)	1
Octopus (M)	*Octopus maorum*	0(0)	0(0)	1(0.02)	1(0.1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1
Gummy shark (F)	*Mustelus antarcticus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.01)	1(0.1)	0(0)	0(0)	1
Wobbegong (F)	*Orectolobus ornatus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.01)	1(0.1)	0(0)	0(0)	1
Abalone (M)	*Haliotis laevigata*	0(0)	0(0)	0(0)	0(0)	1(0.01)	1(0.1)	0(0)	0(0)	0(0)	0(0)	1
Dog Whelk (M)	*Pleuroploca austalasia*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.02)	1(0.1)	1
Catshark (F)	*Parascyllium ferrugineum*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.02)	1(0.1)	1
Cod (F)	*Pseudophycis bachus*	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0.02)	1(0.1)	1

ANOSIM tests validate the presence of different by-catch assemblages from Spencer Gulf and Gulf St. Vincent (Global R = 0.42, p = 0.01), and additionally confirm the presence of significantly different by-catches from commercial and research pots (Global R = 0.86, p < 0.01). They did not, however, detect any significant differences in the by-catch over time (Global R = - 0.14, p = 0.85).

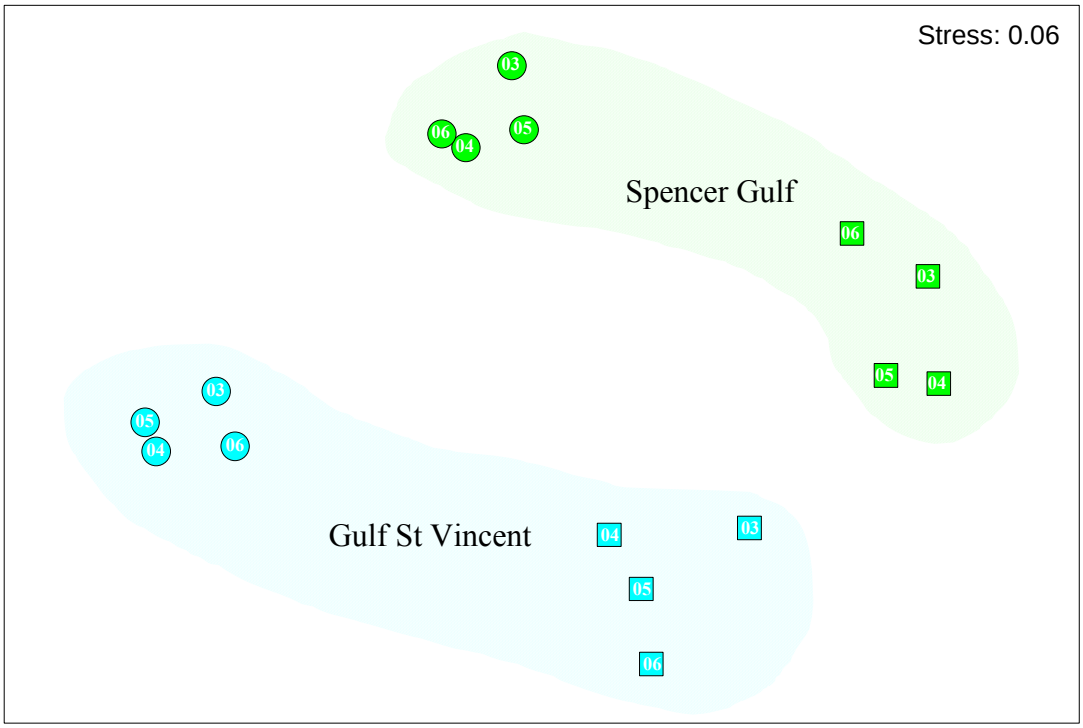


Figure 39. Non-metric MDS ordination of by-catch taken from research pots (circles) and commercial pots (squares) during four annual blue crab surveys (2003, 2004, 2005, 2006) in Spencer Gulf (green fill) and Gulf St. Vincent (blue fill). Numerals within each symbol indicate the year of the survey.

Similarity percentage (SIMPER) analyses were employed to identify those species that contributed most to differences between the two gulfs (Table 14) and between the two pot types (Table 15). Results of these analyses show that one species, the rock crab (*Nectocarcinus integrifrons*) accounts for most (>70%) of the dissimilarity between the two gulfs and two pot types. Rock crabs were, for example, nearly three times more abundant in Gulf St. Vincent than in Spencer Gulf, and were almost an order of magnitude more common in research pots than in commercial pots. Marked regional and gear related differences in spider crab (*Leptomithrax gaimardii*) abundances were also recorded, and accordingly this species of crab was also recognised as a major contributor to the community differences. Like the rock crab, spider crabs were markedly more abundant in Gulf St. Vincent than in Spencer Gulf, however unlike rock crabs they were generally more commonly taken in commercial rather than research pots. Two further by-catch species, the sand crab *Ovalipes australiensis* and the leatherjacket *Acanthaluteres spilomelanurus*, were also identified as making significant contributions to regional and pot-related differences in by-catch composition. Sand crabs did not differ markedly in abundance between research and commercial pots, but were notably more abundant in Gulf St. Vincent

than in Spencer Gulf. In contrast leatherjacket numbers did not vary much between gulfs but were more commonly captured in research pots than in commercial pots.

Table 14. Mean abundance of by-catch species contributing to >90% of the dissimilarity in community structure between Spencer Gulf and Gulf St. Vincent. Average dissimilarities and associated standard deviations (SD) for pair-wise comparisons are presented in this table, together with their percentage and cumulative contributions to the total dissimilarity between the two Gulfs (59.8).

Species	GSV Abundance	SG Abundance	Dissimilarity	S.D.	Contribution %	Cum. Contribution %
Rock crab	2491.0	902.5	42.1	1.7	70.5	70.5
Spider crab	288.4	36.6	9.9	1.1	16.6	87.0
Sand crab	59.4	0.8	2.2	1.1	3.6	90.6

Table 15. Mean abundance of by-catch species contributing to >90% of the dissimilarity in community structure between commercial and research pots. Average dissimilarities and associated standard deviations (SD) for pair-wise comparisons are presented in this table, together with their percentage and cumulative contributions to the total dissimilarity between the two Gulfs (70.4).

Species	Commercial Abund.	Research Abund.	Dissimilarity	S.D.	Contribution %	Cum. Contribution %
Rock crab	384.9	3008.6	58.4	3.9	82.9	82.9
Spider crab	171.4	153.6	4.9	1.0	7.0	89.9
Leatherjacket	7.3	142.8	2.6	1.4	3.6	93.5

4 PERFORMANCE INDICATORS

This section provides a report on the performance of the fishery against the interim performance indicators (PIs), target and limit reference points defined in the Management Plan and documented in Table 1.

There is currently one biological PI for the fishery (i.e. catch) and five PIs for the fishery in each of SG and GSV (i.e. relative exploitation rate, proportion of pre-recruits and sex ratio; the latter two calculated from both fishery-dependent and fishery-independent data).

Data were available to assess fishery performance against 9 of the 11 PI (Table 16). Four of these nine PI were below the target reference point. No data were available for determining the relative exploitation rate in either gulf.

The reported catch for 2005/06 was 619.3 t. This exceeds the limit reference point and is close to the target reference of 626.8 t (the TACC).

Pre-recruits (<110 mm CW) comprised 17.7% and 46.5% of the commercial and fishery-independent survey catch, respectively, in GSV during 2004/05. Similarly, female crabs comprised 31.8% and 39.9% of the commercial and fishery-independent survey catch, respectively, in GSV during the same period. All of these exceeded the target reference point.

Female crabs comprised 20.2% of the commercial catch and 24.9% of the fishery-independent catch in SG during 2004/05. Both these values were below the target reference point for the proportion of females in the catch. Levels of pre-recruitment in SG during 2004/05, determined from both the commercial catch (5.3%) and fishery-independent catch (11.5%), were also below the target reference point. In addition, both of these pre-recruit estimates were below the SG limit reference point.

Table 16. Assessment of the performance of the Spencer Gulf and Gulf St. Vincent blue crab fishery against the Performance Indicators prescribed in the Management Plan. Estimates that are below either interim target or limit reference values are indicated in bold.

Location	Indicator	Data source	Target reference	Limit reference	Value in 2005/06
GSV & SG	Catch	Commercial	TACC	80% of TACC	98.81%
GSV	Relative exploitation rate	No data	50% of 1994 level	100% of 1994 level	Not calculable
	Pre-recruitment (% undersized crabs in June & July)	Commercial	10%	5%	17.7%
		Fishery-independent			46.5%[1]
	Sex ratio (% female crabs in June & July)	Commercial	30%	15%	31.8%
		Fishery-independent			39.9%[1]
SG	Relative exploitation rate	No data	40% of 1994 level	80% of 1994 level	Not calculable
	Pre-recruitment (% undersized crabs in June & July)	Commercial	30%	15%	**5.3%**
		Fishery-independent			**11.5%**[1]
	Sex ratio (% female crabs in June & July	Commercial	30%	15%	**20.2%**
		Fishery-independent			**24.9%**[1]

[1] *Estimate determined from catches in commercial pots only.*

5 GENERAL DISCUSSION

5.1 STATUS OF THE BLUE CRAB FISHERY

This report provides evidence that the sub-populations of blue crabs in SG and GSV are being harvested within sustainable limits. Data from the fishery-independent surveys show that the abundance of crabs has increased in SG for the first time since 2002. This increase was recorded in both commercial and research pots, and was evident in male, female, legal and undersized crabs. Similar increases in the abundance of males, females, legal and undersized crabs were observed in GSV during 2005/06. It is likely that these changes reflect increases in abundance and recruitment in both SG and GSV in 2005/06, however it should also be noted that a range of other biotic and abiotic factors can also influence the abundance and availability of crabs.

Stock assessment of the BCF is supported by documentation of the commercial fishery, catch and effort data from 1983/84, and fishery-independent surveys in GSV and SG since 2002. However, lack of data on the magnitude of the illegal and recreational catch, limitations of the commercial catch, effort and size data, the paucity of biological and ecological data for blue swimmer crabs in SA and the unsuitability of the current PIs hinder the assessment of this fishery. The recent introduction of an industry-sampling program to provide additional information on the size frequency of the catch has the potential to reduce the uncertainty of future assessments. However, the main priority for improving future assessments is to report against revised PIs and reference points and to reassess the fishery on the basis of the two genetically separate stocks.

5.2 CURRENT PERFORMANCE INDICATORS

Catch is a useful PI for the fishery, but the usefulness of the PIs of the relative exploitation rate, proportion of pre-recruits and sex ratio is limited. Relative exploitation rate cannot be calculated reliably. Proportion of pre-recruits is not a useful measure of recruit abundance as it is confounded by the effects of changes in adult abundance. Sex ratio (% females in June and July) does not provide significant insights into the status of the fishery.

Revising the PIs is a high priority for the BCF. Catch should be maintained as a PI, but should be reported separately for each gulf. CPUE of legal-sized crabs in commercial fishing and fishery-independent surveys would provide better PIs for crab abundance than relative exploitation rate. The CPUE of under-sized crabs in commercial fishing and fishery-independent surveys would be better indicators of recruit abundance than the proportion of recruits. Other PIs that could be considered include the mean size of legal- and under-sized crabs in commercial catches and fishery-independent surveys.

A suite of PIs that included catch, and the catch rates of legal- and under-sized crabs in the commercial fishery and fishery-independent surveys would provide a well balanced framework for assessing the status of the resource and fishery in each gulf. Catch rate data from the fishery-independent surveys provides valuable information on the spatial patterns of distribution and abundance of crabs and, importantly, the

sampling regime can be standardised to ensure that effective effort does not change over time. The main limitation of the fishery-independent data is that catch rates are estimated for a "snapshot" in time only and inter-annual variations can reflect differences in environmental conditions, especially water temperature, during surveys as well as changes in abundance. Catch rate data from the commercial fishery has the advantage of being obtained across the entire fishing season, however inter-annual variations can reflect differences in efficiency (effective effort) as well as changes in abundance. Hence, the catch rates of legal- and under-sized crabs in the commercial fishery and fishery-independent surveys would provide complimentary PIs. One option for structuring the future management framework would be to use the universal means for each parameter (i.e. CPUE for legal- and under-sized crabs in the commercial fishery and fishery-independent surveys) as the primary PIs and to use the means for spatial and temporal sub-components of each parameter (e.g. zonal catch rates in fishery-independent surveys, monthly catch rates during commercial fishing) as secondary or explanatory indicators.

5.3 BY-CATCH

None of the 52 by-catch species obtained during the fishery-independent surveys since 2001 are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as Threatened, Endangered or Rare. Most by-catch is returned to the water alive, but their subsequent fate is uncertain and may warrant further investigation. The main species taken as by-catch are rock crabs *Nectocarcinus integrifrons*, spider crabs *Leptomithrax gaimardii* and leatherjackets *Acanthaluteres spilomelanurus*.

5.4 FUTURE RESEARCH NEEDS

The most pressing need for future assessment of the BCF is to revise the PIs and reference points for the fishery, and to establish agreed statistical methods for analysing changes in the catch rates of undersized and legal crab. There is also a need to assess the effectiveness of the newly introduced voluntary pot-sampling program, and for obtaining up-to-date information on the magnitude of the recreational catch.

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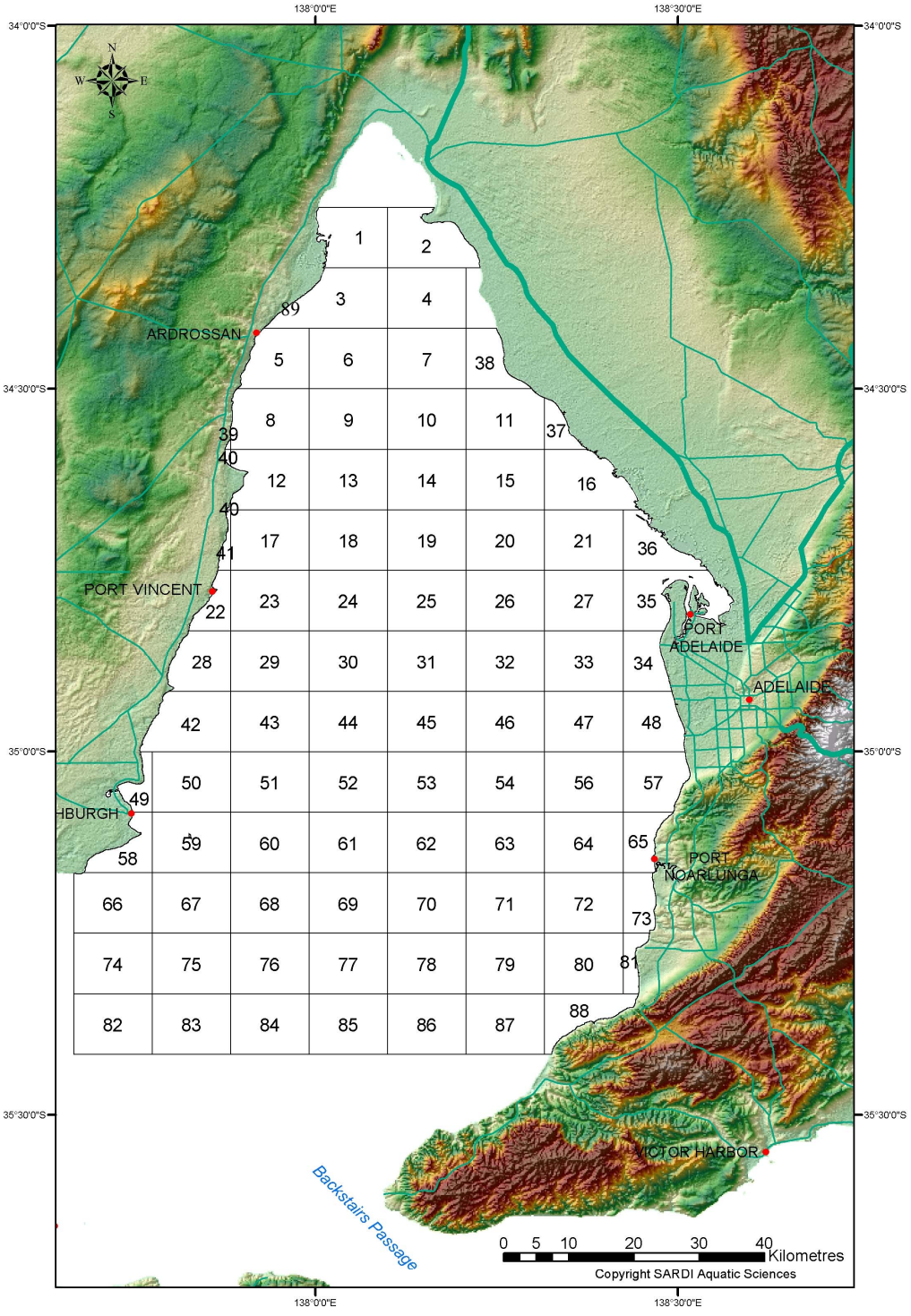
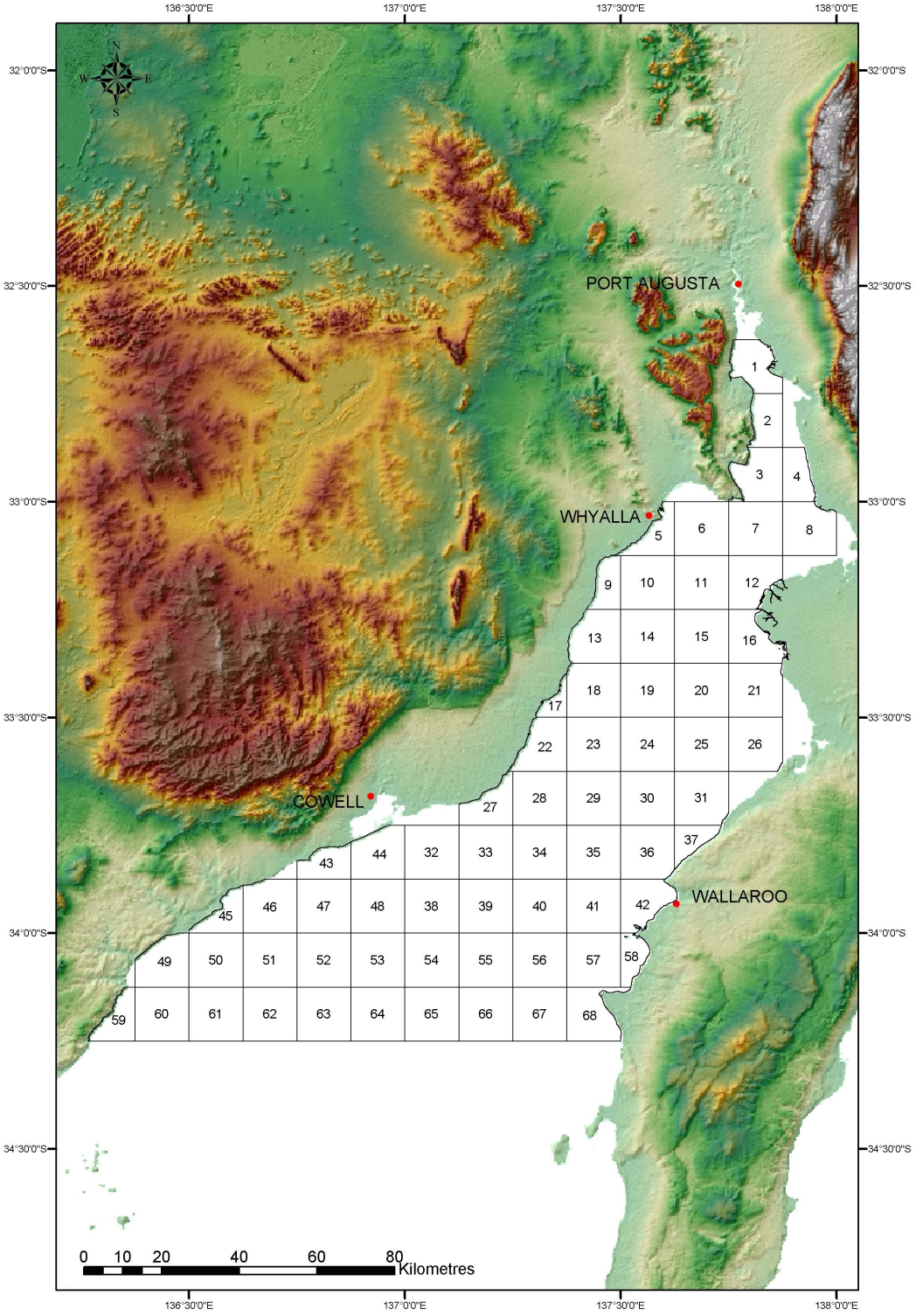
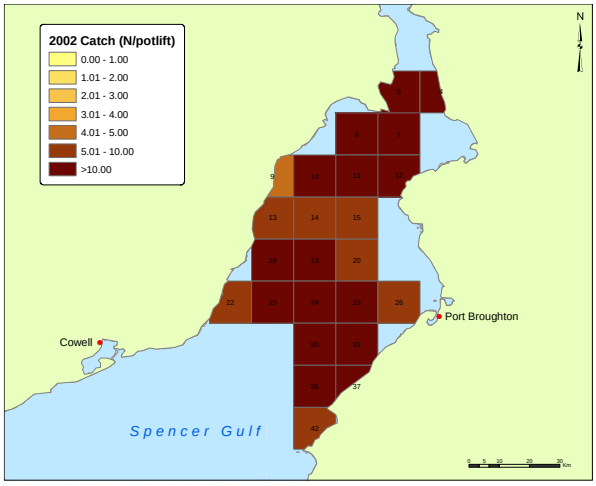
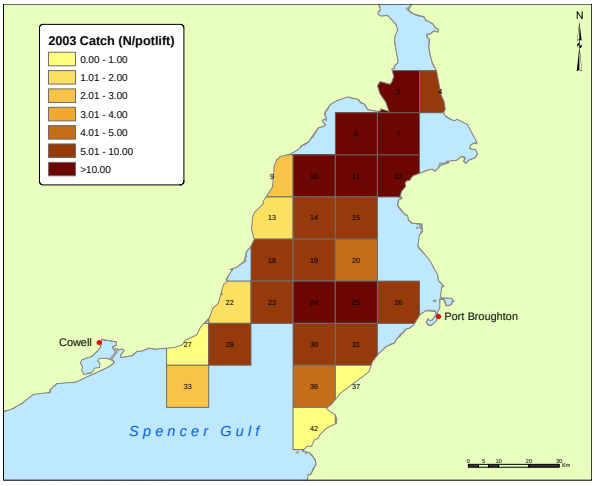


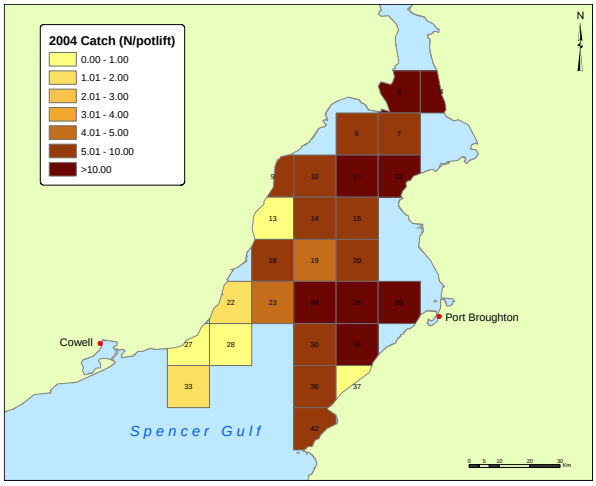
Appendix 1. The commercial fishing blocks for the blue crab fishery in Gulf St. Vincent.

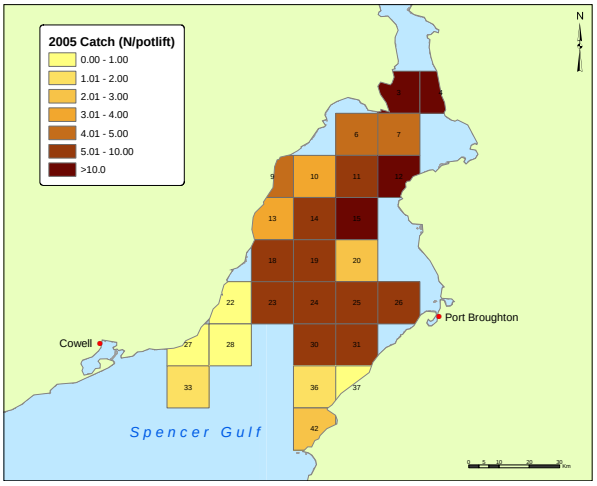


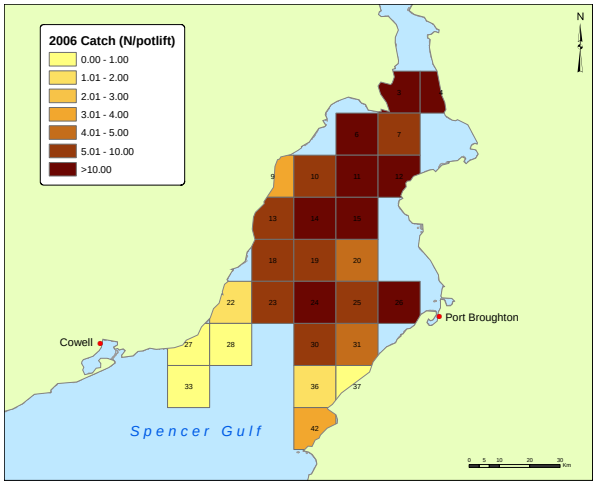
Appendix 2. The commercial fishing blocks for the blue crab fishery in Spencer Gulf.



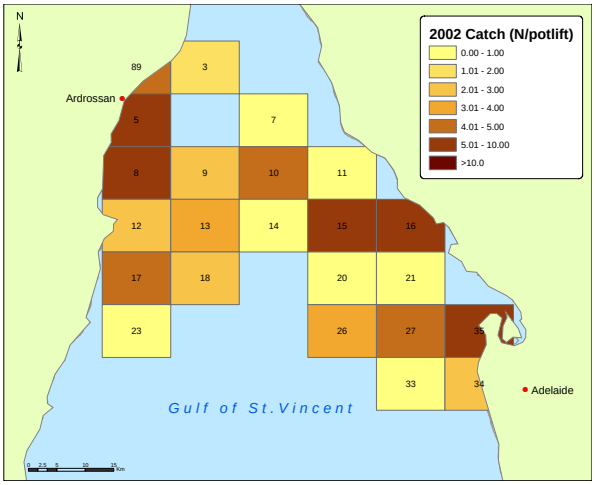


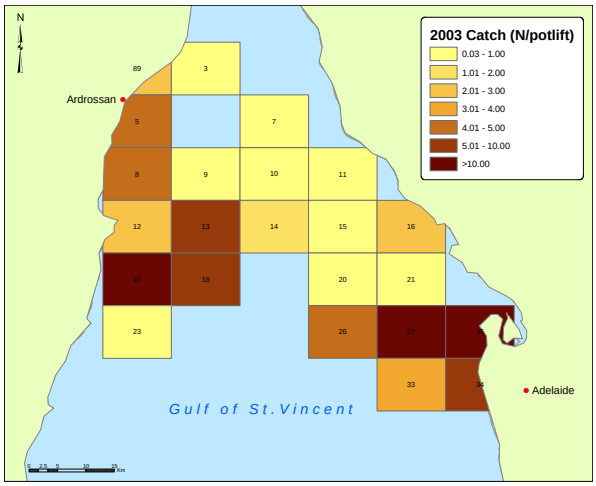


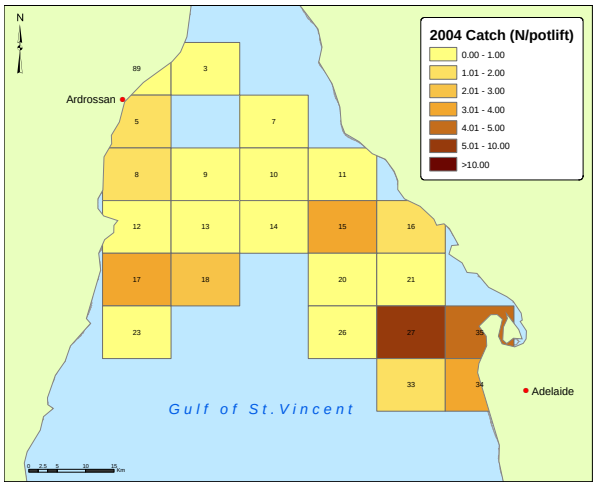


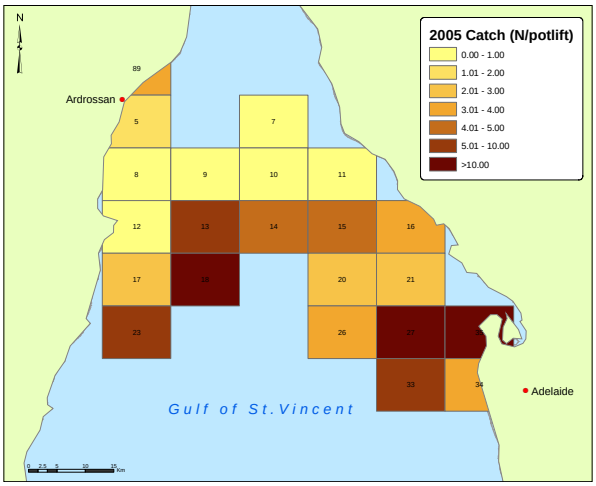


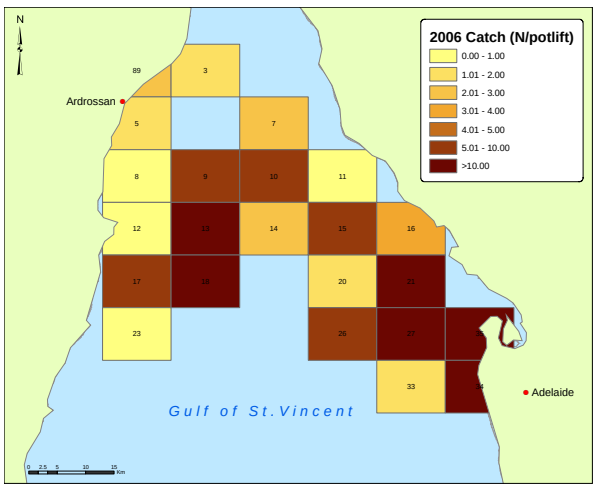
Appendix 3a. Distributional maps showing inter-annual variation in Blue Crab survey catches (Number.potlift^{-1}) in Spencer Gulf.











Appendix 3b. Distributional maps showing inter-annual variation in Blue Crab survey catches (Number.potlift^{-1}) in Gulf St. Vincent.