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Blue Crab (*Portunus armatus*) Fishery 2013/14

C. L. Beckmann and G. E. Hooper

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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

April 2015

Fishery Assessment Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.sardi.sa.gov.au

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Author(s): C. L. Beckmann and G. E. Hooper

Reviewer(s): L. McLeay, C. Noell (SARDI) and K. Rowling (PIRSA)

Approved by: S. Mayfield
Science Leader - Fisheries

Signed: 

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EXECUTIVE SUMMARY

This fishery assessment report updates the 2012/13 report, providing an assessment of the current status of the Spencer Gulf and Gulf St Vincent fishing zones of the South Australian Blue Crab Fishery (BCF).

In 2013/14, 98.8% of the total allowable commercial catch (TACC) of the BCF was harvested, with the Spencer Gulf and Gulf St Vincent pot fishing zones harvesting 99.6% and 97.3% of their share of the TACC, respectively. The pot fishing zone currently holds >99% of the TACC, with some licence holders in the Marine Scalefish Fishery making up the remainder.

There are three performance indicators (PIs) for the fishery, all of which provide a measure of relative biomass or abundance of legal-size or pre-recruit crabs: 1) survey catch per unit effort (CPUE) of legal-size crabs; 2) survey CPUE of pre-recruit crabs; and 3) commercial CPUE of legal-size crabs. The first two indicators, which are derived from fishery-independent surveys, are the most reliable measures of biomass and stock status due to the consistent timing of the survey (i.e. during June or July), pot type used and sampling location and spatial coverage in each gulf. In contrast, the third PI, which is derived from commercial catch and effort data, provides a less reliable index of abundance of legal-size crabs due to historical changes in gear and vessel technology, fisher demographics, experience and behavior, and temporal and regional changes in the distribution of catch and effort.

The 2014 Spencer Gulf survey yielded an average CPUE of 10.00 legal-size crabs/potlift and 9.45 pre-recruits/potlift. Both of these PIs were above the upper reference points, indicating high relative biomass levels. In 2013/14, almost the entire Spencer Gulf component of the TACC for the fishery was caught for the tenth consecutive year and commercial CPUE remained at a high level. Using the national framework for stock status reporting, the Spencer Gulf fishing zone of the BCF is classified as ‘sustainable’.

There are multiple lines of evidence that the relative biomass of blue swimmer crabs in Gulf St Vincent has increased: 1) the survey CPUE of legal-size crabs increased from 1.45 legal-size crabs/potlift in 2013 to 2.54 legal-size crabs/potlift in 2014, the highest value since 2010 (3.11 legal-size/potlift) and above the limit reference point; 2) survey CPUE of pre-recruits increased from 1.23 pre-recruits/potlift in 2013 to 2.12 pre-recruits/potlift in 2014, the highest value since 2011 and above the limit reference point; and 3) commercial catch rates increased in the central and southern regions of the gulf. Thus, using the national framework for stock status reporting, the Gulf St Vincent fishing zone of the BCF is classified as ‘sustainable’. While this reflects a substantial improvement in stock status from 2012/13,

there is evidence that the stock is still in a rebuilding phase. This is because the abundance of pre-recruits in the 2014 survey remained among the lowest values on record and the recent increases in pre-recruit and legal-size abundance observed in the 2014 fishery-independent survey were spatially limited compared to their historical distribution.

1. INTRODUCTION

1.1. Overview

This annual report is the tenth version updated since 2004 as part of the SARDI Aquatic Sciences' ongoing assessment program for the South Australian Blue Crab Fishery (BCF) (Svane and Hooper, 2004; 2005; Currie and Hooper, 2006; Currie *et al.*, 2007; Dixon *et al.*, 2008; Dixon and Hooper, 2009; 2010; 2011; Dixon *et al.*, 2012; Dixon *et al.*, 2013; Noell *et al.*, 2014). The report: 1) synthesises information for the BCF for each of the Spencer Gulf and Gulf St Vincent pot fishing zones; 2) assesses the current status of the blue swimmer crab resource in each gulf and considers the uncertainty associated with each assessment; 3) comments on the current biological performance indicators (PIs) and reference points for the fishery; and 4) identifies future research needs.

This report comprises four sections. Section 1 provides an historic account of the BCF, the management of the fishery, a synopsis of the biology of the target species, the blue swimmer crab *Portunus armatus*, and an overview of the information sources and PIs used for fishery assessment. Section 2 provides the methods of data collection and analyses used in the stock assessment surveys (fishery-independent), and the commercial logbook data and pot-sampling programs (fishery-dependent). Section 3 presents the results of the data analyses in four subsections: 1) annual catch and effort (for both gulfs); 2) detailed analyses of fishery-independent and fishery-dependent data for Spencer Gulf; 3) detailed analyses of fishery-independent and fishery-dependent data for Gulf St Vincent; and 4) assessment of the PIs for the Spencer Gulf and Gulf St Vincent pot fishing zones. Finally, the information presented in the preceding sections is synthesised to determine the status of the resource, harvest strategy development in the context of stock status is discussed and future research priorities are identified.

1.2. History of the fishery

1.2.1. Commercial fishery

The blue swimmer crab, *Portunus armatus*, previously *P. pelagicus* (Lai *et al.*, 2010), was first harvested as by-product in South Australian prawn and marine scalefish fisheries in the 1970s. In 1981, an experimental trawl fishery with four licensed fishers was established in northern Spencer Gulf. This approach was later abandoned, and in 1983, six experimental pot fishing permits were offered to licence holders in the Marine Scalefish Fishery (MSF). In 1985/86, the number of experimental licences was increased to 12 (i.e. four on the West Coast, six in Spencer Gulf, and two in Gulf St Vincent). In 1986, the West Coast fishery

declined and the four licence holders surrendered their entitlements. Also during 1986, the sale of blue swimmer crab as by-product from the prawn fisheries was prohibited.

In June 1996, management arrangements for a separate commercial blue crab fishery in South Australia were established. A management strategy and research program was implemented to support the development of a sustainable fishery. In 1997, Primary Industries and Resources South Australia (Fisheries) proposed a three-year developmental strategy where the potential capacity to expand the fishery was determined through a research program and commercial fishing.

The BCF is based on the capture of a single species (*P. armatus*), although other crab species may also be landed. The fishery comprises two fishing zones; i.e. Spencer Gulf and Gulf St Vincent (**Figure 1.1**). An annual total allowable commercial catch (TACC) or 'quota' is determined for the BCF for the 12-month period from 1 July to 30 June, with separate quota units allocated for each fishing zone. Almost all the TACC (99%) is allocated among the BCF licence holders (also referred to as 'pot fishers'), with the remainder allocated to some MSF licence holders. The *Fisheries Management (General) Regulations 2007* state that blue swimmer crab may also be taken from State waters within three nautical miles of the coast west of longitude 135°E, although this 'West Coast' region of South Australia is not subject to quota management arrangements.

Commercial pot fishers generally haul their gear once or twice every 24 hours using specifically designed crab pots covered with mesh. Marine scalefish fishers use either hoop or drop nets hauled every 20-30 minutes. Blue swimmer crabs are stored live in tanks, iced down uncooked, or cooked before being landed at port.

Most of the commercial catch is sold on the domestic market, primarily in the Sydney and Melbourne fish markets. In 2013/14, 628 t of blue swimmer crab valued at approximately $4.54M were harvested from South Australian State waters (SARDI unpublished data). This value includes commercial quantities of blue swimmer crabs taken from the West Coast, which is not part of the TACC for the BCF.

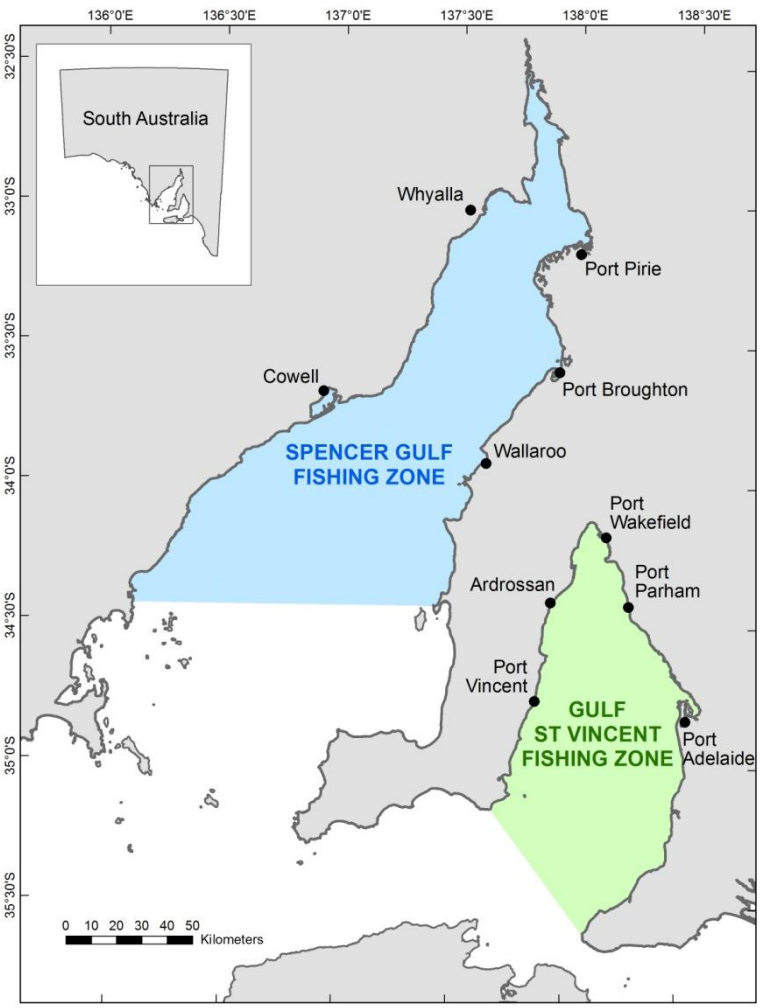

Figure 1.1. Spencer Gulf and Gulf St Vincent fishing zones of the South Australian Blue Crab Fishery.

1.2.2. Recreational fishery

The most recent state-wide recreational fishing survey in South Australia was conducted from November 2007 to October 2008 by Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture (Jones, 2009). Retained catch of blue swimmer crab for this period was estimated at 1,144,837 individuals comprising an estimated weight of 283.7 t. This estimate represents 29.8% of the total annual catch if added to the commercial catch of 2007/08 (Jones, 2009). Of the recreational catch, 48% was caught from Spencer Gulf, 46% from Gulf St Vincent and Kangaroo Island, and 6% from the West Coast.

Two other recreational fishing surveys were undertaken in South Australia prior to the 2007/08 survey. The '*National Recreational and Indigenous Fishing Survey*' was conducted between May 2000 and April 2001 (Henry and Lyle, 2003). The annual catch taken by recreational fishers in South Australia was estimated at 389.8 t, which, when combined with the commercial catch during 2000/01, represented 37.5% of the total catch. Also,

McGlennon and Kinloch (1997) estimated an annual recreational catch of 161.2 t, of which 115.8 t was taken in Gulf St Vincent and 45.4 t in Spencer Gulf. This estimate was derived from a vessel survey only and does not include the recreational shore-based fishery, thus making it difficult to compare with the more comprehensive surveys of 2000/01 and 2007/08.

1.3. Management of the fishery

1.3.1. Legislation

As with all of South Australia's fisheries and aquatic resources, the *Fisheries Management Act 2007* ('the Act') provides the statutory framework for management of the South Australian blue swimmer crab resource. The schemes of management for the fishery are prescribed in the *Fisheries Management (Blue Crab Fishery) Regulations 1998* and the *Fisheries Management (Marine Scale Fisheries) Regulations 2006*, while general regulations pertaining to commercial and recreational take of blue swimmer crabs from State waters are described in the *Fisheries Management (General) Regulations 2007*.

1.3.2. Management history

Several fishing sectors have had historic access to the blue swimmer crab resource in South Australia, including marine scale and prawn fishers. The BCF was established in 1996, with formalised management arrangements that included pot restrictions, formation of two fishing zones (Spencer Gulf and Gulf St Vincent) and a single TACC with quota units allocated separately for each zone. Quota is transferable between the pot fishers of the BCF and eligible MSF licence holders, but only within the same zone.

When quota was first introduced in 1996/97, there were four licensed pot fishers in the Spencer Gulf and two in the Gulf St Vincent. Additional licences were added in 2001/02 (Spencer Gulf), 2002/03 and 2007/08 (Gulf St Vincent) to make up the current numbers of five and four licences for the Spencer Gulf and Gulf St Vincent pot fishing zones, respectively. Since the introduction of quota in the BCF, there has been a transfer of fishing effort from the MSF to the pot fishing sector, with the number of MSF licences holding blue crab quota steadily decreasing from 29 to 3.

1.3.3. Current management arrangements

The TACC for the BCF was initially set by PIRSA Fisheries at 520 t for the 1996/97 fishing season. Over the next four quota years the TACC gradually increased to 626.8 t in 2000/01, where it remained until 2012/13. In 2013/14 the TACC was reduced by 20% in Gulf St Vincent and this resulted in a reduction of the fishery-wide baseline quota to 577 t. A

voluntary commercial closure in Gulf St Vincent was also implemented from 1 July 2013 to 15 January 2014.

The minimum legal size (MLS) for blue swimmer crabs is 11 cm carapace width, measured from the anterior base of the first spine. All licensed and unlicensed persons are prohibited from retaining egg-bearing females. All licensed fishers are prohibited from taking blue swimmer crabs during closed seasons for the commercial fishing zones (Spencer Gulf: 21 December to 19 February; Gulf St Vincent: 1 November to 15 January). Recreational fishers are restricted to a bag limit of 40 crabs (blue swimmer crabs and/or sand crabs combined) per person per day and a boat limit of 120 crabs per day in Spencer Gulf. Concurrent with the reduction in quota for the Gulf St Vincent pot fishing zone, recreational bag and boat limits for Gulf St Vincent have been reduced by 50%, to 20 and 60 crabs per day, respectively.

1.3.4. Management Plan

The Management Plan for the BCF (PIRSA, 2012) was recently prepared by the Fisheries Council of South Australia as required under the Act.

The four primary goals for the BCF as provided in the Management Plan are to:

1. ensure the blue swimmer crab resource is harvested within ecologically sustainable limits;
2. allocate access to the blue swimmer crab resource to achieve optimum utilisation and equitable distribution to the benefit of the community;
3. minimise impacts on the ecosystem; and
4. cost-effective and participative management of the fishery.

An important component of the Management Plan is the harvest strategy. The harvest strategy for the BCF is designed to implement a precautionary approach to managing the fishery and to set the TACC at a level that aims to ensure stock sustainability, as well as certainty and stability for the industry, which relate to Goals 1 and 2 (and associated objectives) of the Management Plan.

Key biological PIs and reference points have been established to guide the annual TACC decision-making process (**Table 1.1**). Harvest decision rules stipulate that if the limit reference point for any PI is not achieved, PIRSA Fisheries and Aquaculture and the South Australian Blue Crab Pot Fishers' Association (SABCPFA) will review the TACC and consider the possibility of a decrease from the baseline TACC of 626.8 t. This is deemed to be a precautionary response in the Management Plan that reflects the current level of

understanding about the species, fishery production and dynamics, and the limitations of existing fishery data. One of the aims of this report is to assess the performance of the fishery in terms of the PIs and reference points specified in the Management Plan.

Table 1.1. Key biological performance indicators and reference points for the Blue Crab Fishery. Abbreviation: CPUE, catch per unit effort; SG Spencer Gulf; GSV, Gulf St Vincent.

Gulf	Data source	Performance indicator	Limit ref. point	
			Lower	Upper
SG	1. Fishery-independent survey	CPUE of legal-size crabs (legal-size crabs/potlift)	5	8
	2. Fishery-independent survey	CPUE of pre-recruits (pre-recruits/potlift)	2	9
	3. Commercial catch and effort	CPUE of legal-size crabs (kg/potlift)	2	4
GSV	1. Fishery-independent survey	CPUE of legal-size crabs (pre-recruits/potlift)	1.5	4
	2. Fishery-independent survey	CPUE of pre-recruits (legal-size crabs/potlift)	1.5	8.5
	3. Commercial catch and effort	CPUE of legal-size crabs (kg/potlift)	2	4

The Management Plan provides a strategic direction for management of the fishery. In addition to providing details of the current harvest strategy, it emphasises the need to improve the quality of both fishery-dependent and fishery-independent information, thereby building scientific knowledge and developing a future harvest strategy that comprises more robust fishery PIs and reference points that are explicitly linked to TACC decisions. Explicit TACC decision rules in the future will provide greater certainty on how the fishery will be sustainably managed under the quota management system.

1.4. Biology of the blue swimmer crab

1.4.1. Taxonomy

The blue swimmer crab *Portunus armatus* (A. Milne Edwards, 1861) (formerly *Portunus pelagicus* Linnaeus, 1758; Lai *et al*., 2010) is decapod crustacean of the infra-order Brachyura and belongs to the Portunidae family. Blue swimmer crabs have five pairs of legs (i.e. a decapod). The first pair is the chelae or claws, the following three pairs are walking legs and the last pair is modified as swimming paddles. The carapace is rough in texture, broad and has a prominent projection/spine on each side. They are active swimmers, but bury in the sediment while resting, 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 1.2**). A detailed description of this species is provided by Stephenson (1972).

Figure 1.2. Differences in coloration and claw size between male (top) and female (bottom) blue swimmer crabs (*Portunus armatus*).

1.4.2. Distribution and stock structure

The blue swimmer crab is distributed within near-shore, marine embayments and estuarine systems in Australia and New Caledonia (Lai *et al*., 2010). In the relatively cold, temperate waters of South Australia, rates of growth and reproduction increase in response to rising water temperatures during the warmer months of the year, while reducing during the colder winter months.

Blue swimmer crabs occur in a wide range of algal and seagrass habitats, and on sandy and muddy substrata, from the intertidal zone to a depth of at least 50 m (Williams, 1982; Edgar, 1990). In coastal waters, smaller crabs are generally found in shallow waters less than 1 m, while adults are found in deeper waters. Juvenile blue swimmer 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 carapace width. Within South Australia, there is a distinct seasonal pattern of movement of adult blue swimmer crabs into shallow inshore waters during the warmer months of September to April, and out to deeper offshore waters during the cooler months of May to August (Smith, 1982).

Using allozyme markers, Bryars and Adams (1999) determined that the populations of *P. armatus* within Spencer Gulf, Gulf St Vincent and West Coast regions of South Australia represented separate sub-populations with limited gene flow. They also found that inter-

regional larval dispersal is restricted, and each sub-population is most likely dependent on its own larval supply.

Using microsatellite markers, Chaplin *et al.* (2001) found that the assemblages of *P. armatus* in different embayments in South Australia constituted genetically different meta-populations, which suggests that the level of migration between these populations is probably limited and likely to be determined by local factors.

1.4.3. Reproductive biology

Male and female blue swimmer crabs generally reach sexual maturity at carapace widths of 70 and 90 mm, respectively, when they are approximately one-year old (Currie and Hooper, 2006). The male and female 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 6–8 hour period (Meagher, 1971).

The spawning season lasts for three to four 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, blue swimmer crabs close to the maximum legal size (MLS, 11 cm carapace width) 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).

Development of the ovaries appears to be triggered by rising water temperature 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, for another portunid, the Chesapeake blue crab *Callinectes sapidus*, the sperm in the female spermatheca could remain viable for at least 12 months. This is likely to also be the case for the blue swimmer crab. Egg extrusion is independent of the timing of copulation.

Ovarian development can be classified by five visually distinguishable stages (see Sumpton *et al.*, 1994, and Figure 1.4):

1. Stage I: gonad immature, white or translucent;
2. Stage II: gonad maturing, light yellow/orange, not extending into hepatic region;
3. Stage III: gonad maturing, yellow/orange, not extending into hepatic region;
4. Stage IV: gonad mature, dark yellow/orange, extending into hepatic region; and
5. Stage V: ovigerous, female bearing fully matured eggs (pale to dark yellow/grey), carried externally.

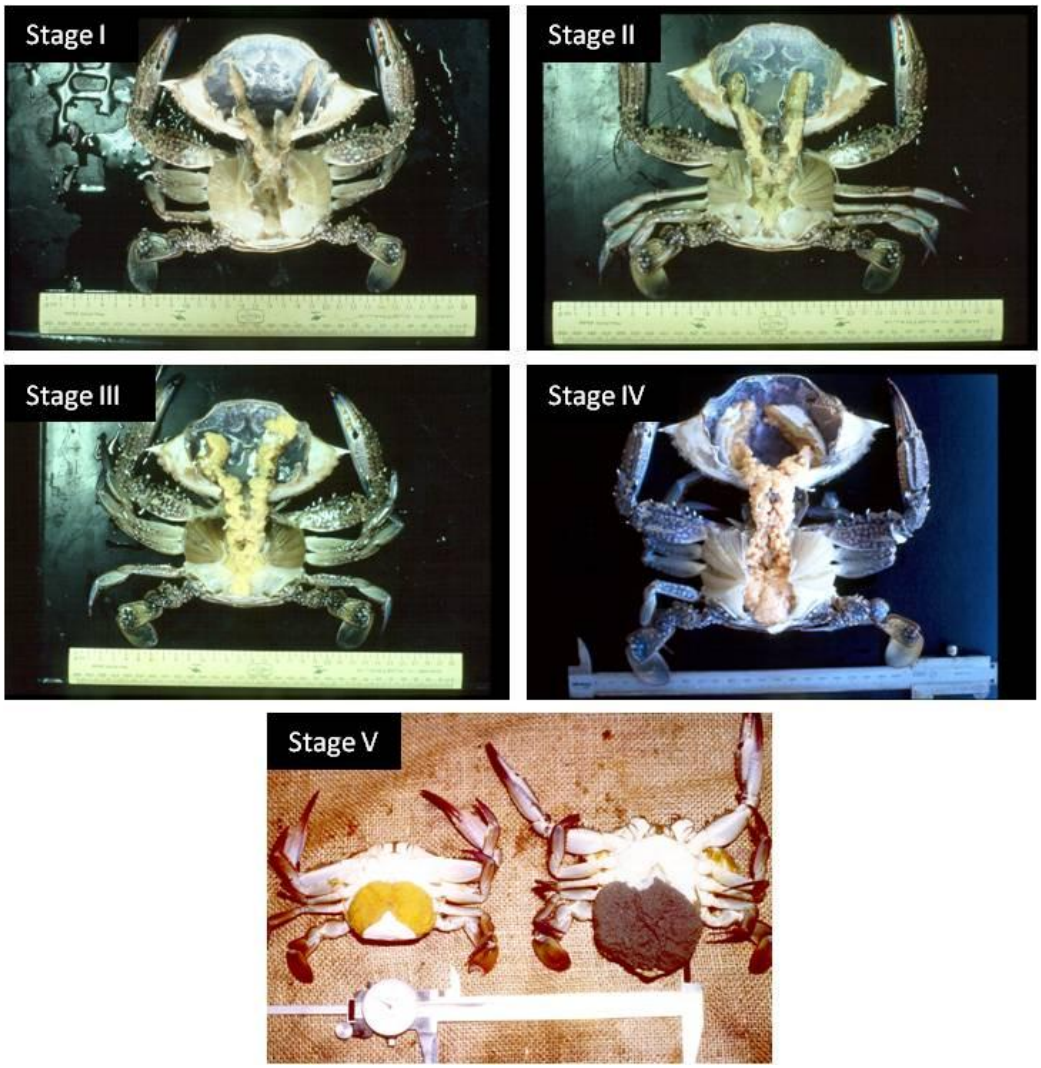

Figure 1.3. The five ovarian stages of the blue swimmer crab (Kumar *et al.*, 2000).

In tropical waters, female blue swimmer crabs carry eggs throughout the year, however, seasonal variation in the number of egg-bearing females can be observed (Kumar *et al.*, 2000). During embryonic development (Stage V), the colour of the eggs change from yellow to a dark grey (**Figure 1.3**).

In South Australia, blue swimmer crabs at Stage IV of ovarian development were observed in late October to November in conjunction with rising seawater temperatures (Kumar *et al.*, 2000). In samples collected during November, 80% of crabs were Stage III or Stage IV, of which more than 40% were at advanced Stage IV. Egg-bearing females are observed throughout the year but peak in late spring. Commercial logbook catch data from July 1997 to June 2005 indicate that high proportions of berried females are observed in October in Gulf St Vincent and November in Spencer Gulf (**Figure 1.4**). This pattern was consistent between these years.

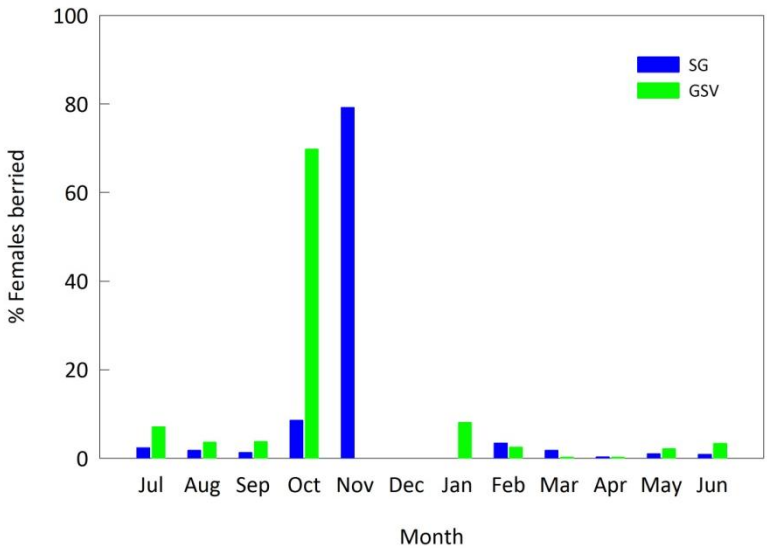

Figure 1.4. Monthly mean percentage of berried female blue swimmer crabs in commercial catches from each gulf from 1997/98 to 2004/05.

Kumar et al. (2000; 2003) found that the fecundity of female blue swimmer crabs was size-dependent, increasing up to a carapace width of 134 mm and decreasing thereafter, with females producing between 650,000 and 1,760,000 eggs per spawning. From 105 mm to 125 mm fecundity was shown to increase by 83.9%, indicating that a single large female can produce as many eggs as two small females (Kumar *et al.*, 2003).

Blue swimmer crabs 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, Kumar *et al.* (2003) found that some carried developing oocytes at Stages II and III in the ovary while also carrying an external egg mass (Kumar *et al.*, 2003). Although blue swimmer crabs are capable of producing more than one batch of eggs in a season, successive ovulations do not always occur (Meagher, 1971).

1.4.4. Length-weight relationship

The relationships between carapace width (mm) and weight (g) for male and female blue swimmer crabs from Spencer Gulf and Gulf St Vincent were determined from a sample of 582 individuals of size range 52-149 mm (SARDI unpublished data, 2009), and were described by the power curve: weight = $a \times$ carapace width^b. The length to weight relationship differed between the sexes but was consistent among gulfs (**Figure 1.5**). In both gulfs, male blue swimmer crabs grew to a larger total weight for a given carapace width.

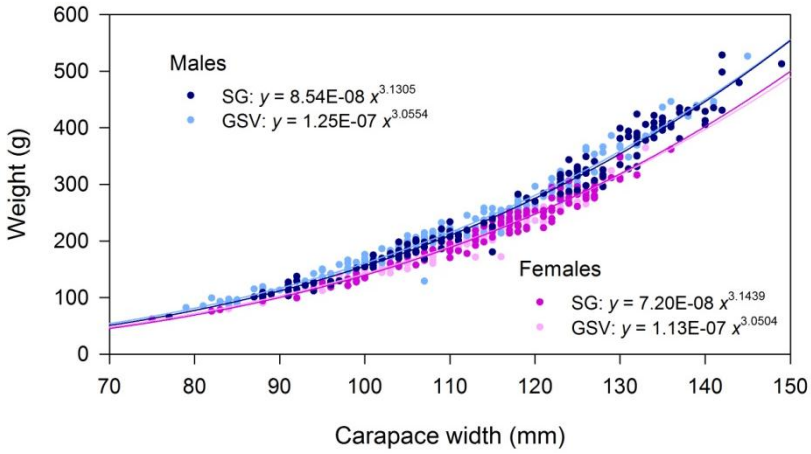

Figure 1.5. Length-weight relationships of male and female blue swimmer crabs from Spencer Gulf and Gulf St Vincent.

1.4.5. Parasites

Levels of parasitism in South Australian blue swimmer crab populations have yet to be examined, however, the parasites of some decapod crustaceans can cause sterilisation of their host, and can have an important impact on the population of an infested species (Gaddes and Sumpton, 2004). The barnacle *Sacculina granifera* is a known parasitic castrator of blue swimmer crabs, and can have a marked effect on gonad development and growth in Australian populations (Shields and Wood, 1993). Parasitic dinoflagellates in the genus *Hematodinium* are also known to infect blue swimmer crabs causing 'bitter crab disease' (Shields, 1992). A *hematodinium*-like parasite was identified in blue swimmer crabs from Gulf St Vincent in 2015 (Shane Roberts, pers. comm.). This disease is typically lethal because of the pathological alterations which occur to organs, tissues and hemolymph (Small, 2012; Butler *et al.*, 2014). Major outbreaks can result in significant impacts on host populations and prevalence is usually highest in juveniles (Small, 2012). Although the prevalence and impact of *Hematodinium* infection has not been quantified in South Australia, similar infections have negatively affected a number of commercial crustacean fisheries in the United States and Europe (Stentiford and Shields, 2005).

1.5. Previous fishery assessments

The first report on the BCF was published in 1987 by the South Australian Department of Fisheries (Grove-Jones, 1987). The fishery was later reviewed in 1994 by Baker and Kumar (1994). SARDI completed the first fishery assessment report for the BCF in 1998 (Kumar *et al.*, 1998), based predominantly on summaries of catch and effort information. These brief reports were then published annually until 2003 (Kumar *et al.*, 1999a; 1999b; Boxshall *et al.*, 2000; 2001; Hooper and Svane, 2003).

Since 2004, fishery assessment reports have documented the biology and management of the BCF in South Australia, presented analyses of commercial logbook and fishery-independent survey data, and provided assessment against the PIs of the management plan for the fishery (PIRSA, 2012). Since 2008, the report has presented information and conclusions for each gulf separately and included information gathered from the fishery-dependent pot-sampling program. Since 2010, the report has provided spatial information, for commercial catch and effort data.

The annual stock assessment report provides the information required to make decisions in accordance with the TACC decision rules provided in the harvest strategy. The report is prepared for PIRSA Fisheries and Aquaculture, and presented to PIRSA and industry each year to inform the TACC decision and supporting research program (in line with the strategic research plan in the Management Plan) for the following season.

Important additional research conducted for the BCF includes an independent review of the research program (Scandol and Kennelly, 2001) and a review of blue swimmer crab biology in South Australia (Svane and Cheshire, 2005).

1.6. Research program

The current research program for the BCF conducted by SARDI Aquatic Sciences comprises four components. These are to: 1) conduct fishery-independent stock assessment surveys during winter to inform fishing strategy decisions and assess the fishery against the PIs defined in the Management Plan; 2) manage fishery-dependent commercial logbook data; 3) collate and analyse fishery-dependent pot-sampling data; and 4) produce an annual stock assessment report for the fishery.

1.7. Information sources used for assessment

1.7.1. Stock assessment surveys

Fishery-independent stock assessment surveys have been conducted for the BCF during June or July on an annual basis since 2002. The primary aim of fishery-independent surveys is to determine the relative abundance and size composition of blue swimmer crabs in Spencer Gulf and Gulf St Vincent during winter (June/July), when juveniles generally recruit to the fishery. This also coincides with the end/beginning of the quota season.

Of the three PIs, the two that are primarily used to inform the annual TACC decision for the fishery are derived from these surveys: 1) survey CPUE of legal-size crabs; and 2) survey CPUE of pre-recruits.

1.7.2. Commercial catch and effort

SARDI maintains a comprehensive catch and effort database for the BCF using data recorded by licensed fishers from the compulsory '*South Australian Commercial Blue Crab Pot Fishery Logbook'*. These data were first collated for the 1996/97 fishing season. Historical data from the fishery were recorded into the 'GARFIS' catch and effort database of the South Australian Fisheries Department from 1983/84.

In addition to the two PIs from the stock assessment survey, the only other indicator for the fishery, commercial CPUE, is derived from the catch and effort logbook, which is completed daily and submitted at the end of each month.

1.7.3. Pot-sampling

The pot-sampling program collects fishery-dependent CPUE data on pre-recruits (pre-recruits/potlift) from small-mesh pots and size composition of blue swimmer crabs throughout the fishing season to provide information on recruitment strength and sex ratio. Pot-sampling data have been voluntarily collected since May 2006 in Spencer Gulf and July 2006 in Gulf St Vincent.

2. METHODS

2.1. Information sources used for assessment

The three different sources of information presented in this report are: 1) fishery-independent survey data; 2) fishery-dependent commercial logbook data; and 3) fishery-dependent pot-sampling data. The primary indicators used to derive stock status of the BCF are relative abundance of legal size and pre-recruit crabs from fishery-independent surveys. These measures are supplemented by pot-sampling data for pre-recruits.

2.1.1. Fishery-independent surveys

Fishery-independent surveys are conducted using industry vessels, skippers and crews, with independent observers placed on each vessel to collect data on blue swimmer crab size and catch rates. While there has been some variability in the timing of fishery-independent surveys, they have been generally undertaken during the winter months of June and July in both gulfs (**Figure 2.1**). In Spencer Gulf, most surveys were conducted in June and early July, except for 2003, when the survey was conducted in late July to early August, and 2005, when the survey was undertaken throughout July. In Gulf St Vincent, surveys were conducted in July from 2002 to 2004, June from 2005 to 2009, July since 2010–2013 and in June 2014.

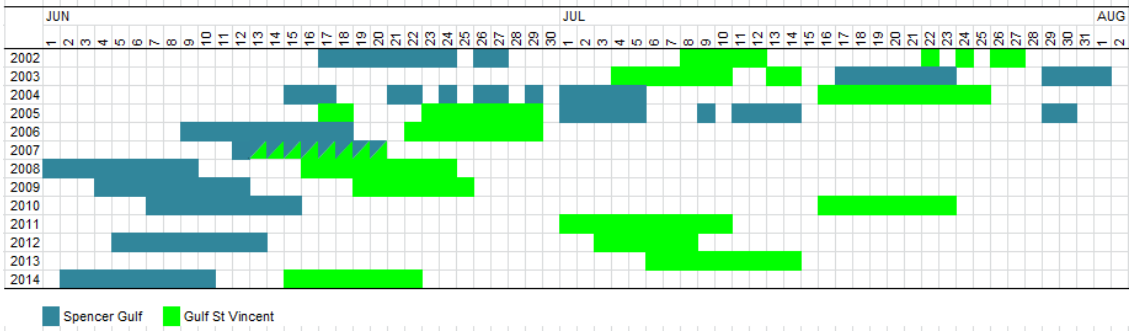

Figure 2.1. Fishery-independent survey calendar for Spencer Gulf and Gulf St Vincent from 2002 to 2014.

In the event that the survey CPUE of pre-recruits is above the mean of the 9-year reference period (2002-2010) for either gulf, the Management Plan provides the option for the survey to be omitted for that gulf in the following year. As a result of high CPUE of legal-size and pre-recruit crabs in Spencer Gulf determined from the 2010 and 2012 surveys, the decision was made by the SABCPFA and PIRSA Fisheries and Aquaculture to not conduct a survey in that gulf in 2011 and 2013.

The area of fishery-independent surveys encompasses waters with depths ranging from 3 to 22 m northwards of a line from Wallaroo to Cowell in Spencer Gulf and northwards of a line from Glenelg to Port Vincent in Gulf St Vincent (**Figure 2.2**). Sampling locations were determined based on fisher knowledge and historical catch and effort data. From these recommendations, four survey sites were selected in each fishing block.

Fewer potlifts (approximately 22% less in Spencer Gulf and 41% less in Gulf St Vincent) were undertaken during 2002 than in subsequent years. From 2008, the survey design was modified by SARDI, PIRSA and industry to provide a more representative measure of relative abundance of blue swimmer crab in each gulf. Changes included, removing all sampling locations from some fishing blocks, adding new survey locations to previously unsurveyed blocks, and relocating sampling locations within existing surveyed blocks (**Figure 2.2**). The regions surveyed are also separated into the northern, central and southern zones as specified in the Management Plan.

Survey CPUE, calculated as the number of legal-size/potlift or pre-recruits/potlift (small-mesh pots only) for each survey, is used as a measure of relative abundance. The relationship between mean yearly pre-recruit and legal-size CPUE was assessed by simple linear regression of the data collected from historical locations. Unless stated otherwise, 'historical locations' refer to locations that have not changed since 2002 while 'historical + new' locations refer to all locations sampled since 2008. For pre-recruit and legal size classes, the relationship between historical and new survey locations was assessed by simple linear regression of the mean yearly CPUE values.

At each survey location, commercial (**Figure 2.3**) and small-mesh pots (**Figure 2.4**) were set and hauled on a daily basis, except for the Gulf St Vincent 2012 survey, where only small-mesh pots were used. For pre-recruit and legal size classes, the relationship between commercial and research pots was assessed by simple linear regression of the mean yearly CPUE calculated from each pot type. Commercial pots have evolved in design through time with a diameter ranging from 120–200 cm, and mesh size ranging from 7.5–11.2 cm (**Table 2.1**). Small-mesh pots which were designed specifically for fishery-independent surveys based on the original pot used in the fishery, have a diameter of 140 cm, a height of 50 cm, and a mesh size of 5.5 cm. At each survey location, five sets of gear were deployed along a line, each set comprising one commercial pot (except for Gulf St Vincent in 2012) and one small-mesh pot. Each set of gear was spaced 150 m apart and, where both pot types were used, each pot was separated by 40 m of rope. For the 2014 Gulf St Vincent survey, pots were set along a single line at each survey location with each set of gear spaced at 76 m

apart. Pots were baited with fresh Australian salmon, sardines or striped trumpeter, and hauled from dawn each day.

A global positioning system (GPS) was used to locate the gear, and depth was recorded for each survey location. Blue swimmer crabs were measured for carapace width (mm) using Vernier calipers, and details of sex (male or female) and condition (dead, soft, berried) were recorded. Data on by-catch species were collected during the survey, however, these are not presented in this report. An assessment of by-catch data from 2002 to 2006 was presented in Currie *et al.* (2007). This dataset will be useful for future work examining changes in community structure.

ArcGIS (ArcMap 10.1) software was used to visualise the spatial patterns in crab abundance over time. The kernel density method was used to calculate the density of point features around each output raster cell (100 m * 100 m). Conceptually, a smoothly curved surface is fitted over each point, where the surface value is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the search radius (7500 m).

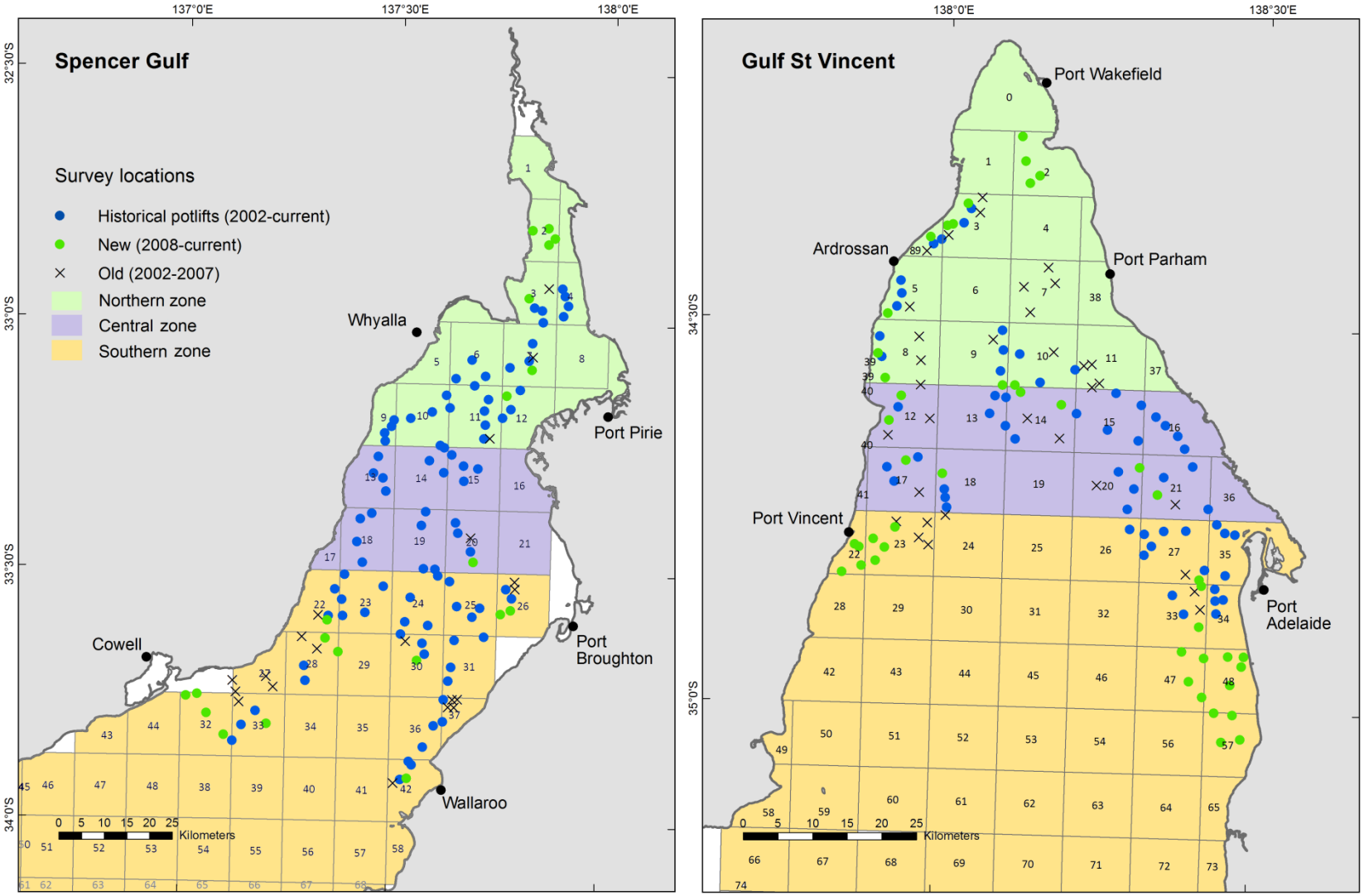

Figure 2.2. Commercial fishing blocks (grid) and survey locations in Spencer Gulf and Gulf St Vincent of the Blue Crab Fishery. Also identified are the northern, central and southern zones as specified in the Management Plan.

Figure 2.3. Commercial crab pots; (a) diameter of 140 cm with mesh size of 9 cm and, (b) diameter of 20 cm with a mesh size of 11.2 cm.

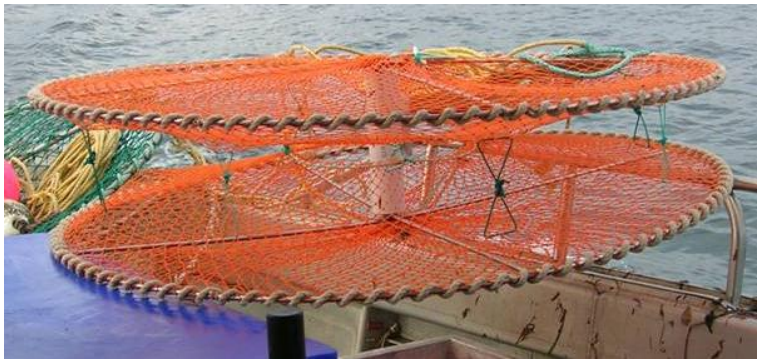

Figure 2.4. Small-mesh crab pot used for surveys with a diameter of 140 cm and mesh size of 5.5 cm.

Table 2.1. Gear variations in the commercial fishery from 1997/98–2014/15 compiled from information provided by four of the nine current licence holders. Pot configurations include 'single' where pots are set individually, double where two pots are set per buoy and 'longline' where a series of pots are set along a single line.

Season	Pot configuration	Mesh size (cm)	Pot diameter (cm)
1997/98	single	10	150
1998/99	single	10	150
1999/00	single	10	150
2000/01	single	7.5/10	140/150
2001/02	single	10	150
2002/03	single	10	150
2003/04	single	10	150
2004/05	single	10	150
2005/06	single	10	150
2006/07	single/longline/double	9/10	120/150
2007/08	single/longline/double	9/10	120/130/150
2008/09	single/double	9/9.8/10	120/130/150
2009/10	single/double	9.8/10	130/150
2010/11	single/longline	9.8/11.2	130/200
2011/12	single/longline	9.8/11.2	130/200
2012/13	longline	9.8/11.2	200
2013/14	longline	9/9.5/9.8/11.2	150/200
2014/15	longline	9.8/10/11.2	150/200

2.1.2. Commercial logbooks

Daily catch and effort data are compulsorily recorded by licensed fishers in commercial logbooks. In addition to catch and effort data, daily records of fishing block, depth, and sex and number of blue swimmer crabs caught are also recorded. With respect to catch and effort, additional information is recorded on second potlifts, when pot fishers may have lifted and reset their on the same day. Under these circumstances, soak time is generally 18 to 20 hours for the first potlift, and 4–6 hours for the second potlift. Logbooks also provide for recording the numbers of undersized blue swimmer crabs (pre-recruits) and berried females. For analyses and presentation of commercial logbook data throughout this report, effort data (and calculated CPUE) is expressed in boat days or potlifts.

Commercial logbook data relates to the Spencer Gulf and Gulf St Vincent pot fishing zones and the marine scalefish zone. Detailed analyses on the Spencer Gulf and Gulf St Vincent pot fishing zones since the introduction of quota (1996/97) are provided in the results. From 2007/08, the small number of MSF participants has precluded the presentation of confidential catch and effort data for that sector in this report.

2.1.3. Fishery-dependent pot-sampling program

The pot-sampling program collects fishery-dependent catch and effort data from small-mesh pots including size composition and sex ratios of blue swimmer crabs throughout the fishing season to provide supplementary information on recruitment strength. These data have been collected since May 2006 in Spencer Gulf and July 2006 in Gulf St Vincent, although data has only been considered reliable since 2008 (a summary of these data are presented in **Tables 2.2** and **2.3**).

Initially, sampling was voluntarily undertaken from one small-mesh pot and one commercial pot each fishing day. The focus of the sampling program shifted towards the CPUE of pre-recruits, so data were collected exclusively from one small-mesh pot only from May 2008 to July 2010, and from up to two small-mesh pots from July 2010 onwards. Data collected from participating licensed fishers include date, licence number, fishing block, GPS coordinates of pot locations, depth, water temperature, and sex and size of individual crabs. In addition to presenting results by fishing season, pot-sampling data are presented by calendar year to ensure that pre-recruits sampled in June and July (i.e. during peak recruitment) in any one year are examined together, thus providing a more consistent interpretation of annual trends.

Table 2.2 Statistics on pot-sampling data collected by the Spencer Gulf pot fishing zone from 2008–2014 (calendar year).

Statistic	2008	2009	2010	2011	2012	2013	2014
No. of active licences*	5	5	4	4	4	4	4
No. of licences providing data	4	4	4	3	4	4	4
No. of boat days during sampling period	971	696	734	526	664	732	700
No. (and % total) of boat days sampled	434	523	493	128	532	665	549
% of total boat days sampled	45%	75%	67%	24%	80%	91%	78%
No. of blocks sampled	28	27	28	8	32	29	20
% of total blocks fished	72%	93%	78%	35%	97%	69%	61%
Pots sampled	435	526	514	129	537	688	552
No. of crabs measured	8,526	8,750	10,204	2,585	12,699	16,307	11,739

Table 2.3 Statistics on pot-sampling data collected by the Gulf St Vincent pot fishing zone from 2008–2014 (calendar year).

Statistic	2008	2009	2010	2011	2012	2013	2014
No. of active licences*	4	3	3	3	3	3	3
No. of licences providing data	3	3	3	3	3	3	3
No. of boat days during sampling period	443	492	425	512	407	203	495
No. of boat days sampled	169	327	352	353	300	188	465
% of total boat days sampled	38%	66%	83%	69%	74%	93%	na
No. of blocks sampled	10	13	19	15	21	14	18
% of blocks fished sampled	67%	59%	70%	63%	72%	70%	na
No. of pots sampled	170	331	374	371	385	261	537
No. of crabs measured	3485	5473	7308	6845	6423	4960	11327

2.2. Quality assurance

2.2.1. Research planning

The research requirements of PIRSA Fisheries and Aquaculture for the BCF were discussed in December 2013 and subsequently provided to representatives of the BCF to confirm their understanding of proposed deliverables. This ensures that the research undertaken and deliverables provided are consistent with the needs of PIRSA Fisheries and Aquaculture to meet their obligations under the *Fisheries Management Act 2007.*

2.2.2. Data collection

Commercial fishers are advised on the procedures and requirements for catch sampling and completion of the required fishing logbook on a regular basis, usually at the commencement of each fishing season. The data provided by commercial fishers are checked by SARDI prior to acceptance and potential errors are corrected through direct correspondence with individual commercial fishers. SARDI staff are trained to undertake fishery-independent data collection using methods described in stock assessment reports for the fishery and by following documented procedures.

2.2.3. Data entry, validation, storage and security

All logbook data are entered and validated according to the quality assurance protocols identified for the BCF in the SARDI Information Systems Quality Assurance and Data Integrity Report (Vainickis, 2010). The data are stored in an Oracle database, backed up daily, with access restricted to SARDI Information Systems staff. Extracts from the database are provided to SARDI crab researchers on request. All fishery-independent data are entered into Excel spreadsheets. Accuracy of data entry is verified by checking a subset (20%) of the data against the original data sheets. Once validated, data stored on a network drive with restricted access to SARDI staff involved in research projects in the Inshore Crustaceans Subprogram.

2.2.4. Data and statistical analyses

Data are extracted from the databases using established protocols. Accuracy of the data extracted is checked by comparing pivot table summaries with previous data extractions. The analyses in this report were carried out independently for multiple years at a time to confirm they were accurate compared to the results of previous reports.

2.2.5. Data interpretation and report writing

The results, their interpretation and conclusions provided in the reports are discussed with peers, PIRSA Fisheries and Aquaculture and BCF licence holders. All co-authors review the report prior to

the report being formally reviewed by two independent scientists at SARDI in accordance with the SARDI report review process.

3. RESULTS

3.1. Total catch and effort (both gulfs)

Catches of blue swimmer crab were first recorded in 1983/84, when 26.9 t were harvested over a total of 530 boat days (**Figure 3.1**), most of which was harvested by the MSF. Over the following twelve years catches progressively increased for all zones of the BCF (Spencer Gulf and Gulf St Vincent pot fishing zones, and the MSF), reaching a combined historical high of 651.3 t in 1995/96. The introduction of quota in the following season (1996/97) resulted in a 29% reduction in total catch to 462.4 t. The total catch generally increased until 2007/08 when the entire TACC was caught. Total catch has remained below the TACC since that time, although the entire TACC was nearly caught (>98%) in 2011/12 and 2013/14.

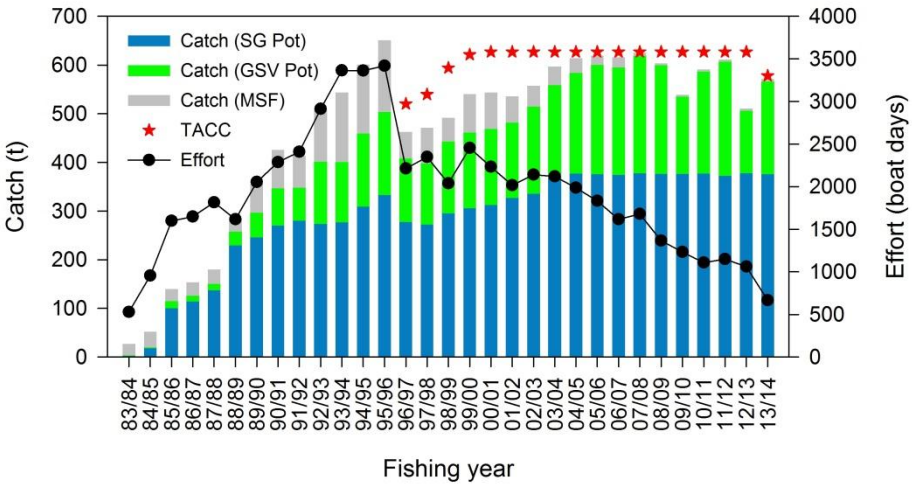

Figure 3.1. Commercial catch, effort and TACC for the Blue Crab Fishery from 1983/84 to 2013/14.

The TACC was set at 626.8 t from 2000/01–2012/13. A 20% reduction in Gulf St Vincent TACC was implemented in 2013/14 resulting in the fishery-wide TACC set at 577.8 t. The total catch during 2013/14 was 571.0 t (98.8% of the TACC), with a majority of catch (>99.2%) harvested by the Spencer Gulf and Gulf St Vincent pot fishing zones.

Prior to the introduction of quota, effort generally followed the upward trend in commercial catch, reaching a historical high of 3,419 boat days in 1995/96. With the introduction of quota in 1996/97, effort dropped to 2,213 boat days, but later increased to a post-TACC maximum of 2,458 boat days in 1999/00. Effort declined to 667 boat days fished in 2013/14 partially as a result of a six month closure from June to December 2013. The overall decline in effort can be attributed primarily to the transfer of quota from the MSF to the pot fishing zones of the BCF but also to the introduction of multiple potlifts per day.

3.2. Spencer Gulf

3.2.1. Fishery-independent surveys

3.2.1.1. Catch per unit effort (CPUE) relationships

For legal-size crabs, the relationship between the CPUE from historical locations and the CPUE from new survey locations was weak (**Figure 3.2a**). There was, however, a strong positive linear relationship between the CPUE of pre-recruit crabs from historical survey locations and the CPUE of pre-recruit crabs from new locations (**Figure 3.2b**). A moderate linear relationship was also apparent between the CPUE from commercial and research pots for both pre-recruit and legal-size estimates of CPUE (**Figure 3.3**). A weak linear relationship was found between the CPUE of legal-size and pre-recruit crabs from research or commercial pots (**Figure 3.4**).

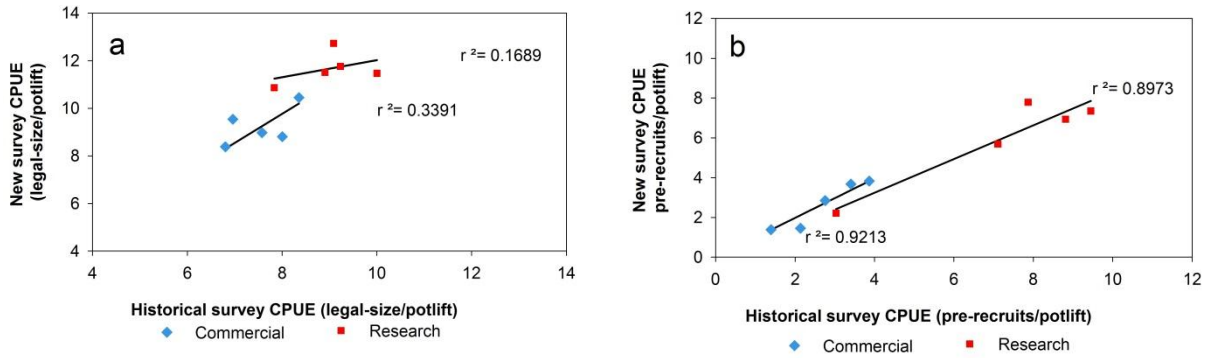

Figure 3.2 Relationship between mean survey catch per unit effort (CPUE) at historical and new locations from commercial and research pots in Spencer Gulf from 2008–14 showing (a) legal-size CPUE (legal-size/potlift) and (b) pre-recruit CPUE (pre-recruits/potlift). Surveys were not conducted in 2011 and 2013.

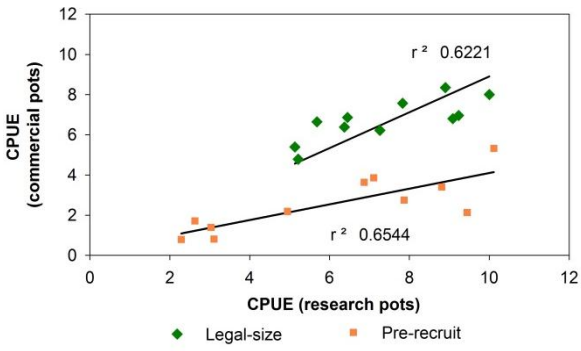

Figure 3.3 Relationship between mean survey catch per unit effort (CPUE) in commercial and research pots for legal-size (legal-size/potlfit) and pre-recruit crabs (pre-recruits/potlift) in Spencer Gulf calculated from historical locations from 2002–14

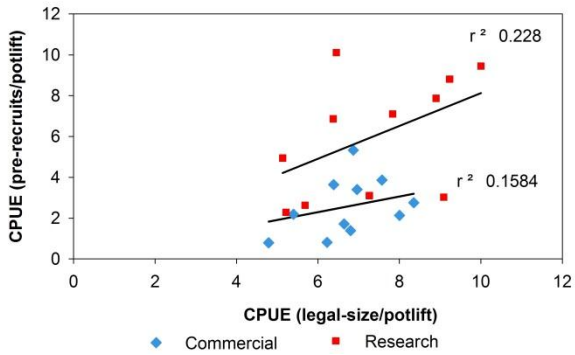

Figure 3.4 Relationship between survey catch per unit effort (CPUE) of legal-size (legal-size/potlift) and pre-recruit (pre-recruits/potlift) crabs in Spencer Gulf calculated from historical locations from 2002–14

3.2.1.2. Relative abundance of legal-size crabs

Research surveys indicated a generally increasing trend in the CPUE of legal-size crabs in Spencer Gulf since 2002 **(Figure 3.5)**. CPUE measured from commercial survey pots increased until 2010, but compared to research pots, CPUE remained at relatively low levels in 2012 and 2014. Estimates of CPUE from historical locations were lowest in 2005 with values of 5.2 and 4.8 pre-recruits/potlift measured in research and commercial pots, respectively. In 2014, estimates of CPUE from research pots reached a high of 10.0 legal-size/potlift from historical locations (10.3 legal-size/potlift from historical + new locations). The values for CPUE historical + new locations suggest that legal-size CPUE was increased with the addition of new survey locations from 2008.

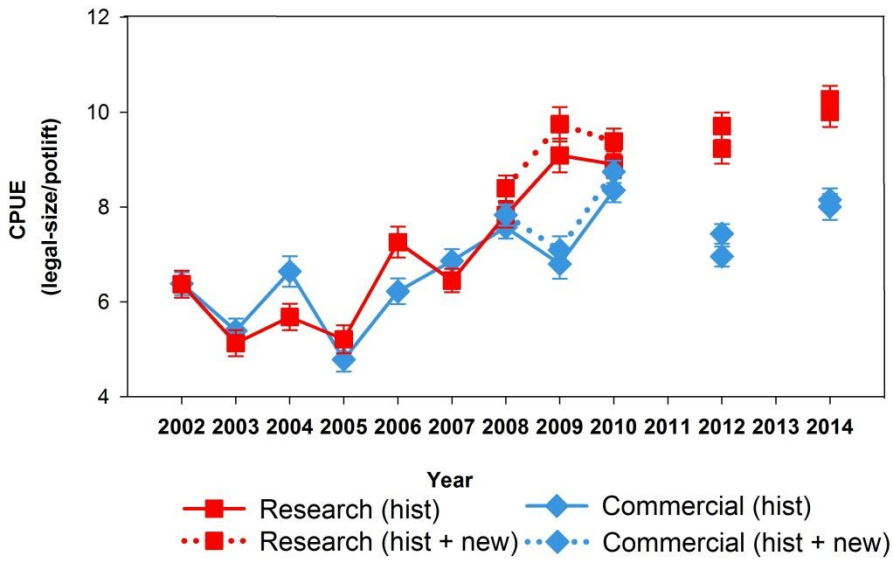

Figure 3.5. Mean catch per unit effort (CPUE, legal-size/potlift) of legal-size crabs from research and commercial pots from historical locations (2002-current) and historical + new locations (2008-current) sampled in Spencer Gulf during June and July from 2002 to 2014. Error bars, standard error. Note, surveys were not conducted in 2011 or 2013.

In the central and northern zones of Spencer Gulf, trends in the CPUE of legal-size crabs measured from historical survey locations were similar to those observed across the fishery, with CPUE increasing until 2009 (**Figure 3.6**). The CPUE of legal-size crabs measured from historical locations was generally high in the northern zone, compared to the central and southern zones; however, from 2012 higher estimates of the CPUE of legal-size crabs were measured in the southern zone compared to the other zones. In the southern zone, the CPUE of legal-size crabs measured from historical + new locations was lower than the CPUE of legal-size crabs measured from historical locations alone in all years. In the central and northern zone the CPUE of legal-size crabs measured from historical + new locations was generally equal to or higher than the CPUE of legal-size crabs measured from historical locations.

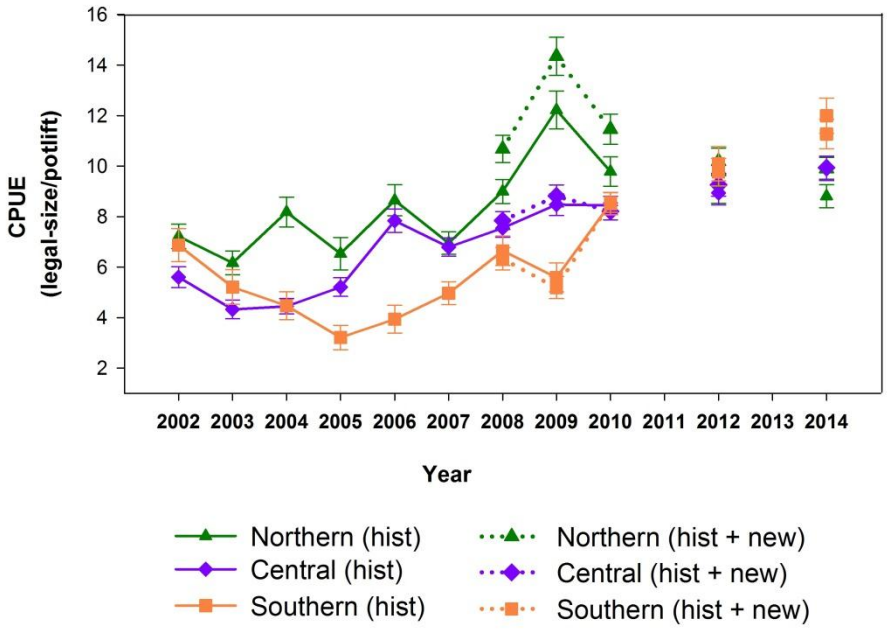

Figure 3.6. Mean zonal catch per unit effort (CPUE, legal-size/potlift) of legal-size crabs for research pots sampled in Spencer Gulf. Historical locations were sampled from 2002–14 and historical + new survey locations from 2008–14. Error bars, standard error. Note, surveys were not conducted in 2011 or 2013.

Figure 3.7 shows the average relative densities of legal-size crabs measured from 2002–07, 2008–2013 and 2014, revealing a similar trend in the density distribution of legal-size crabs to that observed in CPUE estimates by zone (**Figure 3.7**). Concurrent with changes to survey pot locations in 2008, increased relative density of legal-size crabs was observed in the north (block 2, for block locations refer to **Figure 2.2**). Compared to 2002–07, the relative density of legal-size crabs also increased in the northern gulf (Blocks 3, 11 and 12) and central gulf adjacent to Port Broughton (Block 26) in 2008–12. The relative density of legal-size crabs in 2014 was similar to the 2008–13 average, with density concentrated in the region adjacent to Port Pirie (Blocks 11 and 12) and south of Whyalla (Block 9 and 13) and off Port Broughton (Block 26). In 2014, the relative density of legal-

size crabs was decreased in the north (Block 2 and 3) and south (Cowell, Block 32 and 33) compared to the 2008-13 average. Overall, in 2014 the relative abundance of legal-size crabs was equal to or above the 2008–13 average at 65% of survey locations, while the relative abundance of legal-size crabs was equal to or above the 2002–07 average at 64% of survey locations.

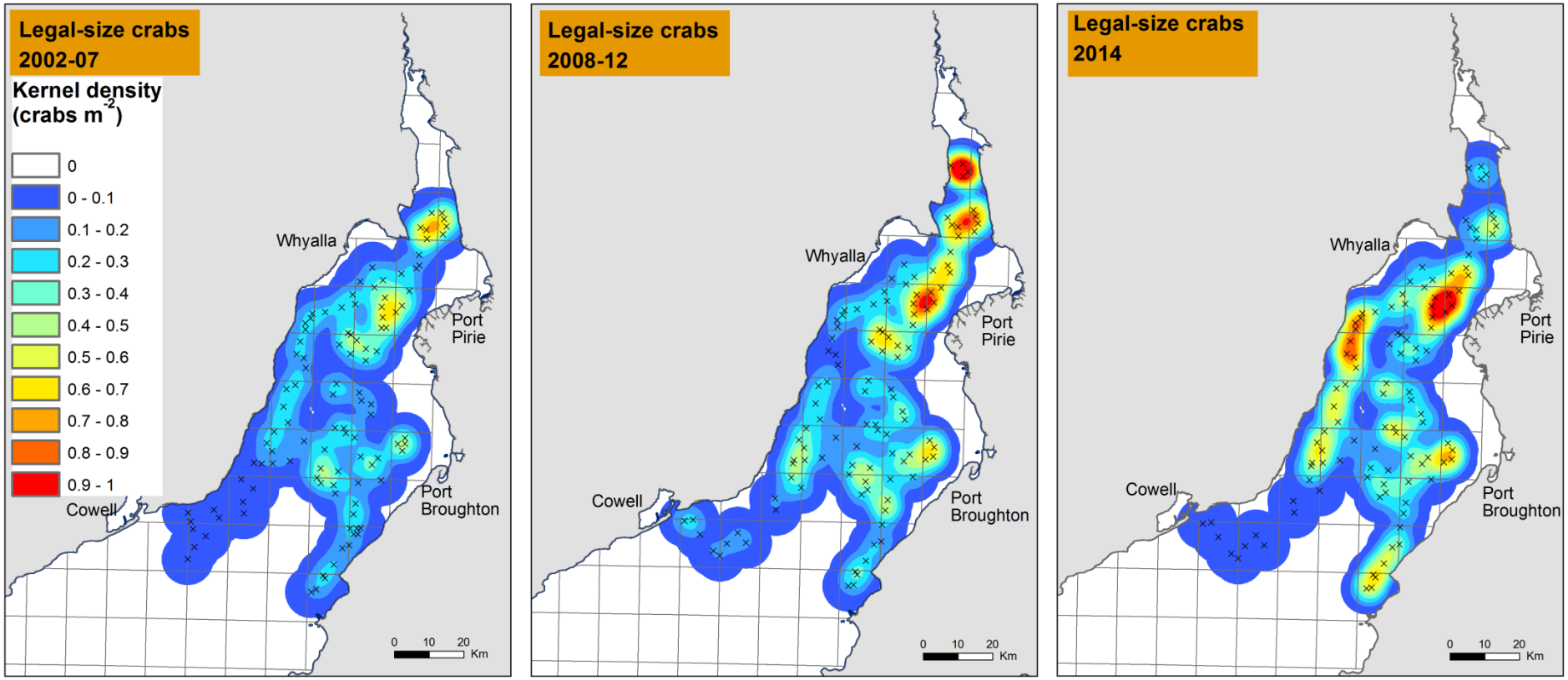

Figure 3.7. Kernel density maps showing the relative density (crabs per square metre) of legal-size crabs from historical (2002-07) and historical + new locations (2008–12 and 2014) in Spencer Gulf. Surveys were not conducted in 2011 or 2013. Sampling locations denoted by x.

3.2.1.3. Relative abundance of pre-recruits

The relative abundance of undersize crabs (pre-recruits) in Spencer Gulf has fluctuated greatly since 2002 (**Figure 3.8**). The estimates of CPUE measured from historical survey locations were lowest in 2005 with 2.3 and 0.8 pre-recruits/potlift from research and commercial pots, respectively. In 2014, the CPUE of pre-recruits measured from historical survey locations reached a high of 9.4 pre-recruits/research potlift which was the second highest value after 2007 (10.1 pre-recruits/potlift). Similarly high estimates of CPUE were measured from historical + new locations with 9.1 pre-recruits/potlift observed in research potlifts in 2014. The CPUE of pre-recruits from commercial pots followed similar trends to CPUE from research pots until 2010 where CPUE remained at low levels. Estimates of the CPUE of pre-recruits from historical + new locations were similar to CPUE estimated from historical locations alone across most years

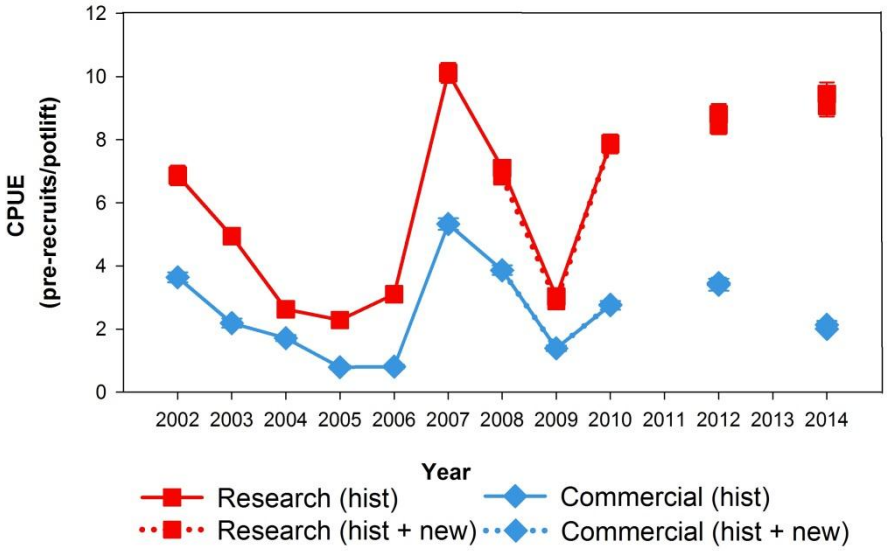

Figure 3.8. Mean catch per unit effort (CPUE, pre-recruits/potlift) of pre-recruit crabs from research and commercial pots from historical locations (2002-current) and historical + new locations (2008-current) sampled in Spencer Gulf during June and July from 2002 to 2014. Error bars, standard error. Note, surveys were not conducted in 2011 or 2013.

Similar trends in the CPUE of pre-recruits measured from historical survey locations were observed across all zones until 2009, with estimates decreasing from north to south **(Figure 3.9)**. In 2010, the CPUE of pre-recruits was higher in the southern and central zones than the northern zones for the first time. Since 2010, a decreasing trend in the CPUE of pre-recruits has been observed in the southern zone. In the northern zone the CPUE of pre-recruits crabs decreased from 2010–12 and increased to similar levels as seen in the central zone in 2014. In the southern zone, the CPUE of pre-recruits from historical + new locations was nearly always lower than from historical locations,

while in the northern and central zones, the CPUE of pre-recruits was slightly higher from historical + new locations in most years.

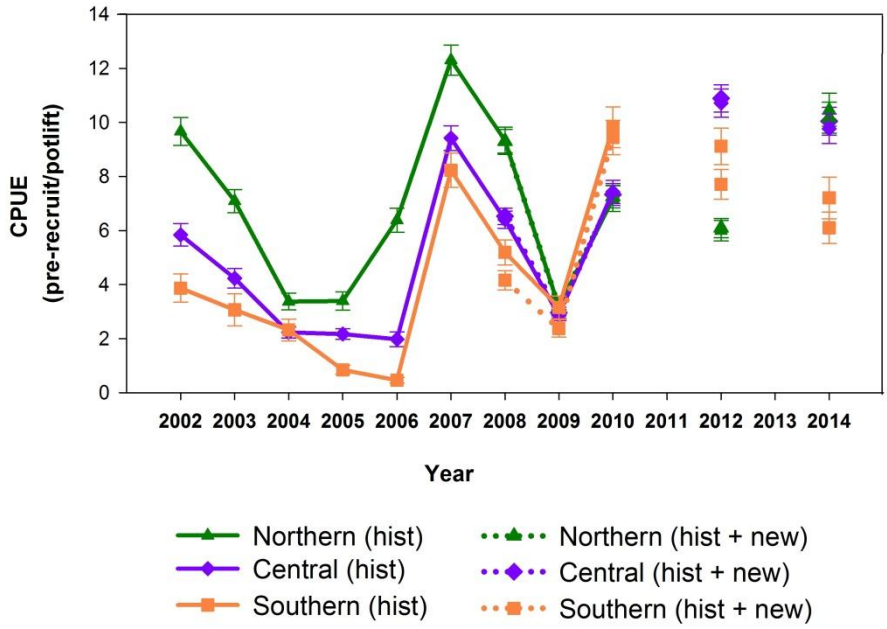

Figure 3.9. Mean zonal catch per unit effort (CPUE, pre-recruits/potlift) of pre-recruits for research pots sampled in Spencer Gulf. Historical locations were sampled from 2002–14 and historical + new survey locations from 2008–14. Error bars, standard error. Note, surveys were not conducted in 2011 or 2013.

Figure 3.10 show the average relative densities of pre-recruit crabs measured from 2002–07, 2008–13 and 2014, revealing a similar trend in the density distribution of pre-recruit crabs to that observed in CPUE estimates by zone (**Figure 3.10**). Compared to 2002–07, the relative density of pre-recruits increased in the central gulf adjacent to Port Broughton (Blocks 24, 30 and 36) and in the south near Wallaroo (Blocks 36 and 42) in 2008–13. The relative density of pre-recruits in 2014 was high compared to the 2008–13 average, with relative density concentrated in the north (Blocks 2 and 3) and the region adjacent to Port Broughton (Blocks 24, 26 and 30). The relative density of pre-recruits increased in the south (Cowell, block 32 and 33) in 2014. Overall in 2014, the relative abundance of pre-recruit crabs was equal to or above the 2008–13 average at 61% of survey locations, while the relative abundance of pre-recruit crabs was equal to or above the 2002-07 average at 81% of survey locations.

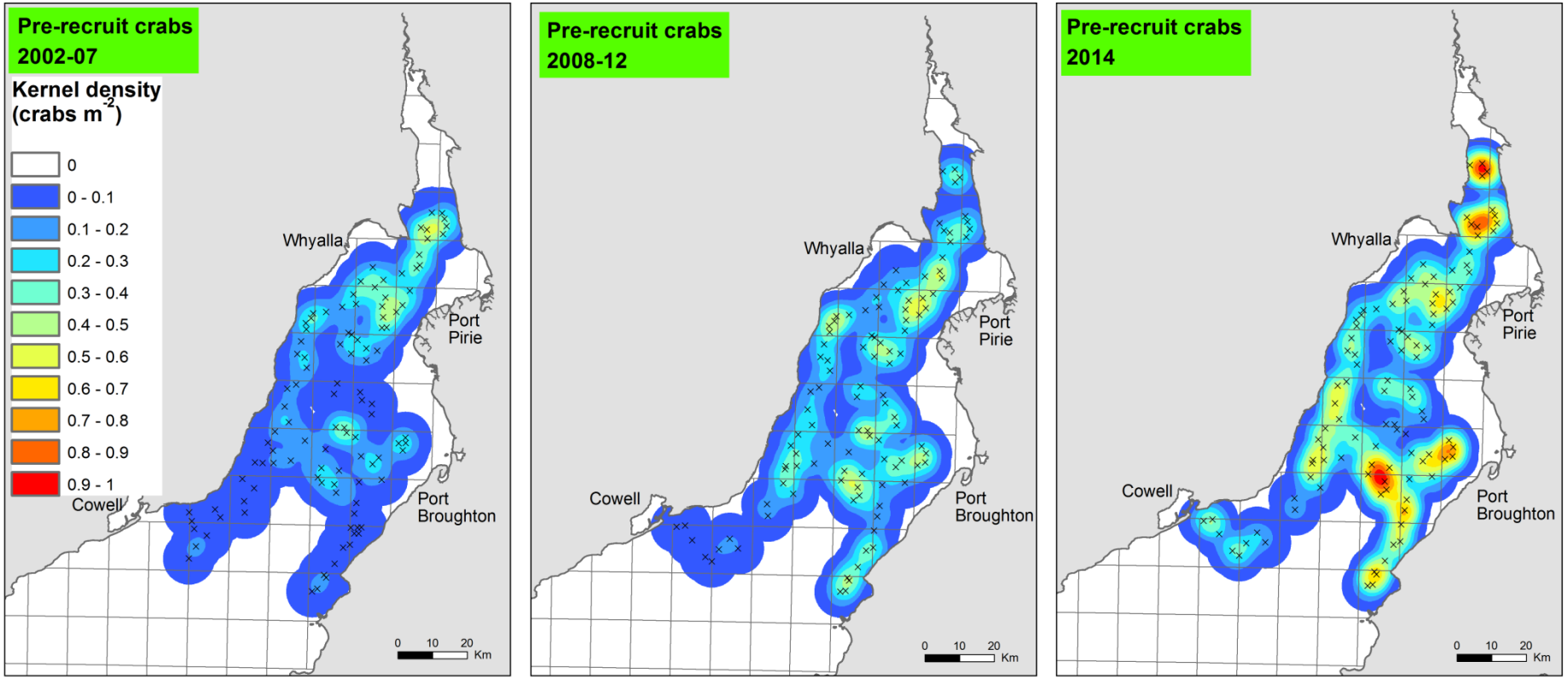

Figure 3.10. Kernel density maps showing the relative density (crabs per square metre) of pre-recruit crabs for historical (2002-07) and historical + new locations (2008–12 and 2014) in Spencer Gulf. Surveys were not conducted in 2011 or 2013. Sampling locations denoted by x.

3.2.1.4. Size distribution

The size distribution of the surveyed population in Spencer Gulf varied substantially among years **(Figure 3.11)**. The modal carapace width of blue swimmer crabs was 100–109 mm (medium, undersize) in 2002 and 2007, 120–129 mm (large, legal-size) in 2005 and 110–119 mm (medium, legal-size) in all other years. The proportion of legal-size crabs increased from 2002 to 2006. A spike in the proportion of medium size crabs in 2007, resulted in higher proportions of legal-size crabs for the only time since 2002. In 2009, increased proportions of large crabs were observed and from 2010 onwards the majority of crabs were either medium or large, with a 47% of crabs being legal-size and 53% of crabs being pre-recruits in 2012 and 2014.

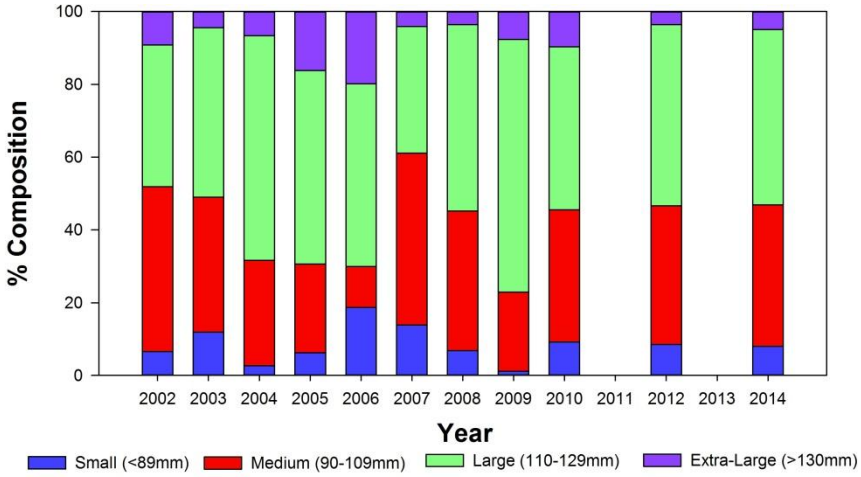

Figure 3.11. Size classes of crabs measured in research pots during fishery-independent surveys in Spencer Gulf from 2002–14 presented as percent composition from historical locations (2002–07) and historical + new locations (2008-14).

3.2.2. Commercial logbook data

3.2.2.1. *Annual trends*

For the 2013/14 fishing year, the Spencer Gulf pot fishing zone held 381.7 t (66%) of the total TACC allocated to the BCF (577.8 t), most of which (380.1 t, 99.6%) was landed. Catch from this zone has been stable since 2003/04. Following the introduction of quota in 1996/97, the number of boat days in Spencer Gulf ranged between 902 and 1065 boat days over the five-year period 1997/98 to 2001/02 (**Figure 3.12**). The number of boat days increased in 2002/03 and 2003/04 after a new licence was issued in February 2002, and then declined in the following years to a historic low (since the introduction of quota) of 607 boat days in 2011/12. Effort decreased from 686 boat days in 2012/13 to 659 boat days in 2013/14, but has remained relatively stable over the last five years.

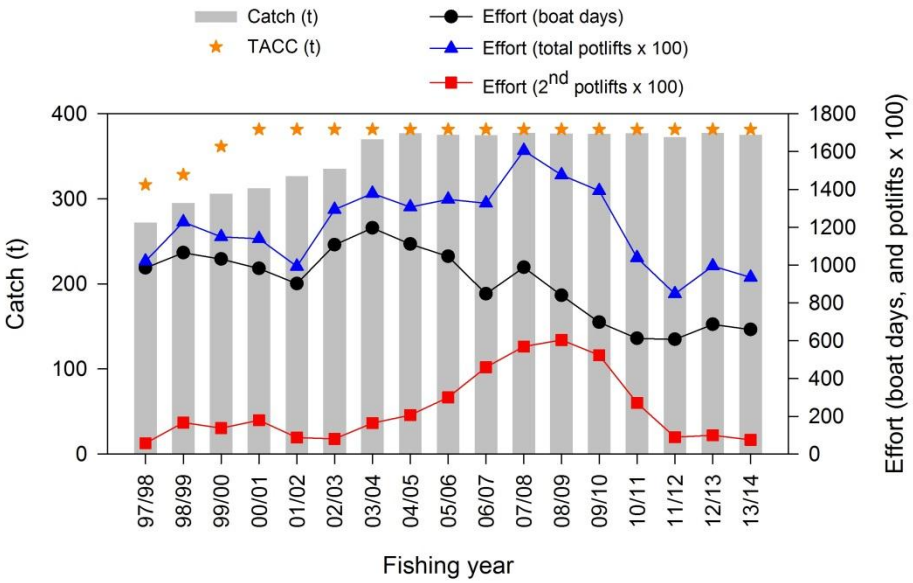

Figure 3.12. Total catch (t) and effort (1st potlifts, 2nd potlifts, total potlifts) for the Spencer Gulf pot fishing zone from 1997/98 to 2013/14.

The number of total potlifts in Spencer Gulf decreased by 11% from 1998/99 to 2001/02 and a 13% increase was observed in 2002/03 (**Figure 3.12**). Between 2002/03 and 2006/07, the number of potlifts was relatively stable with a mean of 133,057 potlifts. Effort increased by 10% from 2006/07 to 2007/08, and then reduced by 27% from 2008/09 to 2011/12 reaching a historic low of 84,756 potlifts. The number of potlifts increased by 8% from 2011/12 to 2012/13. Compared to 2012/13, a 3% decrease was observed with 93,492 potlifts undertaken in 2014.

The number of second potlifts was at a low level (<18,000 potlifts) from 1997/98 to 2003/04 (**Figure 3.14**). From 2003/04 to 2008/09, the number of second potlifts increased by 57% to 60,398 potlifts. Since 2009/10, the number of second potlifts has declined in most years (except for 2012/13), returning

to low levels of 7,529 potlifts in 2013/14. Relative to total number of potlifts, the proportion of second potlifts decreased from 41% in 2008/09 to 8% in 2013/14.

Annual mean estimates of CPUE calculated from first potlifts and total potlifts were relatively similar from 1997/98–2008/09 ranging from 2.6–3.5kg/ first potlift and 2.4–3.3 kg/potlift from total potlifts. The mean CPUE calculated from second potlifts was considerably lower, ranging from 1.1–2.1 kg/potlift from 1997/98–2008/09. In 2009/10, the CPUE from second potlifts was higher than first potlifts and thereafter, mean CPUE for first and total potlifts increased reaching the highest levels recorded in 2011/12 at 4.4 kg/potlift (**Figure 3.13**). Following a small decrease in the mean CPUE from first and total potlifts in 2012/13 (3.8 kg/potlift), CPUE from first and total potlifts increased to 4.0 kg/potlift in 2013/14. The average catch per boat day (kg/boat day) taken in Spencer Gulf followed the same general trend as total CPUE (kg/potlift) until 2007/08. From 2007/08 to 2010/11, average catch per boat day in Spencer Gulf increased more rapidly than measured by average catch per potlift, increasing from 383 kg/boat day in 2007/08 to 616 kg/boat day in 2010/11.

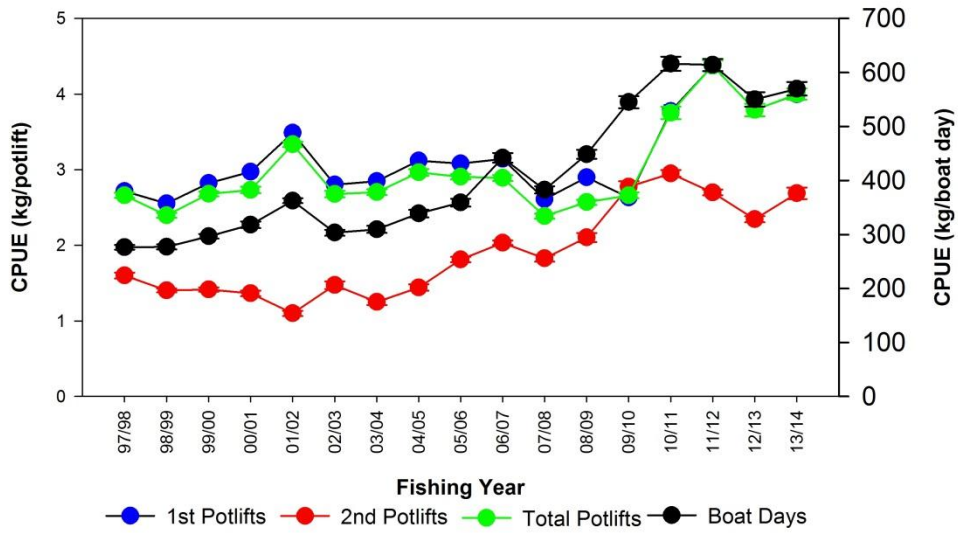

Figure 3.13. Mean commercial catch per unit effort (CPUE, kg/potlift) for 1st pot lifts, 2nd potlifts and total potlifts, and mean commercial CPUE (kg/boat day) for in the Spencer Gulf pot fishing zone from 1997/98 to 2013/14. Error bars, standard error.

3.2.2.2. *Spatial distribution of catch and catch per unit effort (CPUE)*

The proportion of catch taken within the different zones of Spencer Gulf has varied since 1997/98 (**Figure 3.16**). From 1997/98 to 2001/02, the majority of the total catch was harvested in the northern (105–126 t) and central zones (51–137 t). From 2003/04 to 2011/12, the majority of the catch was harvested from the northern zone with catches ranging from 101 to 197 t per year. Increased catches in the southern zone were also observed in 2007/08 (141 t) and from 2012/13 to 2013/14 (154–156 t).

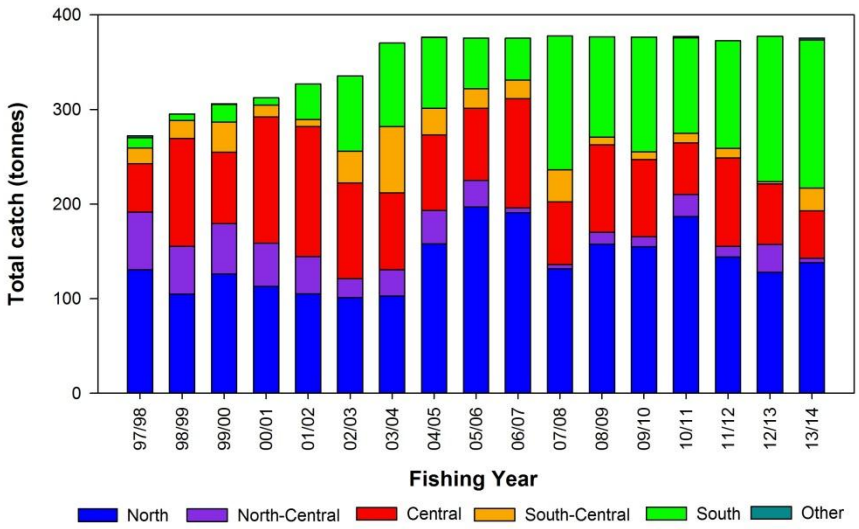

Figure 3.14. Total catch (tonnes) in the northern, central and southern zones of the Spencer Gulf pot fishing zone from 1997/98 to 2013/14. 'Other' includes days where fishing was spread over all zones, and transitional zones (north-central, south-central) were included when catch spread across more than one zone per day.

The number of blocks fished in Spencer Gulf increased steadily from 17 blocks in 1997/98 to 33 blocks in 2004/05 (**Figure 3.15**). A decrease in the number of blocks fished was observed in 2005/06, as fewer blocks were fished in the central zone. However, in 2007/08 the number of blocks fished increased to 40 due to additional blocks fished in the southern and central zones. From 2007/08 to 2013/14, the number of blocks fished per year has fluctuated between 30 and 40 blocks, with the majority of these located in the southern zone.

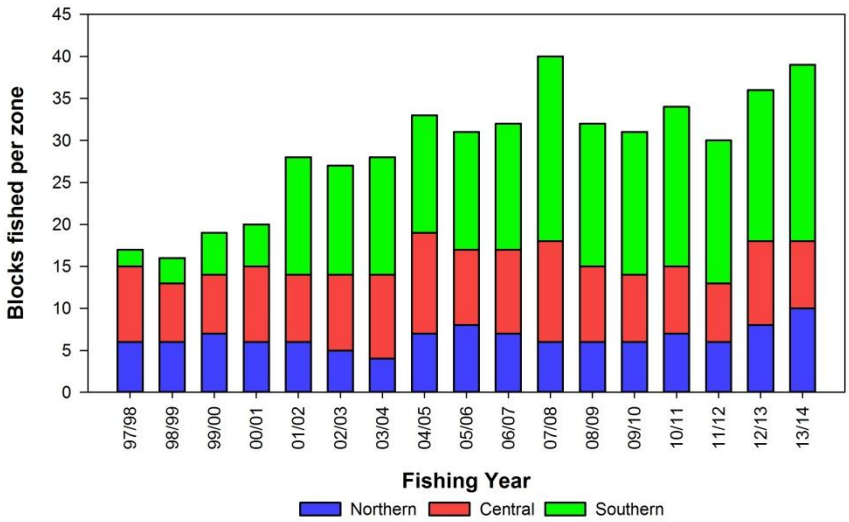

Figure 3.15. The number of blocks fished per zone per fishing year in the Spencer Gulf pot fishing zone from 1997/98 to 2013/14.

In most years, two blocks were fished on a majority of days except for 1998/99, 2003/04, 2005/06 2006/07 and 2007/08 where one block was fished per day on most days (**Figure 3.16**). In 1999/00, 2002/03, 2003/04, more than two blocks were fished per day on some occasions, but accounted for 1–6% of the total days fished. In 2012/13 and 2013/14, however, a relatively high proportion of days (22% and 15%, respectively) fished included more than 2 blocks.

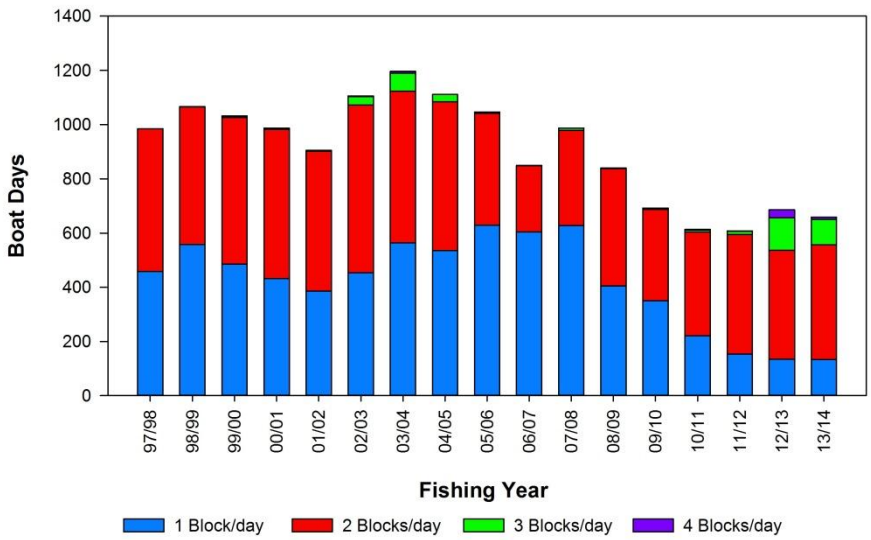

Figure 3.16. The number of blocks fished per boat day per fishing year in the Spencer Gulf pot fishing zone from 1997/98 to 2013/14.

The observed mean CPUE across each zone was generally similar in the northern and central zone. However, from 2004/05 onwards, the northern zone generally had higher estimates of CPUE (**Figure 3.17**). From 1997/98 to 2002/03, catch rates in the southern zone fluctuated, with low levels observed in 1998/99 and 2000/01. Increasing CPUE was observed across all regions from 2009/10 to 2011/12, and a further increase was observed in the northern and central zones from 2012/13 to 2013/14.

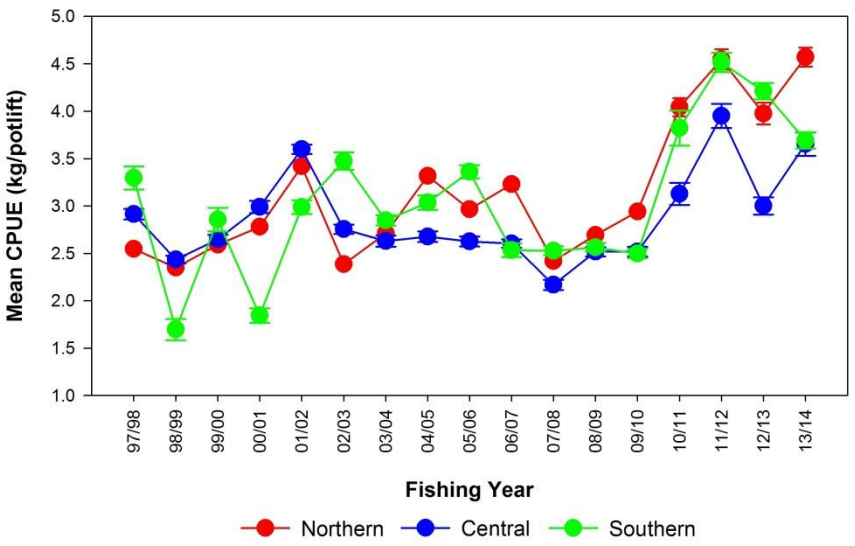

Figure 3.17. Mean catch per unit effort (CPUE, kg/potlift) in the northern, central and southern zone of the Spencer Gulf pot fishing zone from 1997/98 to 2013/14. Days where fishing included more than one zone are not shown. Error bars, standard error.

3.2.3. Pot-sampling data

3.2.3.1. Pre-recruit abundance

Reliable pot-sampling data for Spencer Gulf have been collected since 2008. The mean CPUE of pre-recruits from pot-sampling undertaken in June and July each year has fluctuated since 2008. This is in contrast with CPUE measured over all months of the fishing season which has generally increased since 2009/10 (**Figure 3.18**). Pre-recruit abundance was relatively low in June/July 2009 (5.77 pre-recruits/potlift) and this was supported by low estimates measured over the 2009/10 season (4.64 pre-recruits/potlift). Pre-recruit abundance was again low in June/July in 2011 (5.28 pre-recruits/potlift), however, in the 2010/11 season only a small decrease was observed compared to the previous season. From 2011–2013 estimates of pre-recruit abundance measured from June/July and over all months sampled increased with a maximum of 11.27 pre-recruits/potlift recorded in June/July 2013. In June/July 2014 pre-recruit abundance decreased compared to 2013 values, however, sampling over all months of the fishing season recorded a historical peak in pre-recruit abundance from July–December 2014 at 10.94 pre-recruits/potlift.

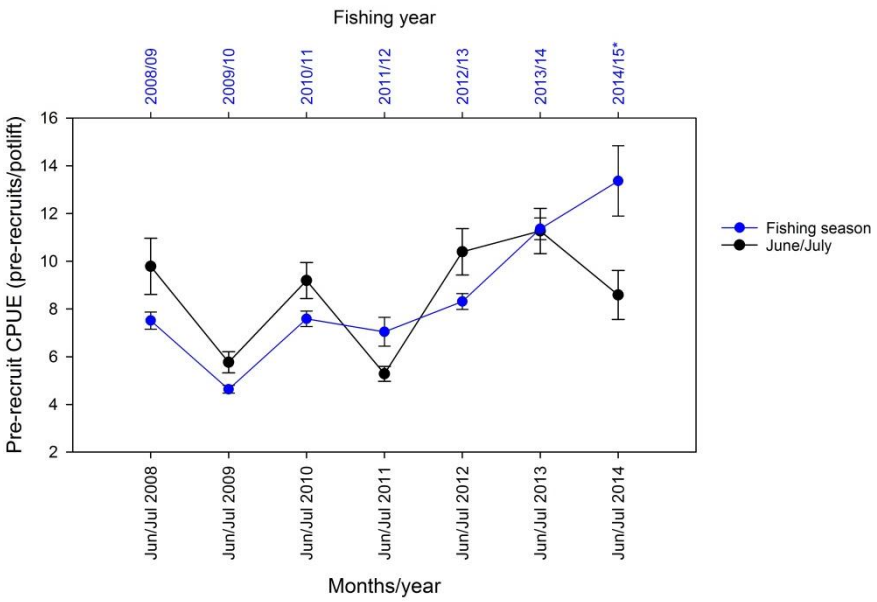

Figure 3.18. Mean catch per unit effort (CPUE, pre-recruits/potlift) of pre-recruits from pot-sampling undertaken by the Spencer Gulf pot fishing zone during June and July from 2008 to 2014 and in all months from 2008/09 to 2014/15. *2014/15 data from July–December 2014. Error bars, standard error.

There is some evidence of seasonal trends in mean estimates of CPUE for pre-recruits measured from pot samples, with peaks in pre-recruit abundance generally occurring in mid-winter and early-summer (**Figure 3.19**). In 2008 and 2009, the peak in pre-recruit abundance occurred in February/March and secondary peaks were observed in July/August in 2008. In 2010 and 2012 the peak in pre-recruit abundance occurred in June/July, however, secondary peaks were also observed in August/September in 2012. In 2011, the peak in pre-recruit abundance occurred in December, however, samples were not available from September–October. In 2013, pre-recruit abundance peaked in September but remained high from July–September and peaked again in December. In 2014, high pre-recruit abundance was observed in July (8.8 pre-recruits/potlift), however, in December a historical high of 20.3 pre-recruits/potlift was observed.

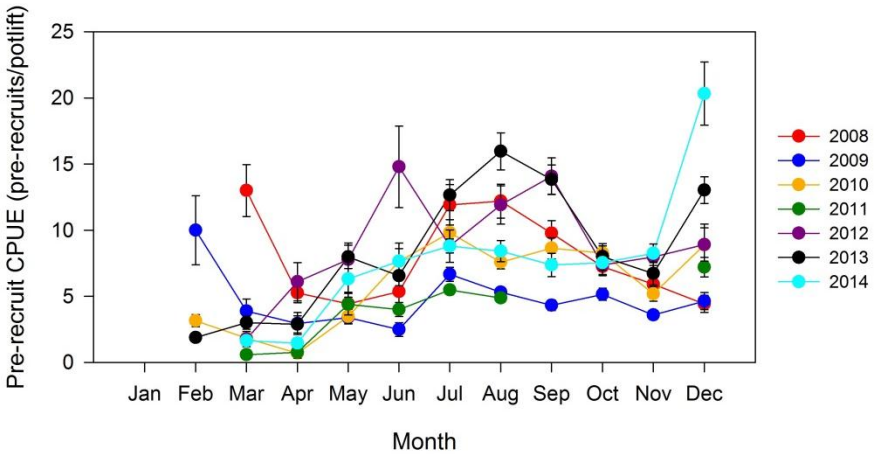

Figure 3.19. Mean monthly catch per unit effort (CPUE) of pre-recruits from pot-sampling undertaken by the Spencer Gulf pot fishing zone from 2008 to Aug 2014. Error bars, standard error.

3.2.3.2. Sex ratios

Sex-ratio estimates were available from pot-sampling in Spencer Gulf for most months between March 2008 and August 2013 (**Figure 3.20**). Female blue swimmer crabs were caught in relatively high proportions from July to December. In 2008 and 2010, high proportions of female crabs were recorded across most months compared to the other years sampled and more than 50% of crabs were female in October in both years. Females were rarely caught during February and March (except for 2008), but appeared in small proportions of the catch from April to June. In June 2013 and 2014, the proportion of female crabs in the catch was higher compared to previous years at 41% and 46%, respectively.

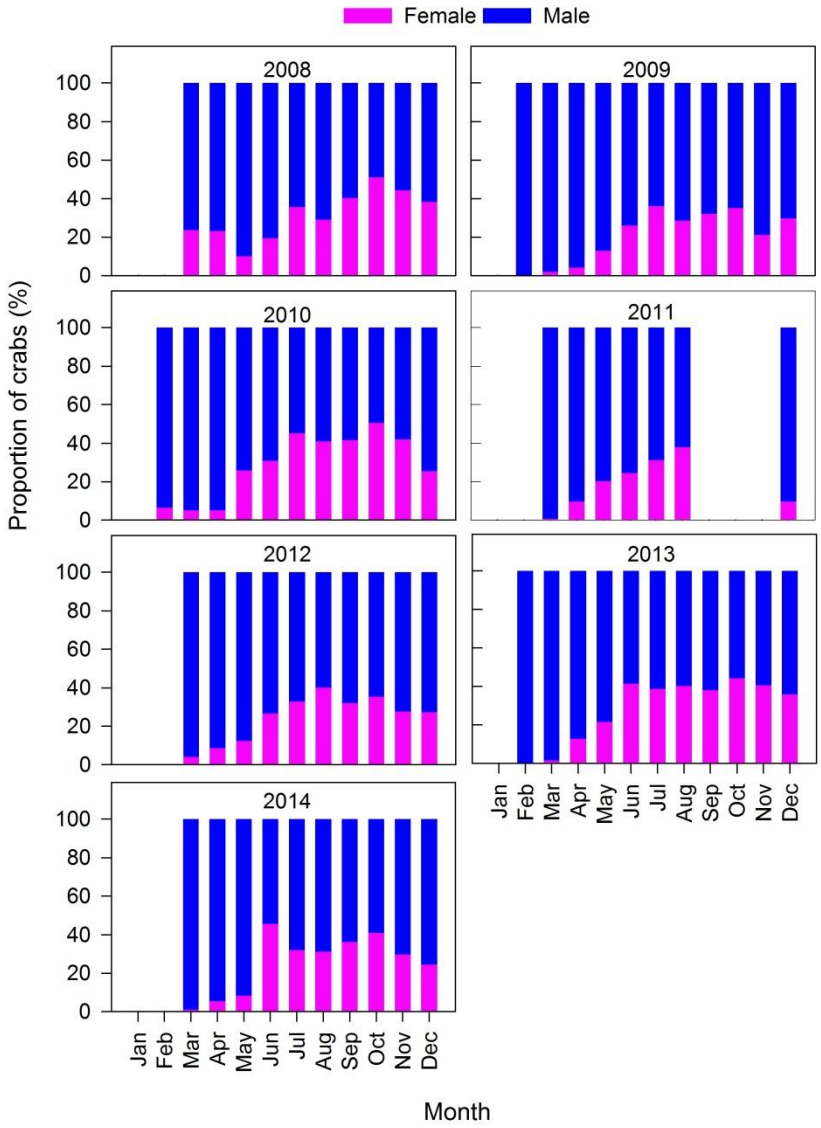

Figure 3.20. Proportion female and male blue swimmer crabs caught in small-mesh pots by Spencer Gulf pot fishing zone during pot-sampling from March 2008 to December 2014.

3.3. Gulf St Vincent

3.3.1. Fishery-independent surveys

3.3.1.1. Catch per unit effort (CPUE) relationships

For legal-size and pre-recruits crabs, the relationship between the CPUE from historical locations and the CPUE from new locations was moderate (**Figure 3.21a**,**b**). There was, however, a strong positive linear relationship between the CPUE from commercial and research pots for both pre-recruits and legal-size crabs (**Figure 3.22**). The relationship between the CPUE of legal-size and pre-recruit crabs measured from research pots was also moderate, however, there was a weak relationship between the CPUE of legal-size and pre-recruit crabs for commercial pots (**Figure 3.23**).

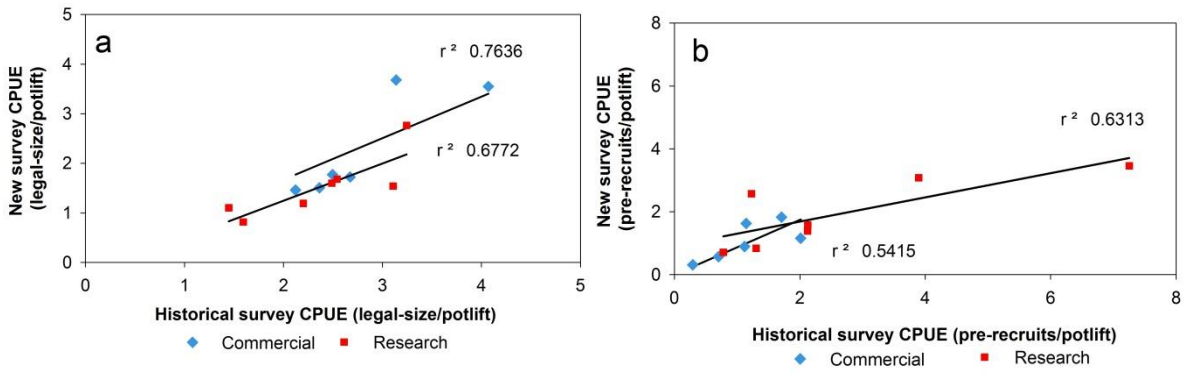

Figure 3.22 Relationship between mean survey catch per unit effort (CPUE) at historical and new locations from commercial and research pots in Gulf St Vincent from 2008–14 showing (a) legal-size CPUE (legal-size/potlift) and (b) pre-recruit CPUE (pre-recruits/potlift). Commercial pots were not sampled in 2012.

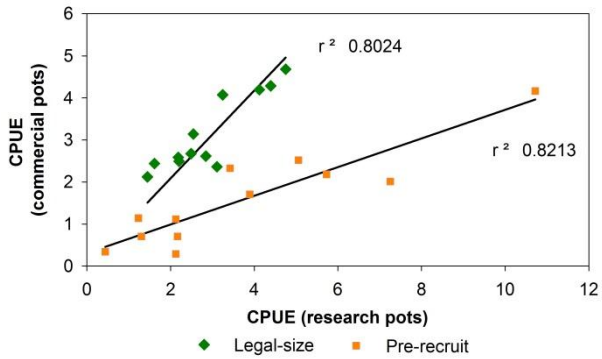

Figure 3.21 Relationship between mean survey catch per unit effort (CPUE) in commercial and research pots for legal-size (legal-size/potlfit) and pre-recruit crabs (pre-recruits/potlift) in Gulf St Vincent calculated from historical locations from 2002–14. Commercial pots were not sampled in 2012.

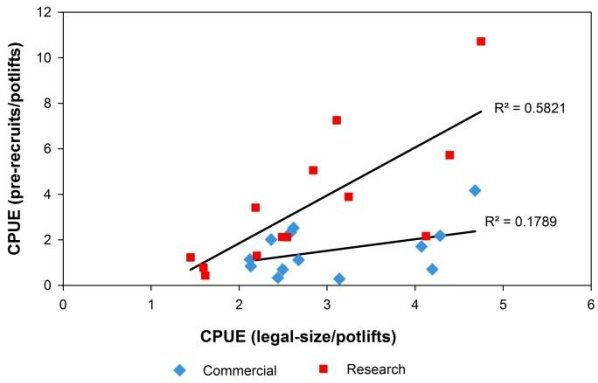

Figure 3.23 Relationship between survey catch per unit effort (CPUE) of legal-size (legal-size/potlift) and pre-recruit (pre-recruits/potlift) crabs in Gulf St Vincent calculated from historical locations from 2002–14. Commercial pots were not sampled in 2012.

3.3.1.2. Relative abundance of legal-size crabs

The CPUE of legal-size crabs has fluctuated through time, with similar trends in CPUE observed in most years for commercial and research pots. Since 2012, however, the CPUE of legal-sized crabs measured from commercial pots has remained higher than from research pots (**Figure 3.24**). The CPUE of legal-size crabs measured from historical locations was at its lowest levels in 2013 with 1.4 and 2.1 legal-size/potlift, in research and commercial pots, respectively. The addition of data from new locations from 2008, generally resulted in decreased estimates of CPUE. The CPUE of legal-size crabs from historical + new locations was lowest in 2012 at 1.3 legal-size/research potlift. In 2014, the CPUE of legal-size crabs from historical locations increased to 2.5 and 3.1 legal-size/potlift, respectively, for research and commercial pots. Similarly, the CPUE of legal-size crabs from historical + new locations increased to 2.2 and 3.3 legal-size/potlift, respectively for research and commercial pots in 2014.

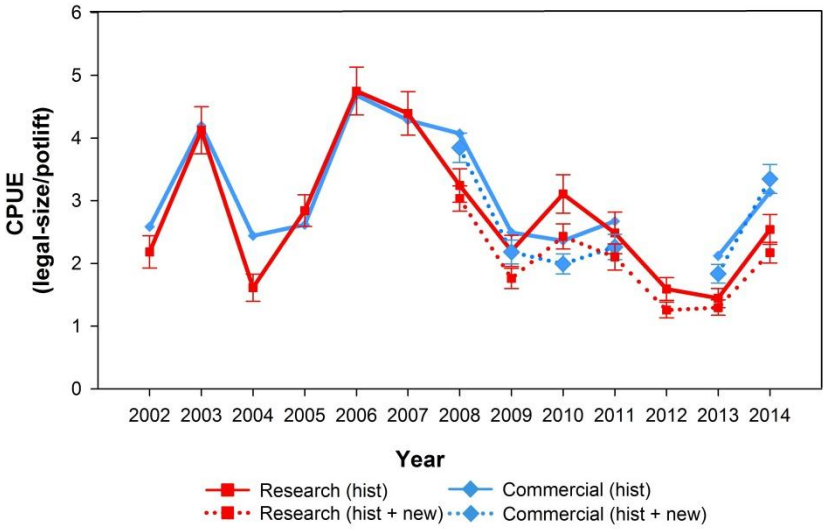

Figure 3.24. Mean catch per unit effort (CPUE) of legal-size crabs from research and commercial pots from historical locations (2002-current) and historical + new locations (2008-current) sampled in Gulf St Vincent during June and July from 2002 to 2014. Error bars, standard error. Note, commercial pots were not sampled in 2012.

In the central and southern zones of Gulf St Vincent, trends in CPUE of legal-size crabs measured from historical surveys were similar to those observed across the fishery. The CPUE of legal-size crabs measured from historical locations was generally highest in the southern zone compared to the central and northern zone, however, in recent years similarly low values were observed across all zones **(Figure 3.25)**. The CPUE of legal-size crabs was much lower from historical + new locations compared to the CPUE from historical locations in the southern zone for all years, while a much smaller difference was observed in the central zone. In the northern zone, the CPUE of legal-size crabs was higher from historical + new locations than from historical locations in all years with the largest differences observed in 2008–10 **(Figure 3.25)**.

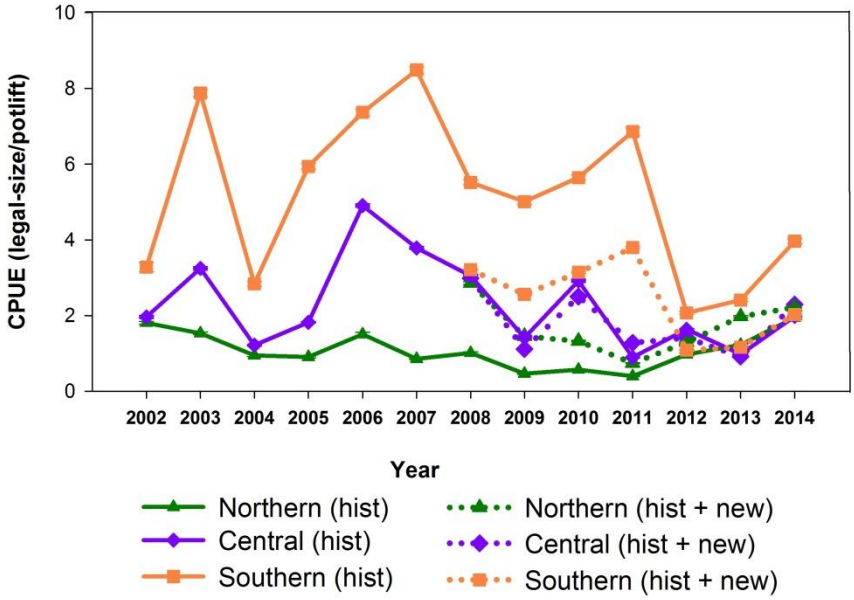

Figure 3.25. Mean zonal catch per unit effort (CPUE) of legal-size crabs for research pots sampled in Gulf St Vincent. Historical locations were sampled from 2002–14 and historical + new survey locations from 2008–14. Error bars, standard error.

Figure 3.26 shows the average relative densities of legal-size crabs measured from 2002–07, 2008–2013 and 2014, revealing a similar trend in the density distribution of legal-size crabs to that observed in CPUE estimates by zone (**Figure 3.26**). Concurrent with changes to pot locations in 2008, increased relative density of legal-size crabs was observed in the north (Blocks 2, 3 and 89). Compared to 2002–07, the relative density of legal-size crabs decreased in the central gulf (Blocks 13 and 14) and north of Port Vincent (Block 17) in 2008–13. In 2014, the relative density of legal-size crabs was similar to the 2008–13 average, with density concentrated in the region adjacent to Port Adelaide (Blocks 33, 34 and 35). In 2014, legal-size crabs were, however, more broadly distributed than compared historical averages, with increased relative density observed stretching north from Port Adelaide. Overall, in 2014, the relative abundance of legal-size crabs was equal to or above the 2008–13 average at 48% of survey locations, while the relative abundance of legal-size crabs was equal to or above the 2002–07 average at 39% of survey locations.

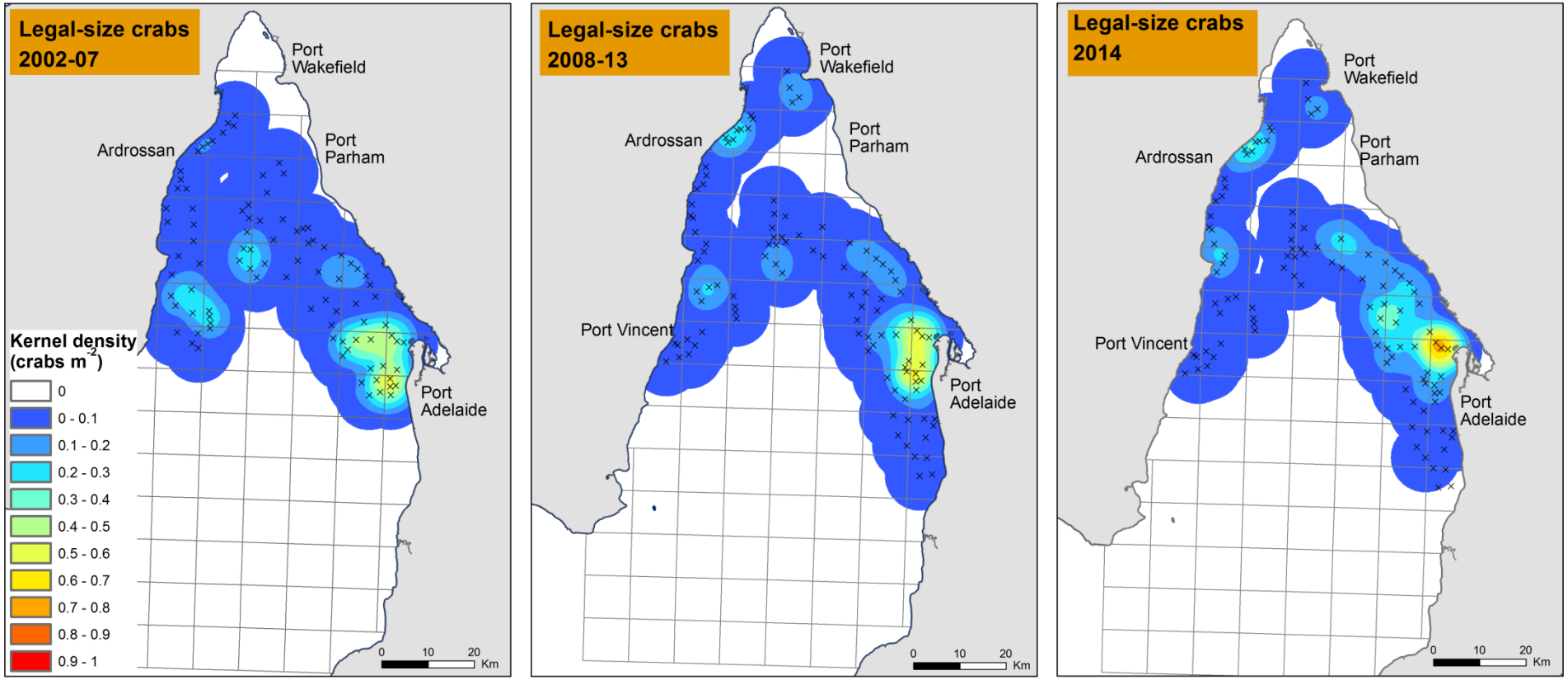

Figure 3.26 Kernel density maps showing the relative density (crabs per square metre) of legal-size crabs from historical (2002-07) and historical + new locations (2008–12 and 2014) in Gulf St Vincent. Sampling locations denoted by x.

3.3.1.3. Relative abundance of pre-recruits

The relative abundance of undersize crabs (pre-recruits) in Gulf St Vincent has fluctuated greatly since 2002 (**Figure 3.27**). The estimates of CPUE measured from historical survey locations were at their highest in 2006 and 2010, with 10.7 and 7.3 pre-recruits/potlift, from research and commercial pots, respectively. The CPUE of pre-recruits from historical locations was lowest in 2004 with 0.4 and 0.3 pre-recruits/potlift recorded for research and commercial pots, respectively. Estimates of the CPUE of pre-recruits from historical + new locations were generally lower than CPUE from historical locations alone (except for 2013), with larger differences generally observed in CPUE estimates from research pots.

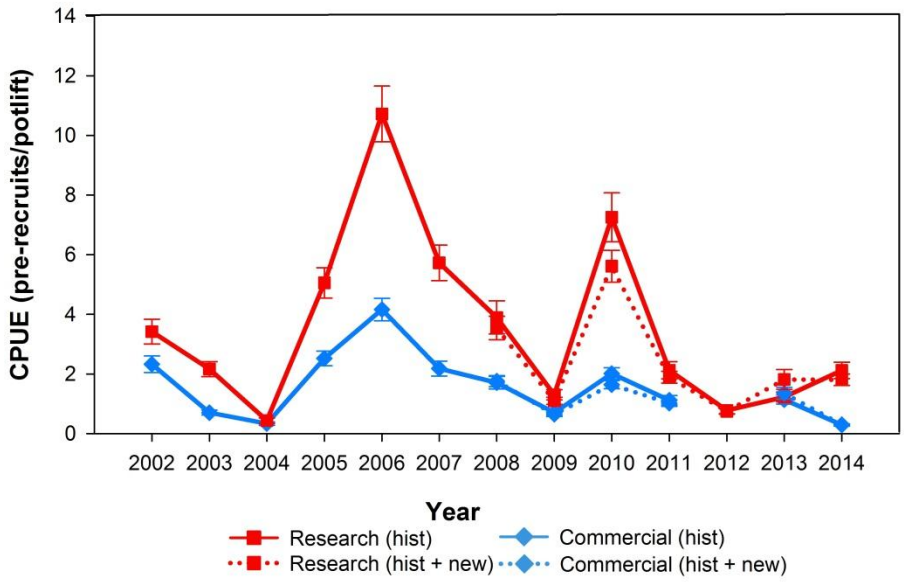

Figure 3.27. Mean catch per unit effort (CPUE) of pre-recruit crabs from research and commercial pots from historical locations (2002-current) and historical + new locations (2008-current) sampled in Gulf St Vincent during June and July from 2002 to 2014. Error bars, standard error. Note, commercial pots were not sampled in 2012.

Similar trends in the CPUE of pre-recruits measured from historical survey locations were observed across the central and southern zones, however the northern zone remained relatively low **(Figure 3.28)**. The CPUE of pre-recruits from historical locations was generally highest in the southern zone. Two major peaks in the CPUE of pre-recruits from historical locations were observed in 2006 and 2010, however, these were less pronounced in the northern zone. The CPUE of pre-recruits from historical + new locations was much lower than the CPUE of pre-recruits from historical locations in the southern zone (except for 2012). In the central zone, a much smaller difference was observed in the CPUE of pre-recruits from historical locations and historical + new locations across all years. In

the northern zone, the CPUE of pre-recruits from historical + new locations was higher than at historical locations alone in all years, with the largest differences observed in 2008, 2010 and 2013.

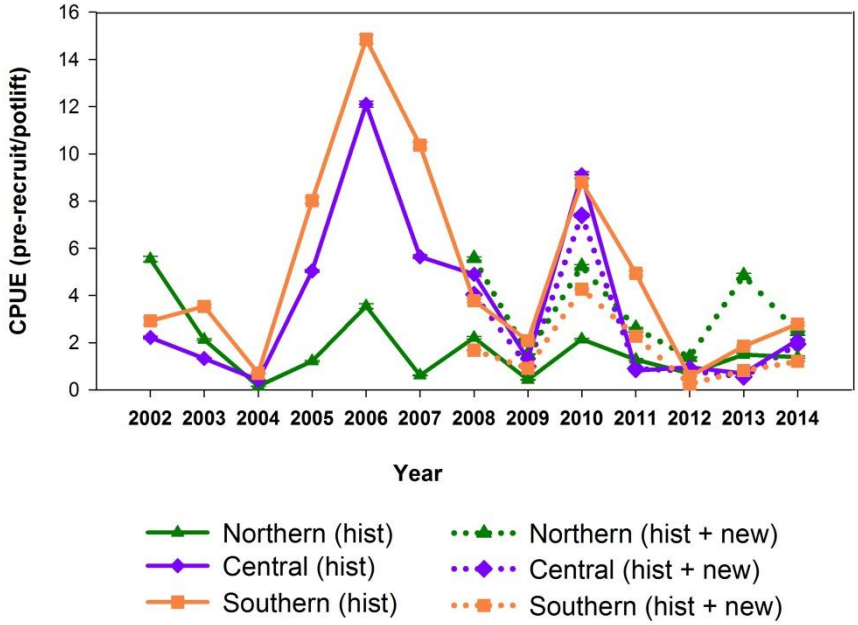

Figure 3.28. Mean zonal catch per unit effort (CPUE) of pre-recruits for research pots sampled in Gulf St Vincent. Historical locations were sampled from 2002–14 and historical + new survey locations from 2008–14. Error bars, standard error.

Figure 3.10 shows the average relative densities of pre-recruit crabs measured from 2002–07, 2008–13 and 2014, revealing a similar trend in the density distribution of pre-recruit crabs to that observed in CPUE estimates by zone. Concurrent with changes to pot locations in 2008, the relative density of pre-recruit crabs increased in the north (Blocks 2, 3 and 89). Compared to 2002–07, the density of pre-recruits decreased in the central gulf (Blocks 13 and 14) and in the north (Blocks 2, 3 and 89) in 2008–13. In 2014, the density of pre-recruit crabs was concentrated in the region adjacent to Port Adelaide (Blocks 33, 34 and 35). Overall in 2014, the relative abundance of pre-recruit crabs was equal to or above the 2008–13 average at 37% of survey locations, while the relative abundance of pre-recruit crabs was equal to or above the 2002–07 average at 24% of survey locations.

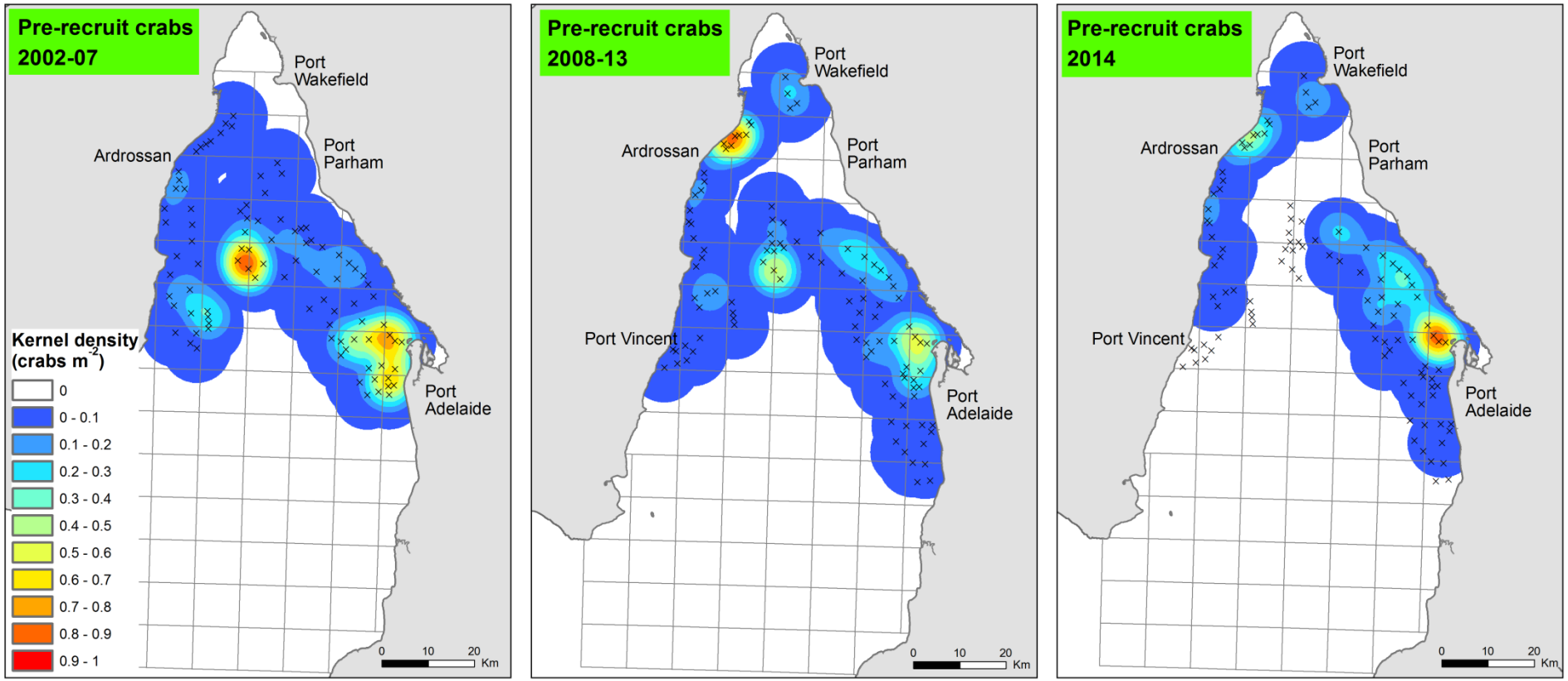

Figure 3.29. Kernel density maps showing the relative density (crabs per square metre) of pre-recruit crabs for historical (2002-07) and historical + new locations (2008–12 and 2014) in Gulf St Vincent. Sampling locations denoted by x.

3.3.1.4. Size distribution

The size distribution of the surveyed population in Gulf St Vincent varied substantially among years, however, no long term trends were apparent (**Figure 3.30)**. The modal size class of blue swimmer crabs was 100–109 mm carapace width (undersize or pre-recruits) during 2002, 2005–08, 2010–11, 2013–14 and 110–119 mm (legal-size crabs) during 2003–04, 2009 and 2012. In 2004, large legal size crabs comprised up to 67% of the survey catch and in the following year the proportion of medium-size crabs increased to 57% and then decreased gradually from 2006–09. A similar pattern occurred in 2009–10 and 2012–13, however, the larger percentages of medium size crabs comprised in the catch were not sustained over multiple years. In 2014, 89% of the catch was made up by medium and large crabs and 10% of crabs were extra-large, the highest value observed since 2004 (12%).

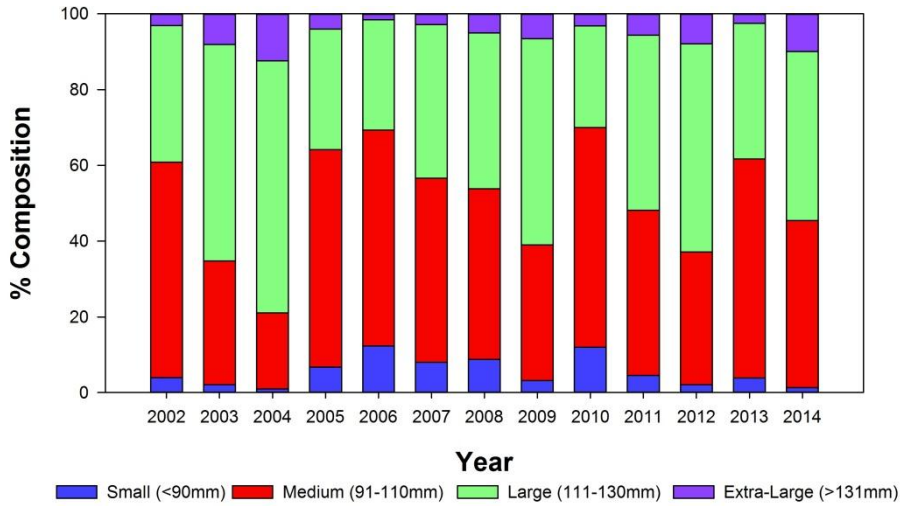

Figure 3.30. Size classes of crabs measured in research pots during fishery-independent surveys in Gulf St Vincent from 2002–14 presented as percent composition from historical locations (2002–07) and historical + new locations (2008-14).

3.3.2. Commercial logbook data

3.3.2.1. *Annual trends*

Following a 20% reduction in TACC for the 2013/14 fishing year, the Gulf St Vincent pot fishing zone held 196.1 t (33.9%) of the total TACC of the BCF (577.8 t). A majority of this allocation (190.8 t, 97.3%) was landed resulting in a 19.3% increase in catch from 2012/13 (**Figure 3.31**). Prior to 2013/14 the TACC had not been reached since 2007/08, the only fishing year in which the Gulf St Vincent component of the TACC was caught in full.

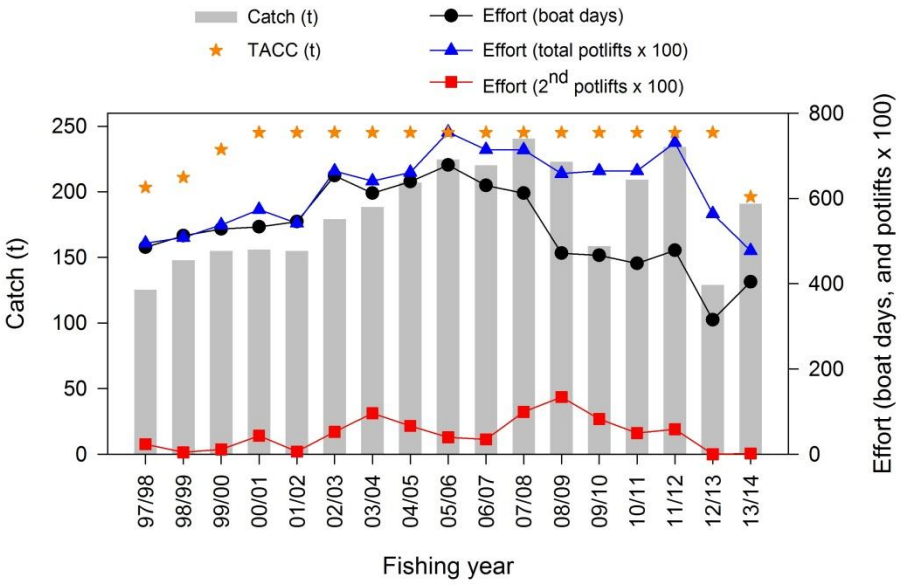

Figure 3.31. Total catch and effort for the Gulf St Vincent pot fishing zone from 1997/98 to 2013/14.

Following the introduction of quota in 1996/97, the number of boat days in Gulf St Vincent increased gradually from 485 to 545 boat days over the five-year period 1997/98 to 2001/02 (**Figure 3.31**). Boat days increased further when a new licence was issued in 2002/03, and then stabilised at this higher level of effort until 2007/08 (mean: 637 boat days), despite the introduction of another new licence in 2007/08. The number of boat days fished decreased in 2008/09, and then stabilised again until 2011/12, at a mean of 466 boat days. In 2012/13, the number of boat days dropped to the lowest recorded (315 boat days), and this was associated with a substantial reduction in total catch in the same year. The number of boat days increased by 12.4% between 2012/13 and 2013/14 to 404 days.

The number of total potlifts and boat days in Gulf St Vincent followed similar trends from 1997/98 to 2004/05. Thereafter, the two measures of effort diverged, with number of potlifts increasing relative to boat days (**Figure 3.31**). In 2012/13, the number of boat days and total potlifts had decreased by 34% and 23%, respectively, since 2011/12 (from 478 to 315 boat bays, and from 73,085 to 56,073

potlifts). From 2012/13 to 2013/14, the number of boat days increased by 12% despite a continuing decrease in the total number of potlifts to 47,677.

The number of second potlifts has fluctuated since the introduction of quota, reaching a maximum number of potlifts (13,367 potlifts) and proportion of total potlifts (20%) in 2008/09 (**Figure 3.31**). A low number of second potlifts (<1,000 potlifts) were recorded in 1998/99 (432 potlifts), 2001/02 (620 potlifts) and 2013/14 (139 potlifts); however, 2012/13 was the only year in which no second potlifts were recorded. In 2013/14, there was a 12% increase in the number of boat days while the number of total potlifts continued to decrease.

Annual mean estimates of CPUE calculated form first potlifts and total potlifts were relatively similar in Gulf St Vincent across all years ranging from 2.3–3.9 kg/potlift, while the average catch per boat day ranged from 274–490 kg/boat day (**Figure 3.32**). The mean CPUE calculated from second potlifts was considerably lower, ranging from 0.22–1.35 kg/potlift from 1997/98 to 200/01 and from 1.8–3.0 kg/potlift in 2002–03 to 2007/08. From 2009/10 to 2010/11, the CPUE calculated from second potlifts increased from 1.8kg/potlift to 3.8 kg/potlift and CPUE from second potlfits has remained above 3 kg/potlift since 2010/11. Substantial decreases for all measures of CPUE were, observed in 2009/10 and 2012/13. In 2013/14, total CPUE was similar to 2011/12 at 3.86 kg/potlift. A CPUE estimate of 472 kg/boat day was also recorded in 2011/12, the highest value recorded (per boat day) since 2011/12.

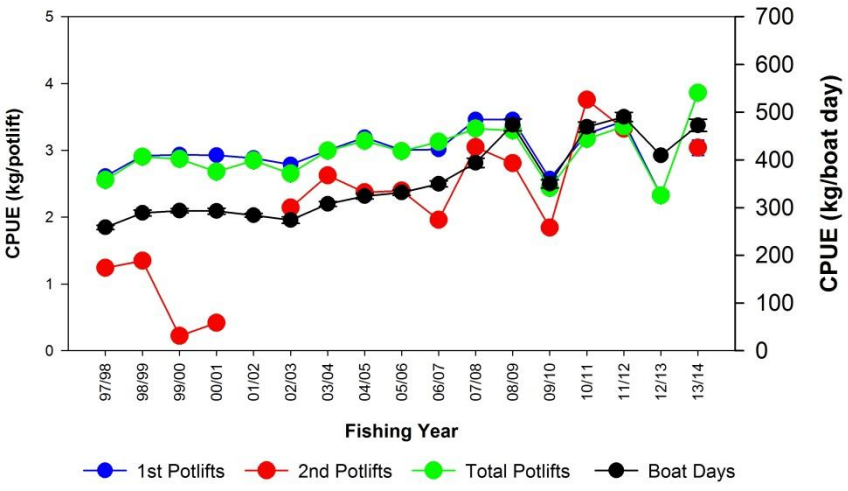

Figure 3.32. Mean commercial catch per unit effort (CPUE, kg/potlift) for 1st pot lifts, 2nd potlifts and total potlifts, and mean commercial CPUE (kg/boat day) in the Gulf St Vincent from 1997/98 to 2013/14. Error bars, standard error.

3.3.2.2. *Spatial distribution*

The proportion of catch taken within the different areas of Gulf St Vincent has varied since 1997/98 (**Figure 3.33**). From 1997/98–2001/02, the majority of the catch was harvested in the central region (≥57 t per season). During the same period, moderate catches (≤ 40 t per season) were recorded in the north–central zone and northern zone, and no catch was harvested from the northern zone from 2003/04–2005/06. High levels of total catch, 80 t and 79 t, respectively, were harvested across the south-central zone (where blocks in both zones were fished on the same day) and the central zone in 2002/03. From 2003/04–2011/12, the majority of the catch was harvested from the southern zone ranging from 76–154 t, while the central zone recorded catches from 32–77 t during this period. Increased catches in the northern zone were also observed in 2007/08–2009/10 (9–30 t) and the north-central zone in 2012/13 (7 t) and 2013/14 (21 t). In 2012/13 and 2013/14, catch was highest in the south-central zone at 48 t and 76 t, respectively.

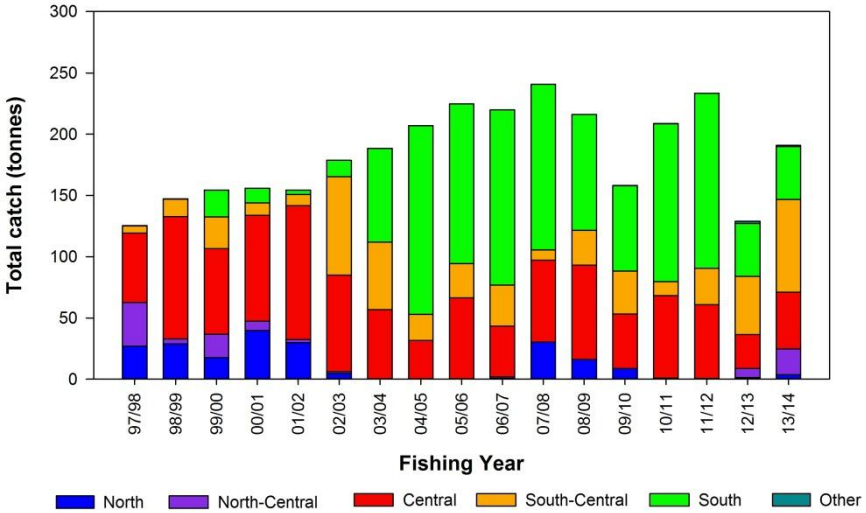

Figure 3.33. Total catch (tonnes) in the northern, central and southern zone of the Gulf St Vincent pot fishing zone from 1997/98 to 2013/14. Other includes days where fishing was spread over all zones and transitional zones (north-central, south-central) were included when catch spread across more than one zone.

The number of blocks fished in Gulf St Vincent ranged from 12 to 17 blocks from 1997/98 to 2007/08, (**Figure 3.34**). In 2008/09, the number of blocks fished increased, particularly in the southern zone and from 2008/09 to 2012/13 the number of blocks fished remained between 24 and 26 blocks. The number of blocks fished decreased to 19 in 2013/14 which was the lowest since 16 blocks were fished in 2007/08.

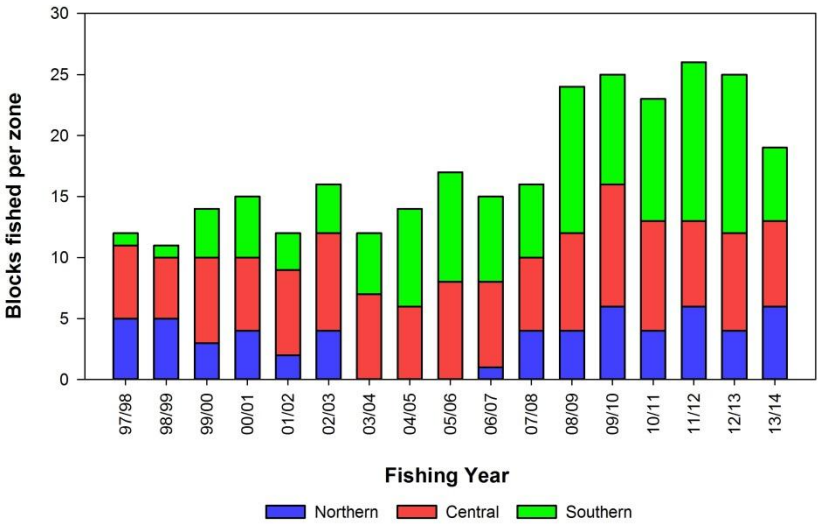

Figure 3.34. The number of blocks fished per zone per fishing year in the Gulf St Vincent pot fishing zone from 1997/98 to 2013/14.

In most years, two blocks were fished on the majority of days except for 2000/01, 2005/06, 2006/07 and 2007/08 where one block was fished per day on most days (**Figure 3.35**). In 2004/05, 2007/08, 2009/10–2011/12 and 2013/14, three blocks were fished per day on some occasions, accounting for 2–6% of the total days fished; in 2012/13 a relatively high proportion of days (23%) included 3 blocks. Less than 1% of effort was spread over 4 blocks per day in 2009/10–2013/14 and 5 blocks per day in 2008/09.

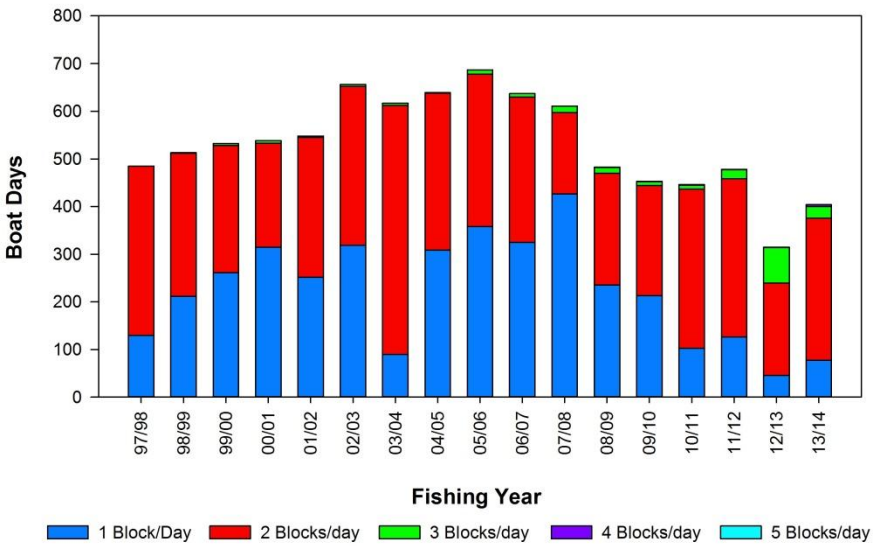

Figure 3.35. The number of blocks fished per boat day per fishing year in the Gulf St Vincent pot fishing zone from 1997/98 to 2013/14.

The observed catch rates across each zone were generally higher in the central and southern regions, with a maximum of 3.8 kg/potlift observed in the central zone in 2011/12 (**Figure 3.40**). Also in 2011/12, the lowest ever catch rate was observed in the northern zone at 1 kg/potlift. Catch rates decreased in the northern zone in 2002/03 and similarly low catch rates were observed in 2010/11 and 2011/12 in the northern zone (**Figure 3.36**).

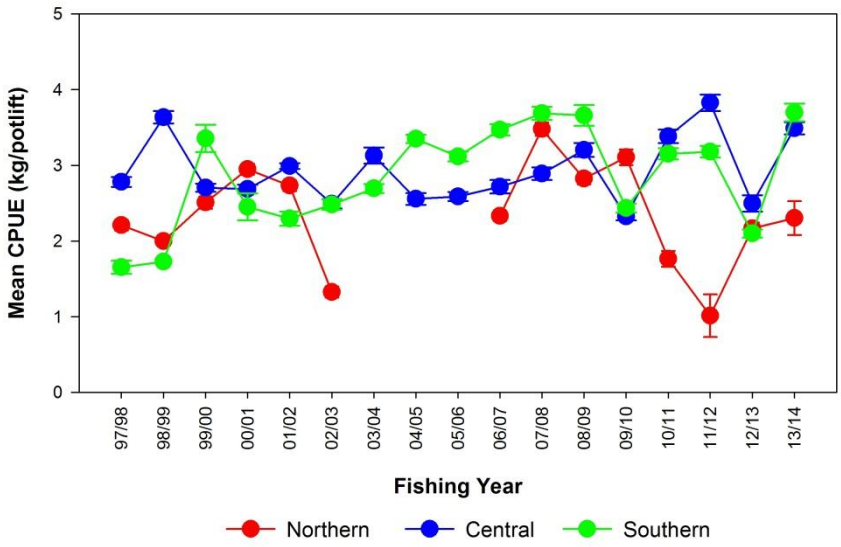

Figure 3.36. Mean catch per unit effort (CPUE, kg/potlift) in the northern, central and southern zone of Gulf St Vincent pot fishing zone from 1997/98 to 2013/14. Days where fishing was spread over more than one zone are not shown. Error bars, standard error.

3.3.3. Pot-sampling data

3.3.3.1. Pre-recruit abundance

The mean CPUE of pre-recruits from pot-sampling during June and July declined from 11.6 pre-recruits/potlift in 2008 to 3.2 pre-recruits/potlift in 2012. Estimated pre-recruit CPUE in June/July has increased since 2012, and the highest levels since 2008 were observed in 2014 at 8.78 pre-recruits/potlift (**Figure 3.41**). The CPUE of pre-recruits measured over all months has fluctuated between years with the largest decrease observed from 2010/11 (7.43 pre-recruits/potlift) to 2011/12 (3.24 pre-recruits/potlift, **Figure 3.41**). From 2012/13 to 2013/14, estimates of pre-recruit CPUE measured over all months decreased by 5% to 5.83 pre-recruits/potlift but increased in 2014/15 (up until December) to 13.34 pre-recruits/potlift.

Monthly estimates of pre-recruit CPUE were variable between years (**Figure 3.38**), particularly between July and October in 2008, 2010 and 2014 when mean monthly CPUE of pre-recruits was relatively high. The CPUE of pre-recruits was marginally higher in June compared to July in all years, except for 2014 (samples were not available in June 2008). Although CPUE was relatively

low throughout 2012, mean monthly CPUE of pre-recruits in 2013 (up to June) were some of the highest levels recorded of all years sampled. No fishing was undertaken in the latter half of 2013; however, when fishing recommenced in 2014, pre-recruit CPUE was at moderate levels before increasing to some of the highest levels ever recorded between July and October 2014. The estimate of pre-recruit CPUE in September of 17.1 pre-recruits/potlift, was the highest recorded since September 2010 (24.8 pre-recruits/potlift).

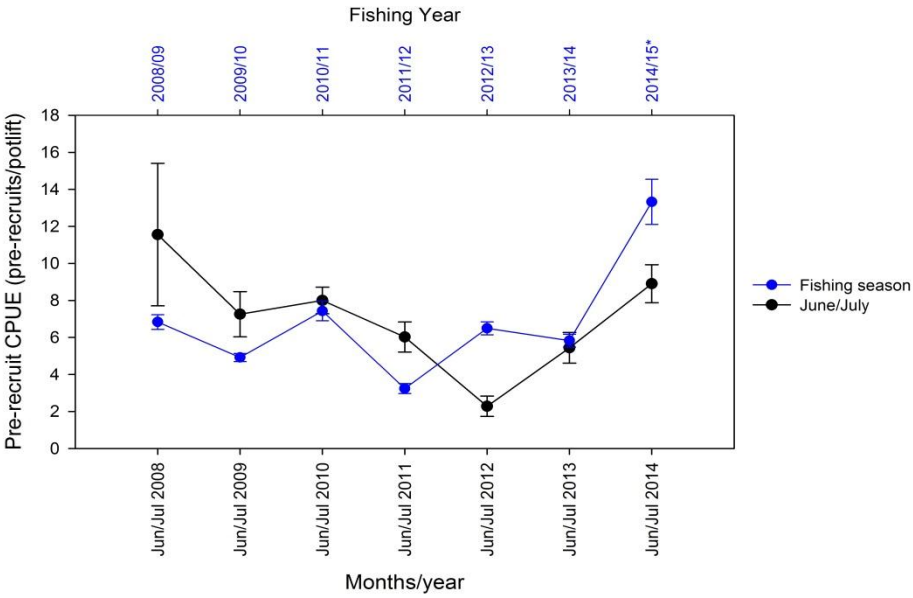

Figure 3.37. Mean catch per unit effort (CPUE) of pre-recruits from pot-sampling undertaken by the Gulf St Vincent pot fishing zone during June and July from 2008 to 2014 and across all months from 2008/09–2014/15. *Data from 2015 was not available at time of analysis. Error bars, standard error.

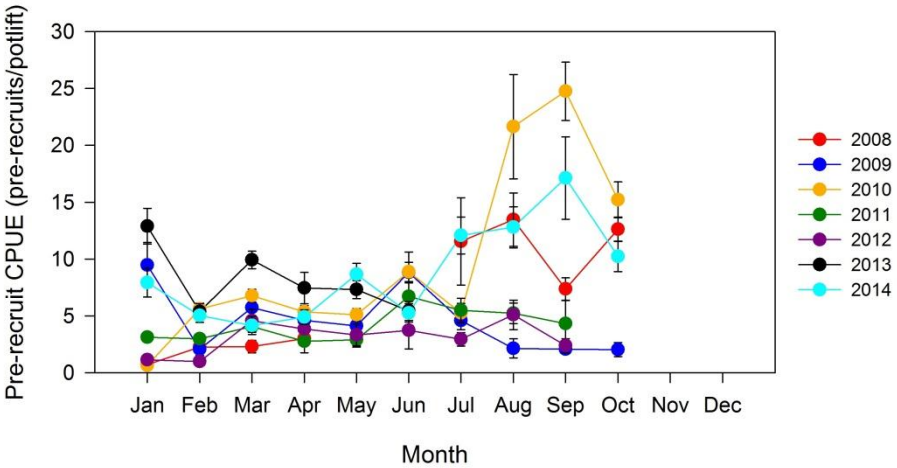

Figure 3.38. Mean monthly catch per unit effort (CPUE) of pre-recruits from pot-sampling undertaken by the Gulf St Vincent pot fishing zone from 2008 to October 2014. Error bars, standard error.

3.3.3.2. Sex ratio

Sex-ratio estimates were available from pot-sampling in Gulf St Vincent for most months between January 2008 and October 2014 (**Figure 3.39**). Female blue swimmer crabs were caught in relatively low proportions from January to March but their proportion increased between May and October. In 2009 and 2012, high proportions of females were recorded from April onwards, with samples comprising more than 50% of female crabs in June, July and October 2009 and June, July and September 2012. In 2014, high proportions of female crabs were recorded from July to October, peaking at 57%.

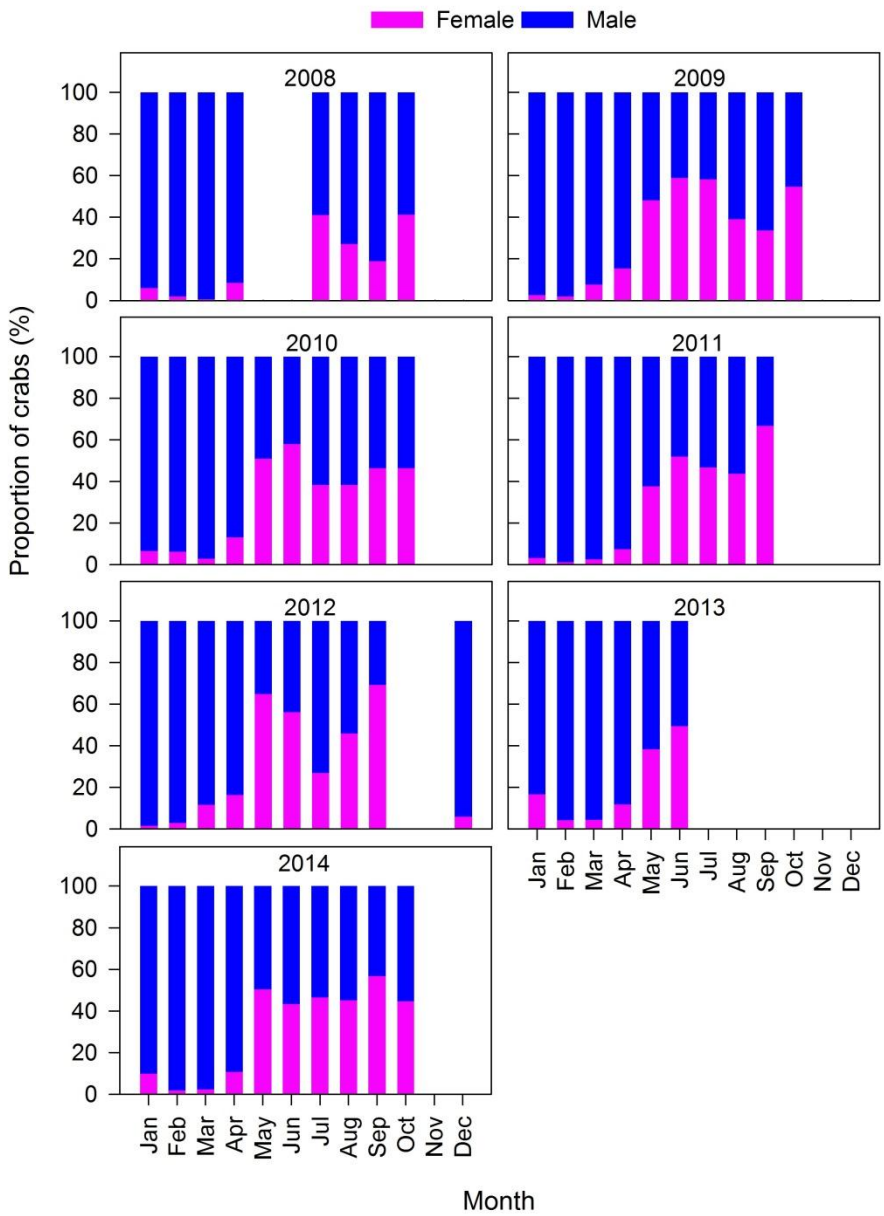

Figure 3.39. Proportion of female and male blue swimmer crabs caught in small-mesh pots by Gulf St Vincent pot fishing zone during pot-sampling from January 2008 to October 2014.

3.4. Performance indicators

3.4.1. Spencer Gulf

Data were available for all three performance indicators (PIs) for the Spencer Gulf pot fishing zone in 2013/14 and all PIs were above the upper limit reference points (**Table 3.3**). Mean survey CPUE for legal-size crabs in 2013/14 increased by 4% from 2012/13 and was above the upper limit reference point for the fourth consecutive survey year (**Figure 3.40**). Similarly, mean survey CPUE for pre-recruit crabs in 2013/14 increased 3.5% from 2012/13 and was above the upper limit reference point for the third consecutive survey year (**Figure 3.41**). The mean commercial CPUE of legal-size crabs increased from 3.79 kg/potlift in 2012/13 to 4.00 kg/potlift in 2013/14 (**Figure 3.42**). The upper limit reference point for commercial CPUE was reached for the first time since 2011/12 (4.38 kg/potlift).

Table 3.1. Summary of the performance of the Spencer Gulf pot fishing zone for 2013/14 against the key biological performance indicators, including a comparison with the previous two years.

Data source	Performance indicator	Limit ref. point		2011/12	2012/13	2013/14
		Lower	Upper			
1. Fishery-independent survey	CPUE of legal-size crabs (legal-size crabs/potlift)	5	8	9.23	-	10.00
2. Fishery-independent survey	CPUE of pre-recruits (pre-recruits/potlift)	2	9	8.81	-	9.45
3. Commercial catch and effort	CPUE of legal-size crabs (kg/potlift)	2	4	4.38	3.79	4.00

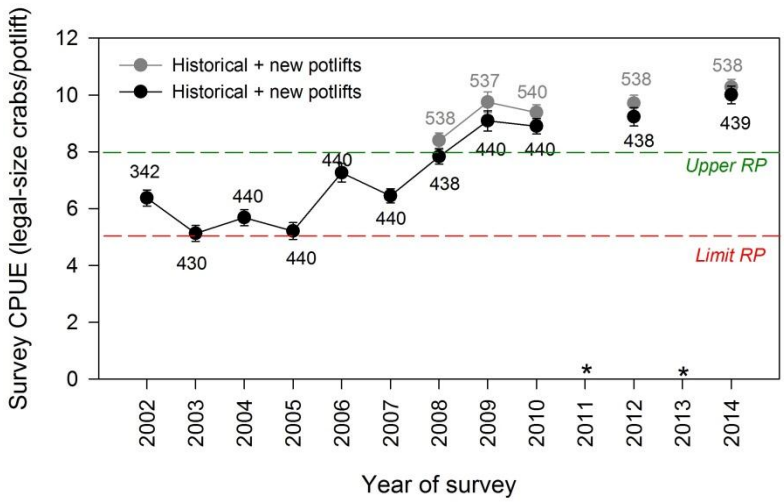

Figure 3.40. Mean survey catch per unit effort (CPUE, legal-size/potlift) for legal-size crabs in the Spencer Gulf pot fishing zone from 2002 to 2014. Error bars, Standard error. *No surveys in 2011 and 2013.

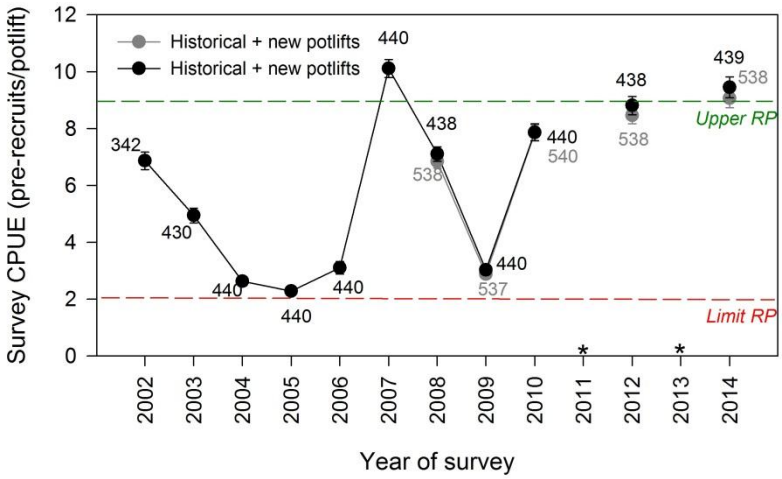

Figure 3.41. Mean survey catch per unit effort (CPUE, pre-recruits/potlift) for pre-recruits crabs in the Spencer Gulf pot fishing zone from 2002 to2014. Error bars, Standard error. *No surveys in 2011 and 2013.

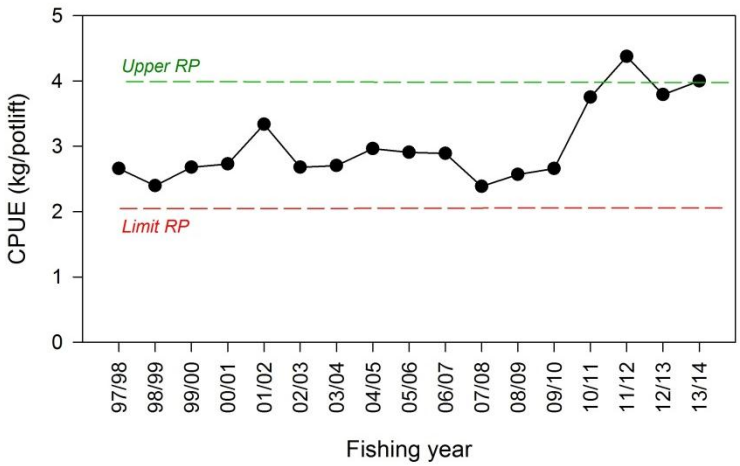

Figure 3.42. Mean commercial catch per unit effort (CPUE, legal-size/potlift) for legal-size crabs in the Spencer Gulf pot fishing zone from 1997/98 to 2013/14. Error bars, standard error.

3.4.2. Gulf St Vincent

Data were available for all three PIs for the Gulf St Vincent pot fishing zone in 2013/14 and all PIs were above the lower limit reference points (**Table 3.4**). Compared to 2012/13, the mean survey CPUE of legal-size crabs increased by 27.5% to 2.54 legal-size crabs/potlift (**Figure 3.43**). Compared to 2012/13, the mean survey CPUE of pre-recruit crabs increased 26.7% to 2.12 pre-recruits/potlift (**Figure 3.44**). The PIs for survey CPUE of legal-size and pre-recruit crabs were above the lower limit reference points for the first time since 2011. The mean commercial CPUE of legal-size crabs approached the upper limit reference point reaching a historical high of 3.86 kg/potlift, an increase of 24.8% compared to 2012/13 (**Figure 3.45**).

Table 3.2. Summary of the performance of the Gulf St Vincent pot fishing zone for 2013/14 against the key biological performance indicators, including a comparison with the previous year. The values highlighted in red indicate that the limit reference point was not achieved for that performance indicator.

Data source	Performance indicator	Limit ref. point		2011/12	2012/13	2013/14
		Lower	Upper			
1. Fishery-independent survey	CPUE of legal-size crabs (legal-size crabs/potlift)	1.5	4	1.59	**1.45**	2.54
2. Fishery-independent survey	CPUE of pre-recruits (pre-recruits/potlift)	1.5	8.5	**0.78**	**1.23**	2.12
3. Commercial catch and effort	CPUE of legal-size crabs (kg/potlift)	2	4	3.36	2.33	3.86

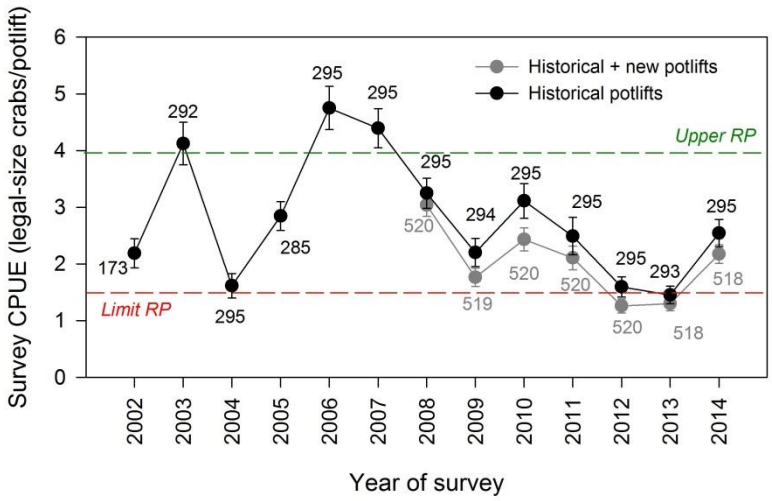

Figure 3.43. Mean survey catch per unit effort (CPUE, legal-size/potlift) for legal-size crabs in Gulf St Vincent pot fishing zone from 2002–14. Error bars, standard error.

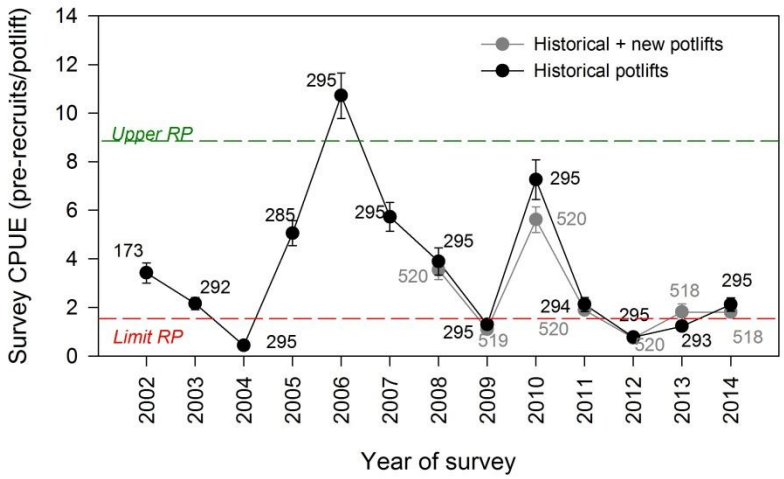

Figure 3.44. Mean survey catch per unit effort (CPUE, pre-recruits/potlift) for pre-recruit crabs in Gulf St Vincent pot fishing zone from 2002–14. Error bars, standard error.

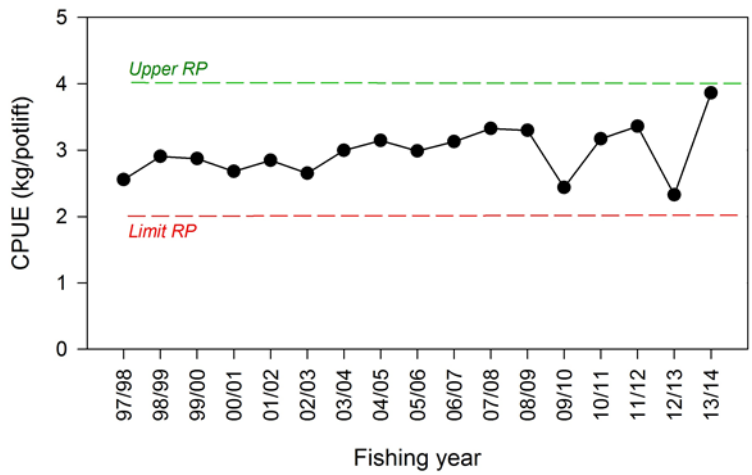

Figure 3.45. Mean commercial catch per unit effort (CPUE, legal-size/potlift) for legal-size crabs in Gulf St Vincent pot fishing zone from 1997/98 to 2013/14. Error bars, standard error.

4. DISCUSSION

4.1. Current status of the Blue Crab Fishery

4.1.1. Data available for assessment

The harvest strategy for the fishery does not provide a definition of when the stock is considered 'recruitment-overfished' and the PIs in this fishery are not explicitly linked to a definition of stock status. Consequently, in this assessment, a ‘weight of evidence’ method has been used to determine stock status.

Three primary datasets were available to assess the status of the BCF in 2013/14. These were: 1) fishery-independent surveys; 2) fishery-dependent commercial logbooks; and 3) fishery-dependent voluntary pot-sampling data. In addition, there was information on the biology of the blue swimmer crab, sex ratios and size composition. While future assessments may be more strongly influenced by the data from the voluntary pot-sampling program, particularly if further analyses can validate the reliability of this measure as an index of recruitment to the fishery, the most appropriate current primary measures of stock status in the BCF are the relative abundance of pre-recruit and legal-size crabs from the annual or biennial fishery-independent surveys.

The fishery-independent surveys are considered to provide the most reliable indices of relative abundance due to 1) their standardised (space, timing, gear) sampling design; 2) the difficulty in quantifying the effects of fisher demographics and experience, temporal and spatial shifts in catch and effort, and improvements in catching efficiency (e.g. gear modification, vessel technology, selectivity of commercial pots) on commercial CPUE; and 3) the limited data (spatially and temporally) available from the voluntary pot-sampling program. In addition, following the inclusion of new sampling locations in 2008, the spatial coverage of these indices, and their reliability as an abundance index, have been substantially improved.

4.1.2. Spencer Gulf

There is compelling evidence that there is a substantial biomass of blue swimmer crabs in Spencer Gulf. Firstly, fishery-independent surveys indicate spatially consistent, high current relative abundances of legal-size and pre-recruit crabs. Secondly, the legal-size CPUE has exceeded the limit reference point in all surveys since 2009 and the pre-recruit CPUE was just below the limit reference point in the previous two surveys (2010 and 2012). Thirdly, the high survey catch rates have been observed throughout the gulf. Fourthly, for the 2013/14 season, almost the entire Spencer Gulf component of the TACC was caught for the tenth consecutive year. Lastly, whilst likely to be positively biased, commercial legal-size CPUE has remained near the upper reference point since 2010/11 and is spatially consistent, providing additional evidence that the stock is in a strong

position. On the weight of evidence, the Spencer Gulf zone of the BCF is not considered to be recruitment overfished, and the current level of fishing pressure is unlikely to cause the fishery to become overfished. Therefore, using the national framework for stock status reporting (Flood *et al.,* 2012), the Spencer Gulf fishing zone of the BCF is classified as 'sustainable'.

4.1.3. Gulf St Vincent

Based primarily on the low catch rates of legal-size and pre-recruit crabs in the 2013 fishery-independent surveys, the Gulf St Vincent stock was classified as 'transitional recovering' in 2012/13. In response, management arrangements were revised for the 2013/14 and 2014/15 seasons to promote stock recovery. These changes included the TACC being reduced by 20%, recreational bag and boat limits being reduced by 50%, and the voluntary implementation of a six-month closure by commercial fishers in 2012/13.

There are multiple lines of evidence that the relative abundance of blue swimmer crabs has increased, indicating a positive stock response to these actions (i.e. stock rebuilding). This evidence includes 1) the survey CPUE of legal-size crabs increasing from 1.45 legal-size crabs/potlift in 2013 to 2.54 legal-size crabs/potlift in 2014, the highest value since 2010 (3.11 legal-size/potlift) and above the limit reference point; 2) pre-recruit CPUE increasing from 1.23 pre-recruits/potlift in 2013 to 2.12 pre-recruits/potlift in 2014, the highest value since 2011; 3) survey CPUE being equal to or above the 2008–13 average at 48% of survey locations for legal-size crabs and 37% of survey locations for pre-recruits; 4) increased commercial catch rates in the central and southern regions of the Gulf; and 5) all three PIs were above the lower reference points. Consequently, using the national framework for stock status reporting, the Gulf St Vincent fishing zone of the BCF is classified as ‘sustainable’. While this reflects a substantial improvement in stock status from ‘transitional recovering’ in 2012/13, there is evidence that the stock is still in a rebuilding phase. Notably, 1) the abundance of pre-recruits in the 2014 survey remained among the lowest values on record; and 2) the recent increases in pre-recruit and legal-size abundance observed in the 2014 fishery-independent survey were spatially limited compared to their historical distribution.

4.2. Harvest strategy

The current harvest strategy for the fishery is being reviewed, due for completion in June 2015. This review will 1) evaluate the reliability of the existing PIs for determining stock status; 2) develop the reliability of the existing PIs for identifying when a stock will be defined as recruitment overfished; 3) review the potlift locations to be used for setting reference points (e.g. historical or historical + new potlifts); 4) identify other potential indicators; and 5) consider how the biological PIs should be weighted when assessing stock status and setting TACC.

There are three major limitations of the current harvest strategy. The first is that it does not provide a definition of when the stock should be considered to be recruitment-overfished, in part because PIs are not linked to an annual determination of stock status. Revision of the harvest strategy should require the development of a reference point for identifying when a stock will be defined as recruitment-overfished for which the existing survey CPUE limit reference point would provide a reasonable starting point. One approach to define the annual stock status would be to classify levels of relative abundance above the threshold reference point as “sustainable”, levels of relative abundance between the threshold and limit reference point as “transitional” and levels of relative abundance below the limit reference point as “overfished” (**Figure 4.1**). Linking the biological reference points to a definition of recruitment overfishing is important to ensure that the spawning stock biomass is maintained and recruitment overfishing avoided.

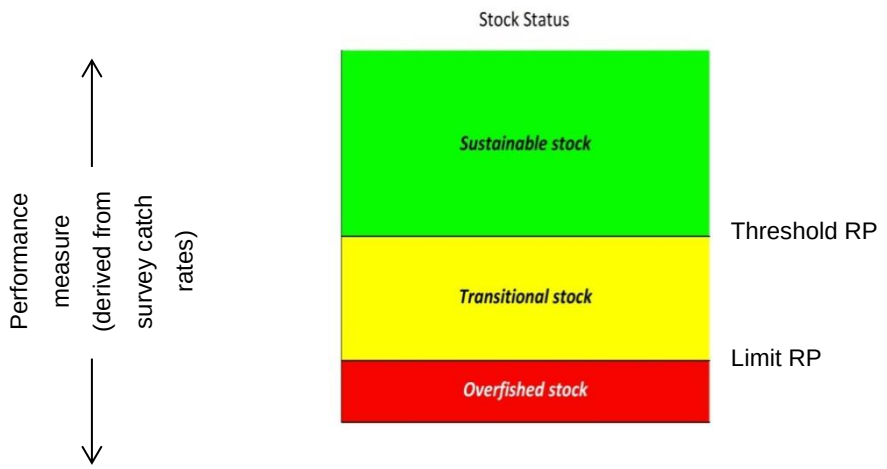

Figure 4.1 Assessment of stock status using survey catch rate as a key biological performance indicators (PIs), with reference points (RPs) based on stock assessment survey results.

The second limitation of the current harvest strategy is that stock status is assessed using information from the previous financial year. Consequently, there is a lag from the time changes occur in the fishery to the time that any required management responses can be implemented. Such delays may result in reduced profitability, an increased risk of stock collapse and subsequent reduced productivity from excessive exploitation levels (Shertzer and Prager, 2007), particularly for short lived species such as the blue swimmer crab. There are two potential solutions to this problem. First, the timing of the survey could be changed (e.g. to March) to reduce the time period between surveys and TACC setting in this fishery. However, it would take several years of paired March and June/July surveys to allow direct comparison between current and historical abundance. Nevertheless, such a change could also consider the need for ongoing biannual surveys to overcome the temporal limitations (i.e. annual or biennial) of the current surveys. It may also be

possible to use the pot-sampling data to directly inform the timing of the fishery-independent surveys. Alternatively, the season start date could be moved to later in the year (e.g. October). This would prevent the need to change the timing of the surveys and enable the TACC to be set using 1) survey data less than four months old (rather than the current 10 months); 2) pot-sampling data from the previous summer period when growth and reproduction is increased; and 3) contemporary fishery-dependent data.

The third limitation of the current harvest strategy is that there are no clearly-defined decision rules for setting the annual TACCs. Similar to the Southern Rock Lobster Fishery (PIRSA, 2013) and the Lakes and Coorong Pipi Fishery (Ferguson and Ward, 2014), a decision making framework could be structured around a quota-setting matrix to determine the TACC. For example, the current TACC level (y axis) could be cross-referenced with a measure of current abundance (e.g. commercial CPUE or survey CPUE) to determine the corresponding threshold range (x axis, **Figure 4.2**).The resulting TACC would then reflect the fishery's stock status category (green, yellow, blue or red). Under this model, PIs would need to be selected and decision rules subsequently developed to link abundance with catch levels. Economic PIs and market price estimates should also be considered to allow the resource to be exploited for maximum economic value within the framework of sustainable exploitation. However, this could be achieved either explicitly within the framework, or remain vested with the industry. Economic returns should be examined over a range of sustainable TACC levels, similar to the harvest strategy model currently used in the South Australian Pipi Fishery (Ferguson and Ward, 2014). The major benefit of this approach is that industry can provide structured and direct input on the impacts of external factors on expected future prices over a range of TACCs.

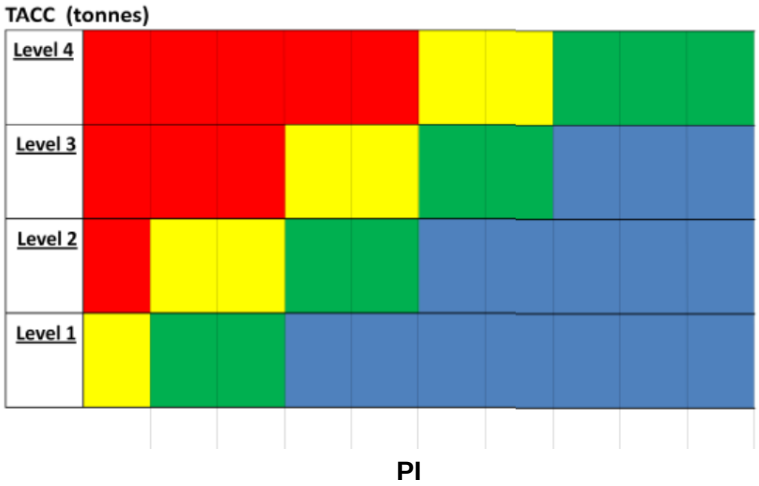

Figure 4.2 Example matrix showing catch per unit effort (CPUE) thresholds and corresponding total allowable commercial catch (TACC) levels, modified from the Southern Zone Rock Lobster Fishery (PIRSA, 2013). PI, performance indicator.

4.3. Future research needs

The most important future research need for the Blue Crab Fishery is to evaluate the reliability of the current indices of stock abundance. This should include 1) continuing to evaluate options to standardise fishery-dependent data (e.g. commercial CPUE and pot-sampling CPUE); 2) exploring alternative datasets that could be used as PIs to assess stock status; and 3) optimising the survey design to maximise information for assessment of stock status.

The fishery-independent surveys undertaken using standardised gear, which have typically been paired with commercial gear when set, will likely provide useful information on 1) temporal changes in gear efficiency; 2) differences among licence holders using different gear configurations over time; and 3) relative catchability of blue crabs. The latter is important because, since 2012, commercial pots have increasingly caught fewer legal-size crabs than research pots in Spencer Gulf, while in Gulf St Vincent the opposite trend has occurred. Further information on historical changes in gear configuration is required and collectively, these could inform CPUE standardisation. Such a standardisation process could also be used to enhance the value of the pot-sampling data, which has a high level of spatial and temporal variability. The pot-sampling program was designed to provide supplementary information on the relative abundance of pre-recruits where survey CPUE was below the limit reference point. Currently, there are several ways this index could be calculated and there are no associated PI or limit reference points. The reliability of this index could also be enhanced by continuing to sample only those blocks with the greatest historic temporal coverage. In addition, as the pot-sampling program is resource intensive, new technology such as smart tags and electronic logbooks should be investigated as a means to reduce onboard processing time and allow more timely use of information.

Other estimates of relative abundance should also be investigated and these could include biomass estimations from prawn trawl surveys, or the use of larval collectors and/or tidal flat and beach sampling to directly monitor recruitment. The evaluation of these alternative methods is likely to be time consuming and is outside the scope of the current work program for this fishery.

There is also a need to periodically re-evaluate the fishery-independent survey design to ensure the surveys are representative of blue crab distribution. This is important because consistently low crab abundances in some areas can skew the data and add uncertainty to the assessment of stock status, particularly in Gulf St Vincent where the population is patchily distributed. Changes in blue swimmer crab distribution can also result in over- or under-estimated crab abundance. For example, there is anecdotal evidence of an increase in blue crab abundance in southern Spencer Gulf which is outside the spatial extent of existing surveys.

In addition, a *hematodinium*-like parasite was recently identified in blue swimmer crabs from Gulf St Vincent (Shane Roberts, pers. comm.). Although the prevalence and impact of *Hematodinium* infection has not been quantified in South Australia, similar infections have negatively affected a number of commercial crustacean fisheries in the United States and Europe (Stentiford and Shields, 2005). Continued monitoring of the disease status of blue swimmer crabs in both Gulfs will be useful to determine the extent and potential impact on stock status.

5. REFERENCES

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