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Blue Crab (*Portunus armatus*) Fishery 2012/13

C. J. Noell, C. L. Beckmann and G. E. Hooper

SARDI Publication No. F2007/000729-10
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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

March 2014

Fishery Assessment Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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EXECUTIVE SUMMARY

This fishery assessment report updates the 2011/12 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) up to the end of June 2013.

In 2012/13, 81% of the total allowable commercial catch (TACC) of the BCF was harvested, with Spencer Gulf and Gulf St Vincent pot fishing sectors harvesting 99% and 53% of their share of the TACC, respectively. The Gulf St Vincent pot fishers deliberately caught less than their allocated TACC in response to the decline in biomass, which became noticeable early in the 2012/13 season. The pot fishing sector currently holds >99% of the TACC, with some licence holders in the Marine Scalefish Fishery making up the remainder.

There are three performance indicators 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), standardised pot type and location and spatial coverage in each gulf. In contrast, the third performance indicator, which is derived from commercial catch and effort data, provides a less reliable index of abundance of legal-size crabs because of the effects of changes in gear and vessel technology, fisher demographics, experience, potlift behavior, and temporal and regional distribution of catch and effort.

In accordance with an option in the Management Plan, a fishery-independent survey was not conducted in Spencer Gulf in 2013 as a result of a higher-than-average CPUE of pre-recruit crabs in the 2012 survey. Consequently, there are no fishery-independent data to provide information on current biomass. The most recent survey (2012) yielded a CPUE of 9.23 legal-size crabs/potlift and 8.81 pre-recruits/potlift, both of which are either above or near their respective upper reference point, thus indicating high relative biomass levels. In 2012/13, almost the entire Spencer Gulf component of the TACC for the fishery was caught for the ninth consecutive year. Commercial CPUE remained at a high level. Based on the latest evidence available, and using the national framework for stock status reporting, the Spencer Gulf fishing zone of the BCF would be classified as ‘sustainable’.

There are multiple lines of evidence that the relative biomass of blue swimmer crabs in Gulf St Vincent remains at a low level: 1) the survey CPUE of legal-size crabs decreased from 1.59 legal-size crabs/potlift in 2012 to 1.45 legal-size crabs/potlift in 2013, the lowest value

on record and below the limit reference point; 2) although the pre-recruit CPUE from the 2013 survey (1.23 pre-recruits/potlift) improved from 2012 (0.78 pre-recruits/potlift), values for both years were below the limit reference point and among the lowest on record; 3) there has been a substantial reduction in the number of blocks with medium or high survey CPUE for both legal-size and pre-recruit crabs; 4) only half the Gulf St Vincent component of the TACC was caught in 2012/13; 5) it is the fifth consecutive year (since 2007/08) that the TACC for this zone was not caught in full; 6) more blocks were fished in 2011/12 and 2012/13 than any other year (and at low catches); 7) low catch rates were observed throughout the gulf. Management arrangements were revised for the 2013/14 season to promote stock recovery (six-month closure, TACC allocation was reduced by 20%, and recreational bag and boat limits were reduced by 50%). Whilst the stock response to these actions will not be known for at least another 12 months, supplementary pot-sampling data from January to June 2013 indicated an increase in abundance of pre-recruits. This was consistent with previous advice from industry that the abundance of juveniles was increasing. Based on the available information, and using the national framework for stock status reporting, the Gulf St Vincent fishing zone of the BCF would be classified as 'transitional-recovering'.

A review of the harvest strategy is scheduled to take place in 2014. Through this process, there is a need to develop a limit reference point that explicitly identifies when a stock is recruitment overfished. The review will also provide the opportunity to evaluate existing and other potential indicators for determining stock status, with compulsory annual surveys being an appropriate trade-off for potential increases in TACC to ensure regular monitoring of the stock biomass.

1. INTRODUCTION

1.1. Overview

This report is the ninth version that has been updated annually since 2004 as part of the SARDI Aquatic Sciences ongoing assessment program for the South Australian Blue Crab Fishery (BCF) (Svane and Hooper, 2004; Currie and Hooper, 2006; Currie *et al.*, 2007; Dixon *et al.*, 2008; Dixon and Hooper, 2009; 2010; 2011; Rodgers *et al.*, 2013). The report aims to: 1) synthesise information for the BCF for each of the Spencer Gulf and Gulf St Vincent pot fishing sectors; 2) assess the current status of the blue swimmer crab resource in each gulf and consider the uncertainty associated with each assessment; 3) comment on the current biological performance indicators and reference points for the fishery; and 4) identify 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 used and performance indicators for fishery assessment.

Section 2 provides the methods for data collection and analyses for the stock assessment surveys (fishery-independent), and the commercial logbook data and pot-sampling programs (fishery-dependent) for both gulfs.

Section 3 presents the results of the data analyses in three subsections: 1) annual catch and effort (for both gulfs); and 2) detailed analyses of fishery-independent and fishery-dependent data for Spencer Gulf; and 3) Gulf St Vincent pot fishing sectors. The section includes temporal and spatial analyses of catch, effort and CPUE from all data sources, a breakdown of some of these measures by size (legal-size crabs, i.e. ≥110 mm carapace width, and ‘pre-recruits’, i.e. <110 mm carapace width) and sex, and highlights the measures against the performance indicators for the fishery.

Section 4 synthesises the information presented in the preceding sections to determine the status of the resource. This section also summarises the strengths and weakness of the information sources upon which the assessment is made, and identifies future research priorities for the BCF.

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 fishery 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 capacity for expansion of the fishery was to be 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 fishing zones (**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 of 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 marketed in Australia, primarily in the Sydney and Melbourne fish markets. In the 2012/13 financial year, 569 t of blue swimmer crab valued at approximately $3.67M 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.

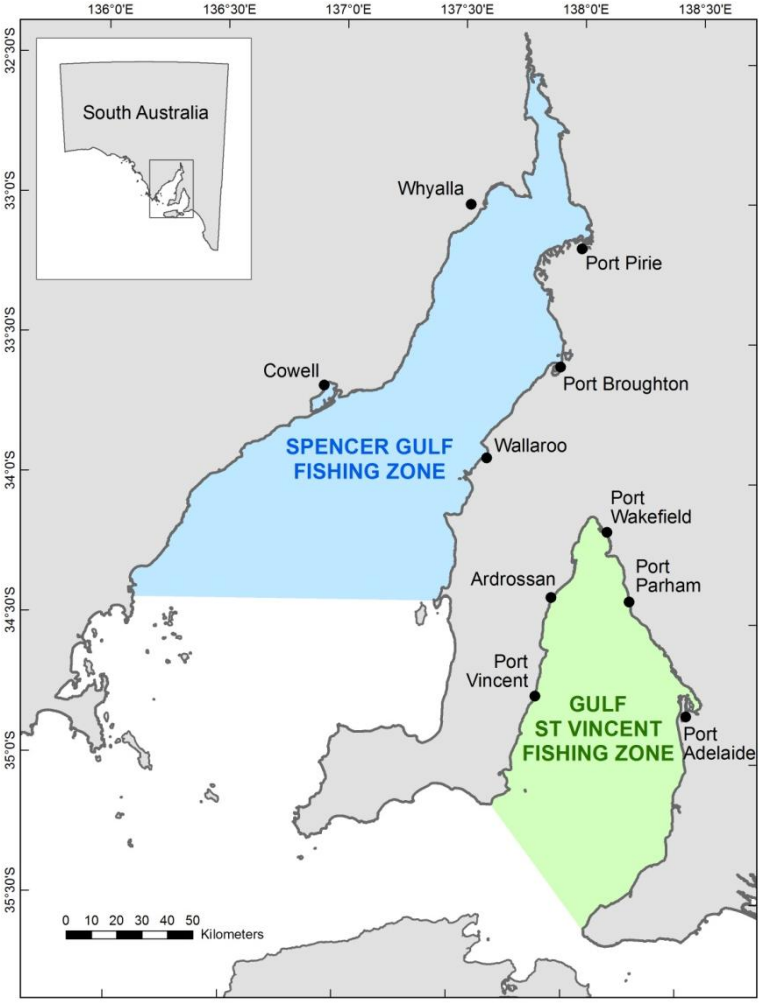

Figure 1.1. Spencer Gulf and Gulf St Vincent fishing zones of the South Australian Blue Crab Fishery.

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 was estimated at 1,144,837 individuals for this period, with an estimated weight of 283.7 t. This 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*' (Henry and Lyle,

2003) was conducted between May 2000 and April 2001. 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') and relevant subordinate regulations provide 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 sectors, 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 (**Figure 1.2**), with the number of MSF licences holding blue crab quota steadily decreasing from 29 to 3.

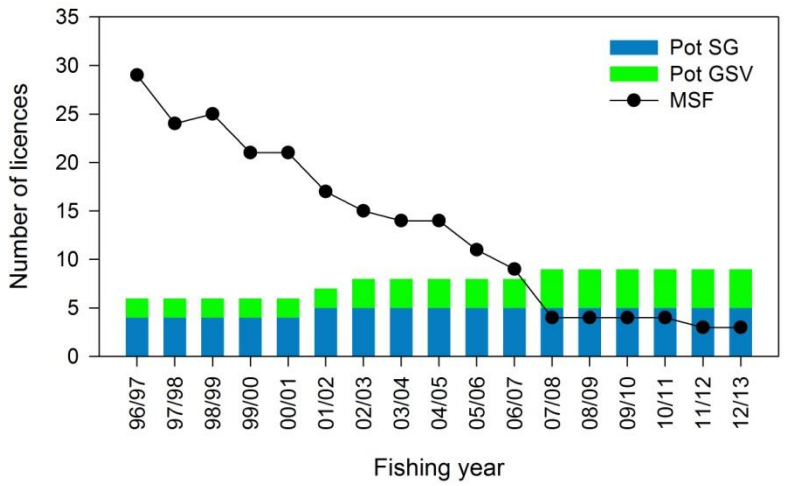

Figure 1.2. Numbers of licences in the Blue Crab Fishery since 1996/97.

1.3.3. Current management arrangements

The TACC was initially set by PIRSA Fisheries at 520 t for the 1996/97 fishing season. Over the next four seasons the TACC gradually increased to 626.8 t in 2000/01, where it remained until 2012/13.

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 sectors (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 sector, recreational bag and boat limits for Gulf St Vincent have been reduced to 20 and 60, respectively, for 12 months from July 2013 to June 2014.

1.3.4. Management Plan

The Management Plan (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:

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 performance indicators 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 performance indicator 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 an appropriately 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 performance indicators 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.

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 build scientific knowledge through improvements in the quality of both fishery-dependent and fishery-independent information, with the view of developing a future harvest strategy that comprises more robust fishery performance indicators 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* (Lai *et al.*, 2010) is a true crab (Brachyura) belonging to the family Portunidae. 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 are 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 1.3**). A detailed description of this species is provided by Stephenson (1972).

Figure 1.3. Differences in coloration and claw size between male (top) and female (bottom) blue swimmer crabs (*Portunus armatus*).

1.4.2. Distribution and stock structure

Blue swimmer crabs are distributed throughout the coastal waters of the tropical regions of the western Indian Ocean and eastern Pacific Ocean (Kailola *et al.*, 1993). In the relatively colder, temperate Australian waters, the life cycle has evolved to increase growth and reproduction during the warmer part of the year when water temperatures increase to those similar in tropical regions. Activity reduces 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 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 will form a pre-corpula for eight to ten days before ecdysis of the female. After female ecdysis, when the female is soft-shelled, copulation takes place over a six to eight-hour period (Meagher, 1971).

The spawning season lasts for 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 MLS (110 mm 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.

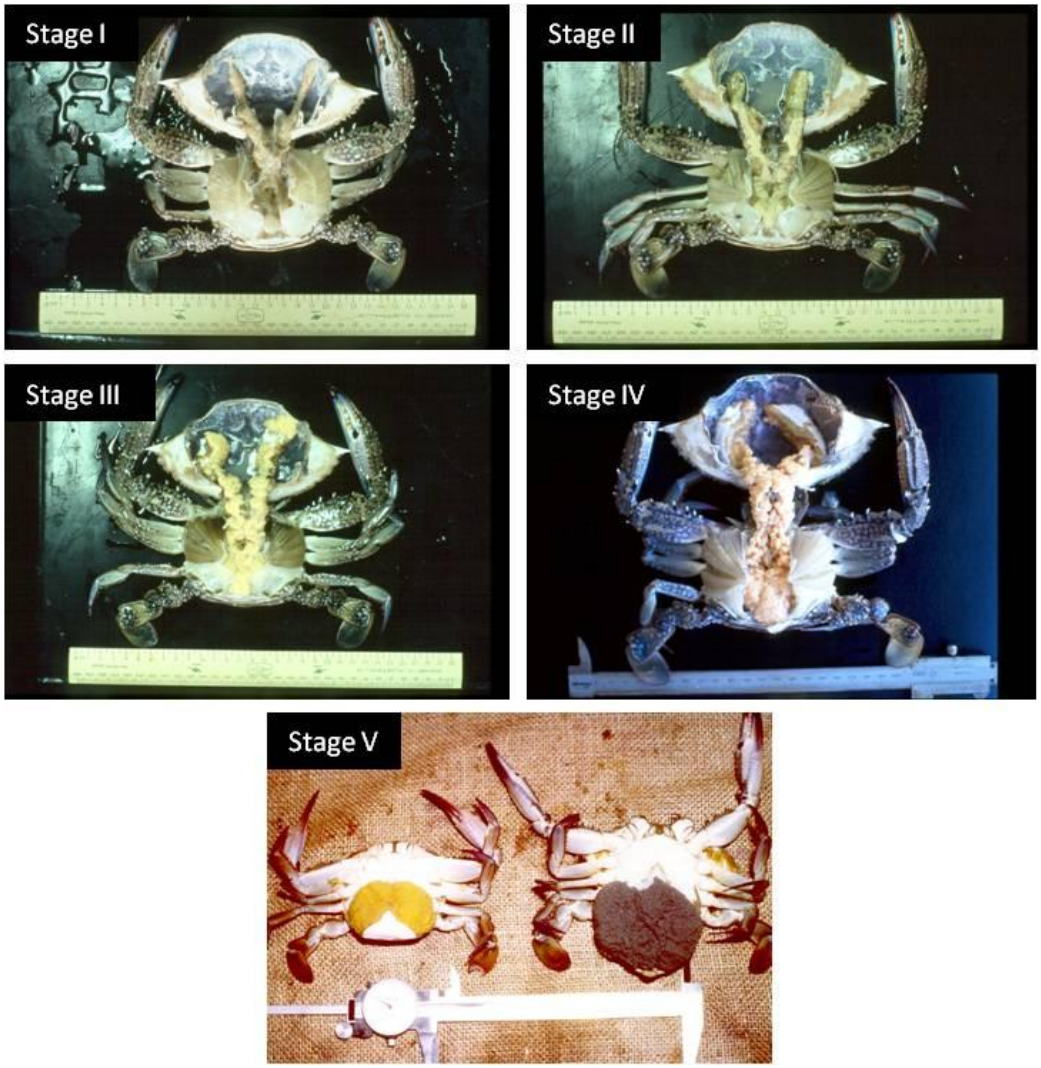

Figure 1.4. The five ovarian stages of the blue swimmer crab (Kumar *et al.*, 2000).

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.

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 changes from yellow to a dark grey (**Figure 1.4**).

In South Australia, 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 appear in October in Gulf St Vincent and November in Spencer Gulf (**Figure 1.5**). This pattern was consistent between these years.

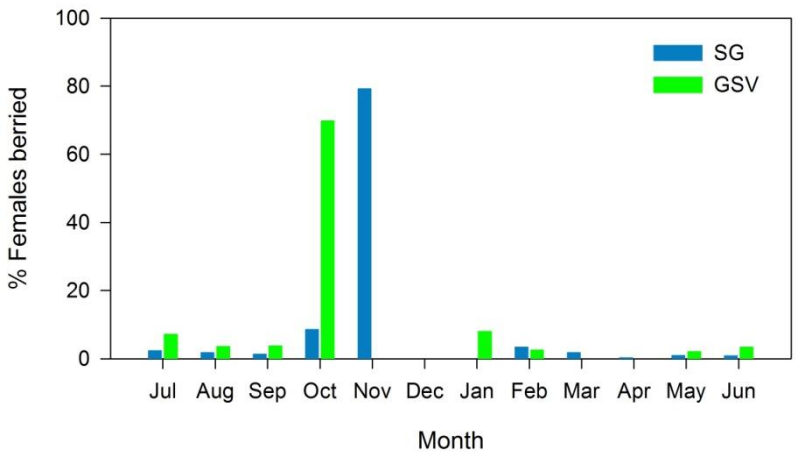

Figure 1.5. Monthly mean percentage of berried female blue swimmer crabs in commercial catches from each gulf from 1997/98 to 2004/05.

Fecundity is determined by the number of eggs carried externally by the female. Kumar *et al.* (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. Fecundity increased by 83.9% from 105 mm to 125 mm, implying that a single large female could produce as many eggs as two small females. Kumar *et al.* (2000) found that a female blue swimmer crab can produce between 650,000 and 1,760,000 eggs per spawning.

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 was 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 1.6**). In both gulfs, male blue swimmer crabs grew to a larger total weight for a given carapace width.

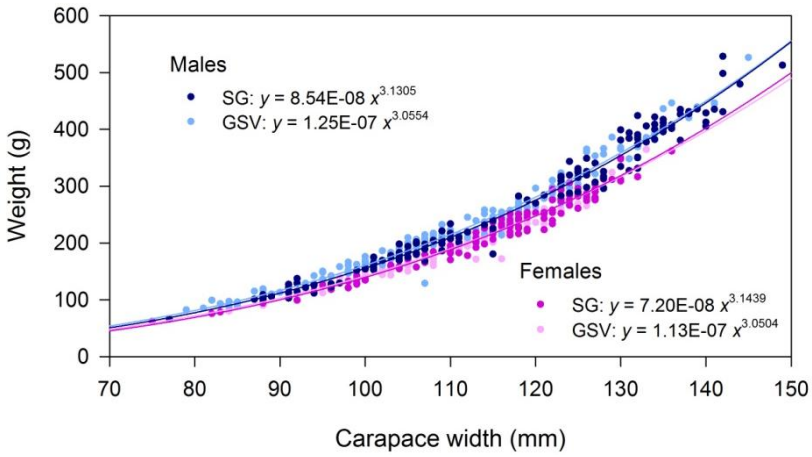

Figure 1.6. Length-weight relationships of male and female blue swimmer crabs from Spencer Gulf and Gulf St Vincent.

1.4.5. Parasites

The parasites of some decapod crustaceans are known to cause sterilisation of their host, and can therefore have an important impact on the population of 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). Levels of parasitism in South Australian blue swimmer crab populations have yet to be examined.

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 predominately 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 performance indicators 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 explicit spatial information, at the fishing block scale, for commercial catch and effort data.

The fishery assessment report has evolved since 2004 to provide, on an annual basis, documentation, analyses and interpretation of the available data, and assess the BCF against the performance indicators identified in the Management Plan (PIRSA, 2012). It formally 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 performance indicators defined in the Plan; 2) manage fishery dependent commercial logbook data; 3) collate and analyze fishery-dependent pot-sampling data; and 5) 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 biomass 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 performance indicators, 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 performance indicators 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 biomass of legal size and pre-recruit crabs from surveys. These measures are supplemented by pot-sampling data for pre-recruits.

2.1.1. Fishery-independent surveys

Fishery-independent surveys have been conducted since 2002 for stock assessment purposes. 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.

Whilst 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 protracted throughout July. In Gulf St Vincent, surveys were conducted in July from 2002 to 2004, in June from 2005 to 2009, and then in July since 2010.

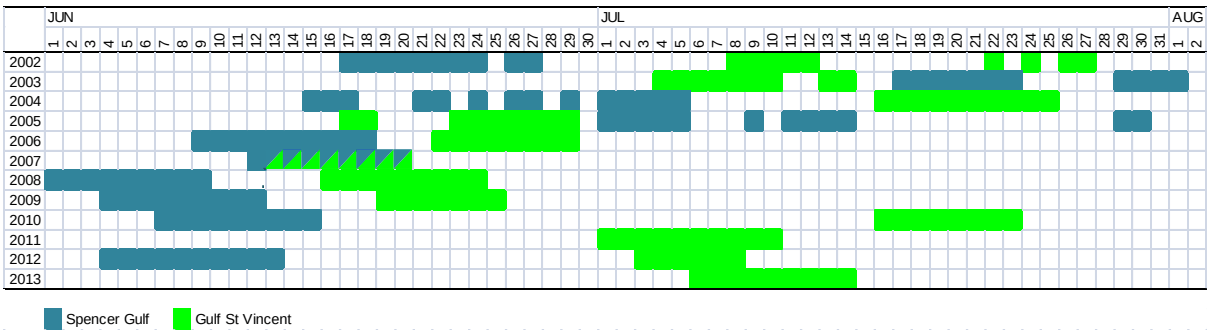

Figure 2.1. Fishery-independent survey calendar for Spencer Gulf and Gulf St Vincent from 2002 to 2013.

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 line from Glenelg to Port Vincent in Gulf St Vincent (**Figure 2.2**). Sampling sites were determined based on fisher knowledge and historical catch and effort data. From these recommendations, four sites were selected in each fishing block to be surveyed.

Fewer potlifts (approximately 22% less in Spencer Gulf and 41% less in Gulf St Vincent) were done during 2002 than in subsequent years. From the 2008 survey, the locations of survey sites were modified by SARDI, PIRSA and industry to provide a more accurate measure of relative biomass of blue swimmer crab in each gulf. These changes included the removal of all sites from some fishing blocks, addition of new sites within previously unsurveyed blocks, and movement of sites within existing surveyed blocks (**Figure 2.2**).

Survey CPUE, calculated as the number of legal-size crabs/potlift or pre-recruits/potlift (small-mesh pots only) for each survey, is used as the measure of relative biomass. Unless stated otherwise, survey CPUE data presented in this report refer to sites that have not changed since 2002 (these are referred to as ‘standardised’ potlifts).

At each site, both commercial crab pots (**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. Commercial pots have a diameter of 1.2-1.4 m, a height of 50 cm, and are covered with 90 mm mesh. Small-mesh pots, designed specifically for fishery-independent surveys, have a diameter of 1.4 m, a height of 50 cm, and a mesh size of 55 mm. At each survey site, 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. 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 site. 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).

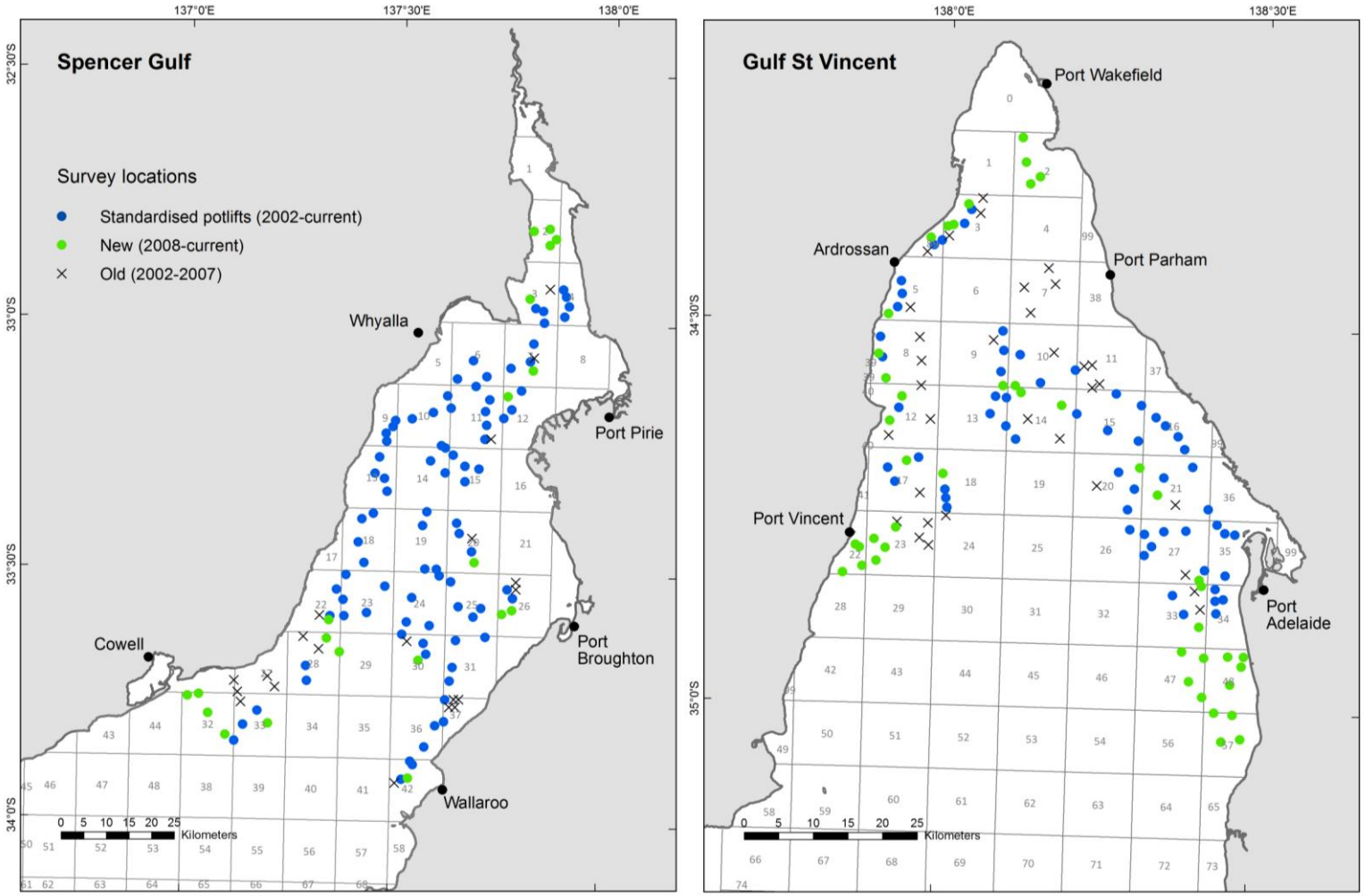

Figure 2.2. Commercial fishing blocks (grid) and survey locations in Spencer Gulf and Gulf St Vincent of the Blue Crab Fishery.

Figure 2.3. Commercial crab pot (mesh size of 90 mm).

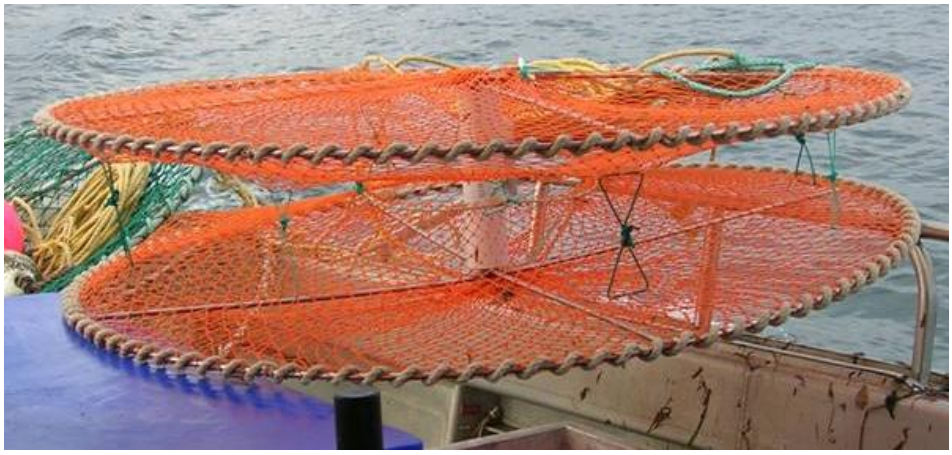

Figure 2.4. Small-mesh crab pot used for surveys (mesh size of 55 mm).

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, 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, where pot fishers may lift and reset their gear twice in the one 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.

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

Spatial distribution of the annual catch includes examination of the number of blocks fished and the magnitude of catches within those blocks. When considering the spatial distribution of the catch in cases where pots were set over more than one fishing block, an equal distribution of catch across the first two blocks recorded was assumed for the analysis.

For analyses and presentation of commercial logbook data throughout this report, effort data (and calculated CPUE) is expressed in boat days or potlifts. Catch, effort and CPUE data are presented at annual and monthly scales, and as a time series of maps showing the distribution of catch and CPUE by fishing block. As juvenile blue swimmer crabs generally recruit to the fishery each year during winter, the CPUE of pre-recruits is determined from commercial potlifts during June and July each year to provide a recruitment index to supplement the more reliable survey CPUE measure.

Information on sex ratio was obtained from the daily catch weight by sex where provided. When calculating monthly and annual catches of each sex, several assumptions were necessary to deal with missing data:

1. When male catch weight was not provided (but female was) or male plus female weight did not sum to the total, estimates of female weight and total weight were assumed correct;
2. When neither male nor female catch weight was provided (but total was), catches were determined for two scenarios: 1) assume that all catch was male (minimum % female) and 2) assume that days of missing data comprised the same percentage of females as other days for that month where female data were available; and
3. When calculating monthly catches, where neither male or female catch weight was provided (but total was) for that entire month, the proportion of females in the catch was assumed from other comparable data.

2.1.3. Fishery-dependent pot-sampling program

The pot-sampling program involves the collection of fishery-dependent catch and effort data on pre-recruits (pre-recruits/potlift) from small-mesh pots (i.e. smaller escape gaps) and size composition of blue swimmer crabs throughout the fishing season to provide supplementary information on recruitment strength and sex ratio. These data have been collected since May 2006 in Spencer Gulf and since July 2006 in Gulf St Vincent; however, the data collected prior to 2008 were excluded from analysis in this report due to the limited number of boat day samples.

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 since May 2008, and from up to two small-mesh pots since 2010/11. 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. Results of the pot-sampling program 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 trend at this time of the year.

2.2. Quality assurance

2.2.1. Research planning

The research requirements of PIRSA Fisheries and Aquaculture for the BCF were discussed in December 2012 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 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 preocedures.

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 of the data (20%) against the original data sheets. Once validated, data are uploaded and 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. Accuracy of data analyses is achieved in two ways. First, data analysis is simultaneously carried out for multiple years at a time (where possible) to reproduce the same results of previous years. Second, data analyses are independently undertaken by two SARDI researchers and results subsequently compared. If either method yields any discrepancies in the data or the results, the two SARDI researchers will review each others' analyses to resolve the discrepancy.

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 sectors of the BCF (Spencer Gulf and Gulf St Vincent pot fishing sectors, 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.

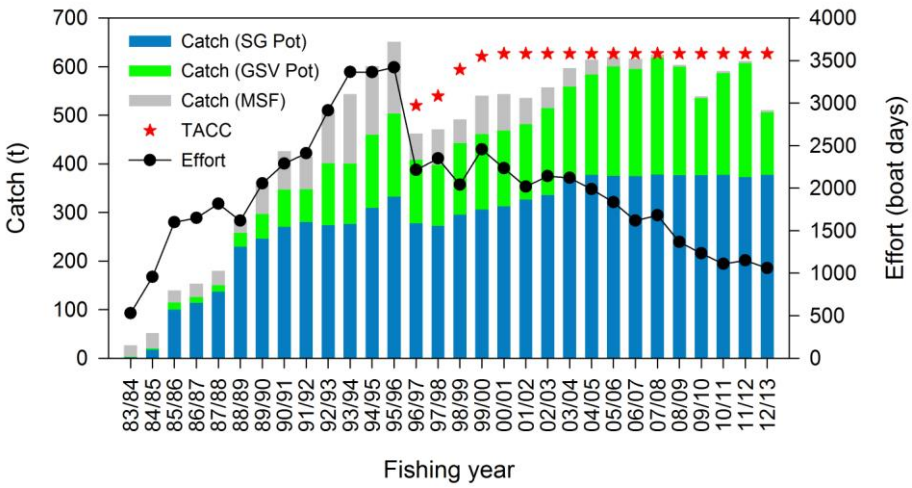

Figure 3.1. Commercial catch, effort and TACC for the Blue Crab Fishery from 1983/84 to 2012/13.

The TACC has been set at 626.8 t for the past thirteen years (2000/01-2012/13). The total catch during 2012/13 was 510.7 t (81% of the TACC), with almost all this catch (>99%) harvested by the Spencer Gulf and Gulf St Vincent pot fishing sectors. Prior to the introduction of quota, the trend in 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. Since then, effort has declined, with the 1,059 days fished during 2012/13 being less than half the effort in 1999/00. This decline was attributed mostly to the transfer of quota from the MSF to the pot fishing sectors of the BCF and the introduction of multiple potlifts per day.

3.2. Spencer Gulf

3.2.1. Fishery-independent surveys

3.2.1.1. Relative biomass of legal-size crabs

Relative biomass of legal-size crabs has increased substantially over time in Spencer Gulf, with survey CPUE since 2009 (three-year mean: 9.07 legal-size crabs/potlift) being 74% higher than the mean in 2005 (5.21 legal-size crabs/potlift) (**Figure 3.2**). The mean survey CPUE of 9.23 legal-size crabs/potlift in 2012 was the highest recorded since fishery-independent surveys began in 2002. This latest estimate is above the upper reference point (8 legal-size crabs/potlift).

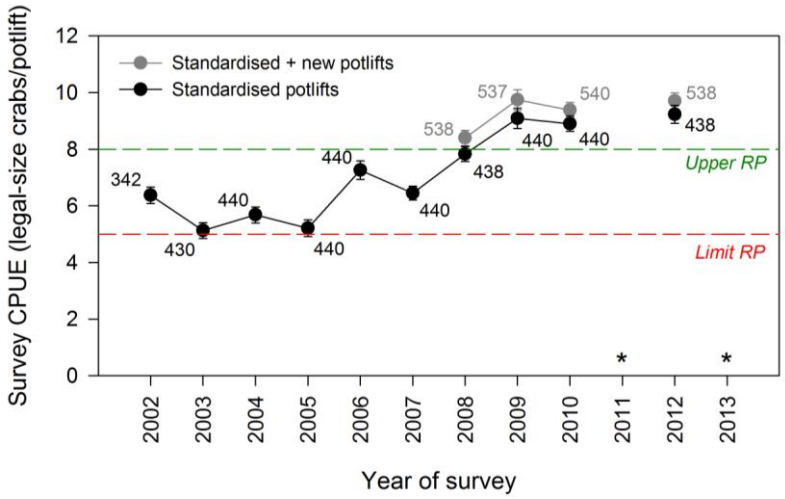

Figure 3.2. Mean (± SE) survey CPUE of legal-size crabs for standardised potlifts (2002-current) and standardised + new potlifts (2008-current) in Spencer Gulf during June and July from 2002 to 2013. Labels indicate the number of potlifts. Asterisks (*) denote years in which there was no survey.

3.2.1.2. Relative biomass of pre-recruits

Relative biomass of pre-recruits in Spencer Gulf was highly variable between 2002 and 2012 (**Figure 3.3**). The mean survey CPUE of pre-recruits generally declined from 2002 (6.87 pre-recruits/potlift) to 2005 (2.29 pre-recruits/potlift), and then increased sharply to its highest level in 2007 (10.11 pre-recruits/potlift) before consecutive declines in 2008 and 2009 (to 3.03 pre-recruits/potlift). More recently, mean survey CPUE was relatively high in 2010 and 2012 (7.87 pre-recruits/potlift and 8.81 pre-recruits/potlift, respectively). The latest estimate is just below the upper reference point (9 pre-recruits/potlift)

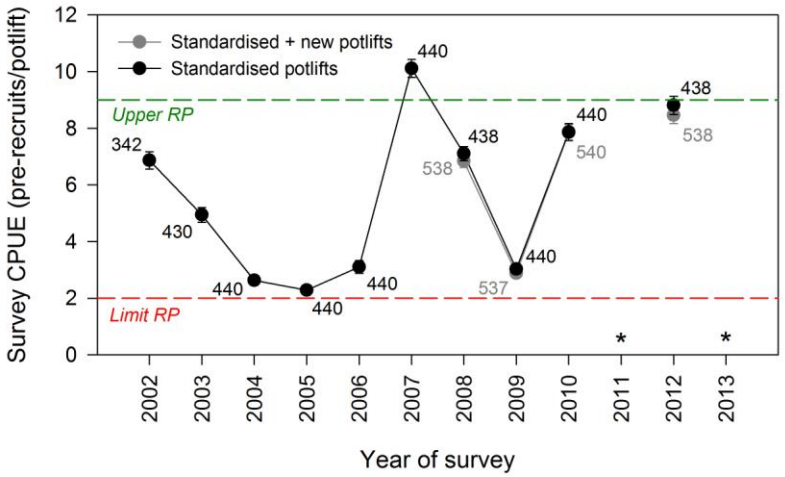

Figure 3.3. Mean (± SE) survey CPUE of pre-recruits for standardised potlifts (2002-current) and standardised + new potlifts (2008-current) in Spencer Gulf during June and July from 2002 to 2013. Labels indicate the number of potlifts. Asterisks (*) denote years in which there was no survey.

3.2.1.3. Spatial distribution of legal-size crabs

Legal-size crabs were broadly distributed throughout the Spencer Gulf survey area in most years (**Figure 3.4**). A very high mean survey CPUE (>10 legal-size crabs/potlift) was recorded consistently in Block 3 in the upper region of the gulf (in nine of ten years), and sporadically in several other blocks throughout the survey period (Block 3, 4, 7, 11, 12, 14, 15, 23, 24, 26 and 31). In 2012, a very high mean survey CPUE of pre-recruits was recorded in the south-eastern Block 30, 36 and 42 for the first time. A high mean survey CPUE (>5 legal-size crabs/potlift) was recorded in almost all blocks surveyed in 2012, except Block 9 and 10, where the mean survey CPUE of pre-recruits were within the medium category of 2-5 legal-size crabs/potlift.

3.2.1.4. Spatial distribution of pre-recruits

The index of abundance of pre-recruits varied substantially among blocks and between years in Spencer Gulf (**Figure 3.5**). Nevertheless, pre-recruits were broadly distributed throughout the surveyed area, and there was a general trend of decreasing CPUE of pre-recruits from north to south during most years, with the exception of 2010, when the CPUE was highest in several southern blocks, and 2012, when CPUE was highest in central and south-eastern blocks of the gulf.

A finer-scale ‘heat map’ of the average densities of legal-size and pre-recruit crabs from standardised potlifts in Spencer Gulf reveals a similar spatial pattern between 2002-2007 and 2008-2013, although there has been a general increase in densities for both size classes during the latter period (**Figure 3.6**).

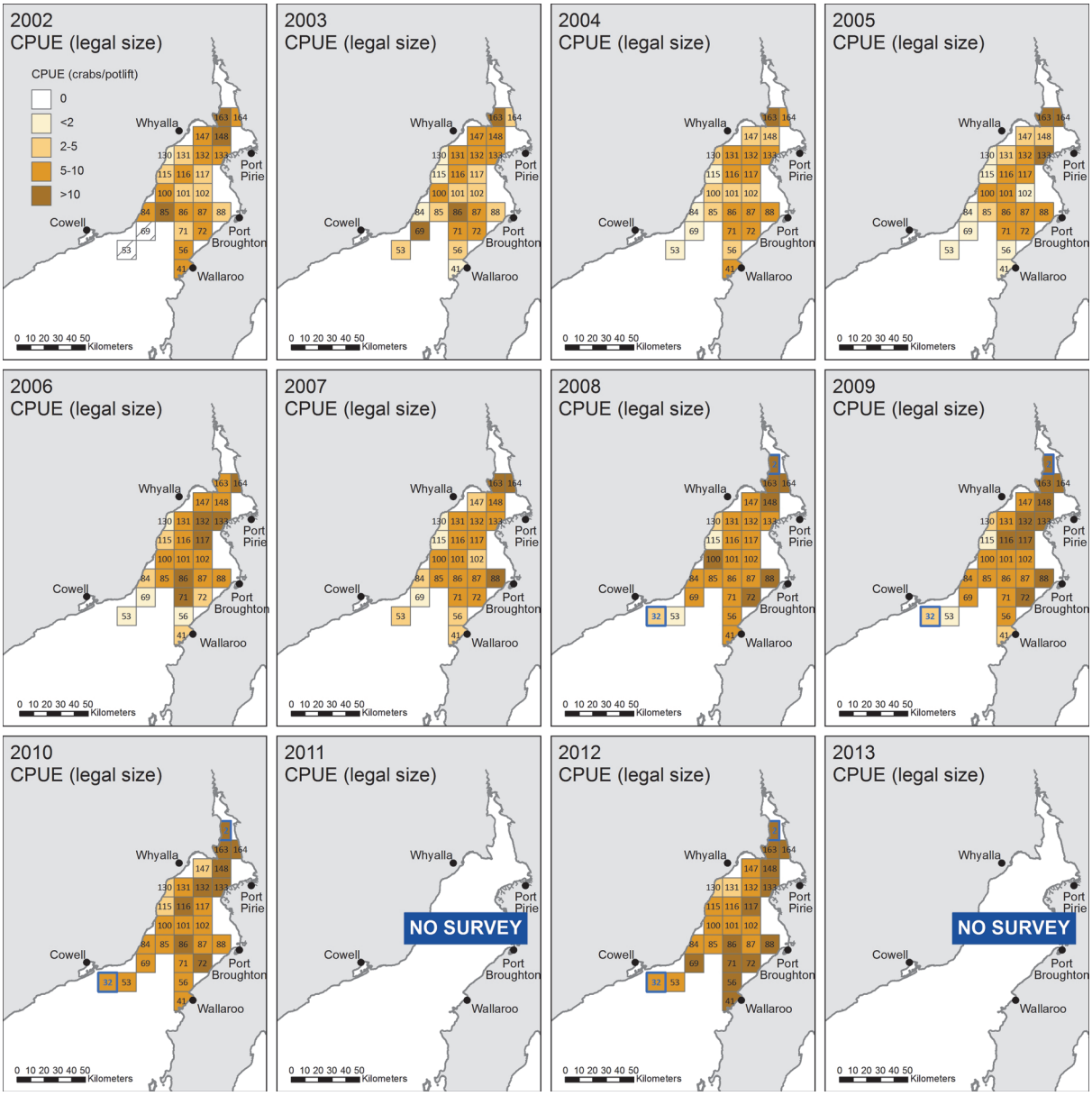

Figure 3.4. Spatial distribution of survey CPUE of legal-size crabs from standardised + new potlifts in Spencer Gulf during June and July from 2002 to 2013. Note: 2008 to 2013 maps include new blocks surveyed (Block 2 and 32). See 2002 map for legend.

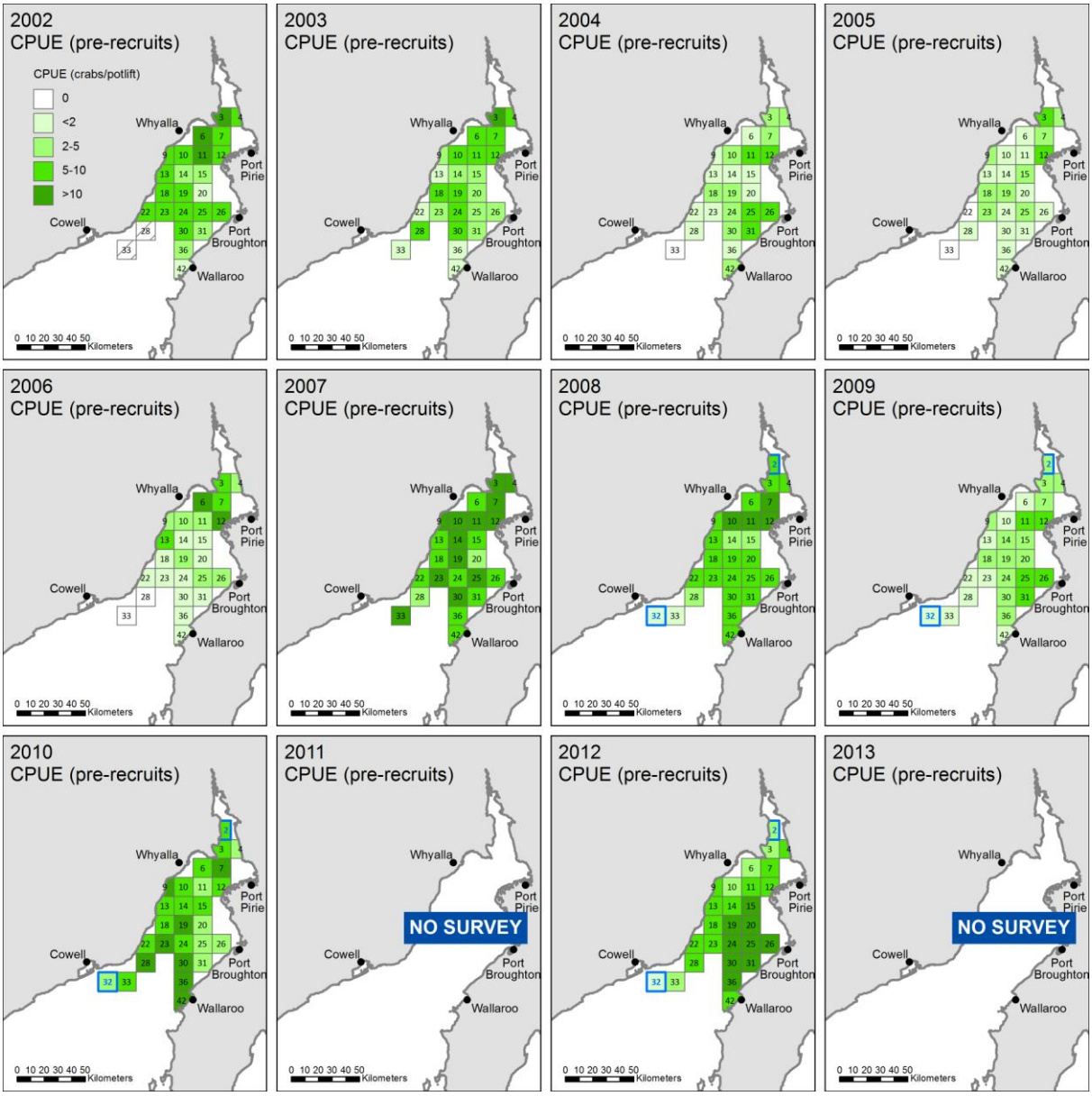

Figure 3.5.Spatial distribution of survey CPUE of pre-recruits from standardised + new potlifts in Spencer Gulf during June and July from 2002 to 2013. Note: 2008 to 2013 maps include new blocks surveyed (Block 2 and 32). See 2002 map for legend.

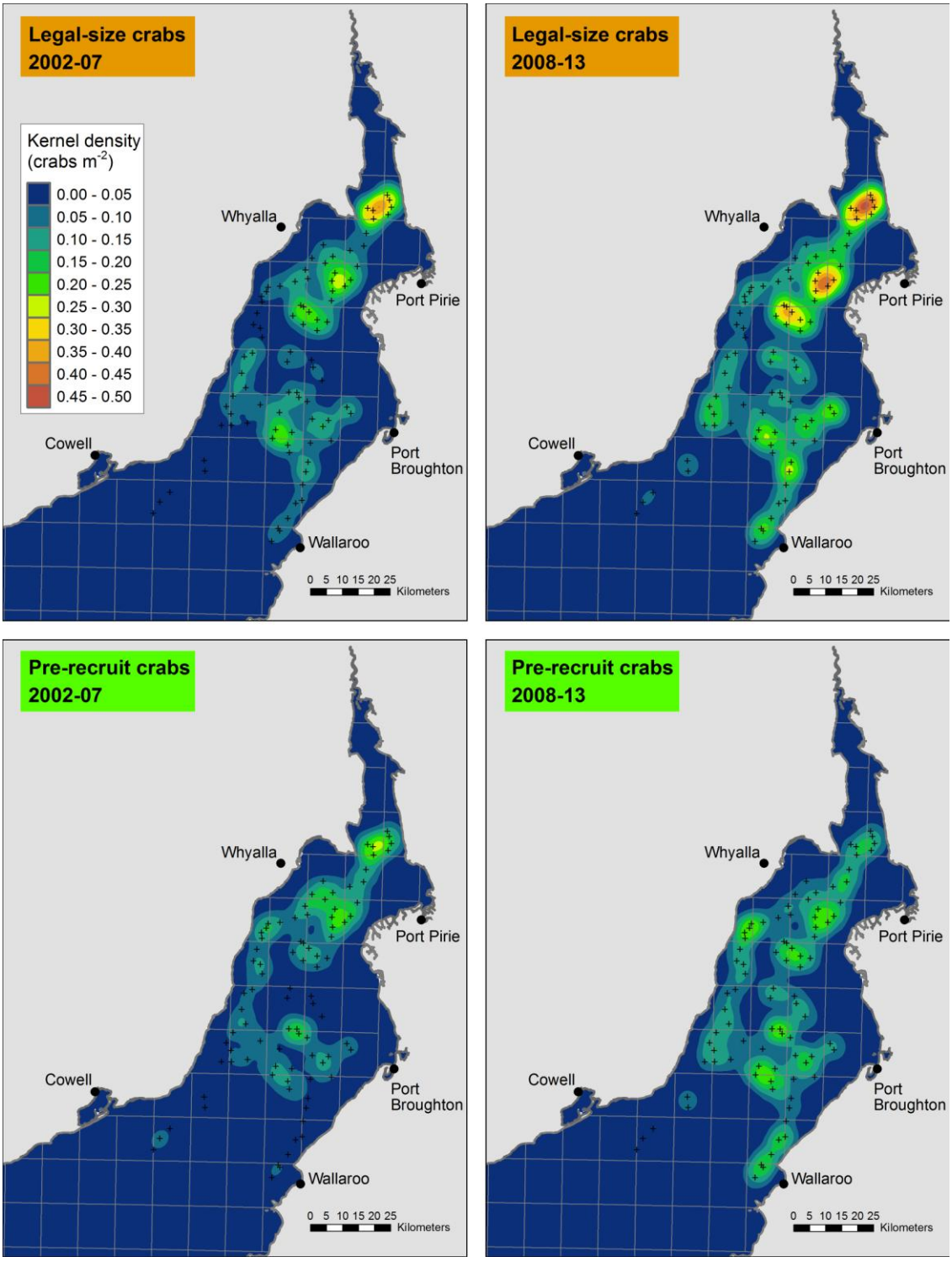

Figure 3.6. Kernel density maps showing average distribution of legal-size and pre-recruit crabs for standardised potlifts from surveys conducted in Spencer Gulf for 2002-2007 and 2008-2013. See 2002-2007 map of legal-size crabs for legend.

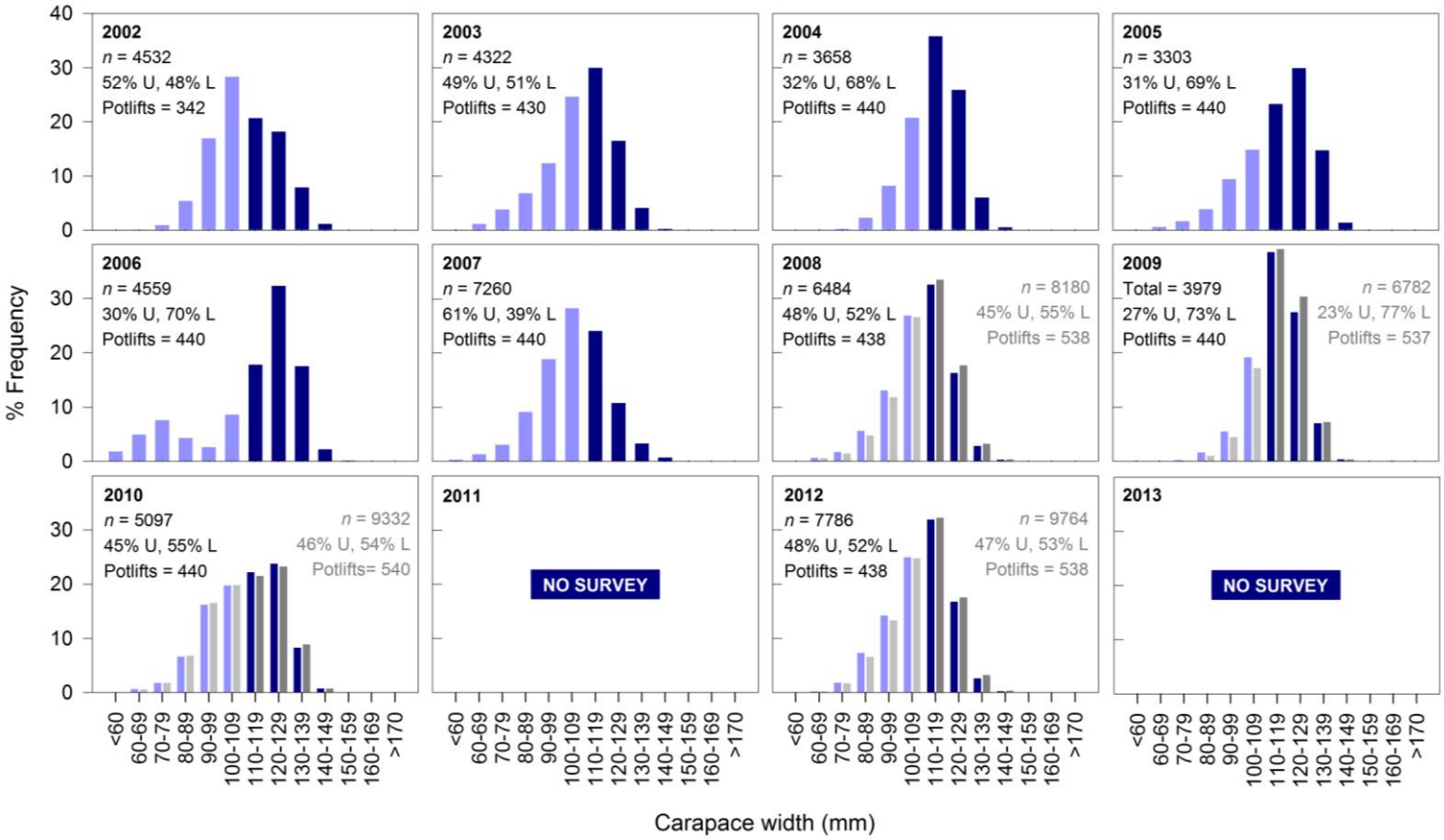

Figure 3.7. Size-frequency distribution of blue swimmer crabs caught during fishery-independent surveys conducted in Spencer Gulf during June and July from 2002 to 2013. Light and dark blue bars represent pre-recruits and legal-size crabs, respectively, caught using standardised potlifts (2002-current), while grey bars and text represent those caught using standardised + new potlifts (2008-current).

3.2.1.5. Size distribution

The size distribution of the surveyed population in Spencer Gulf varied substantially among years (**Figure 3.7**). The modal size of blue swimmer crabs was 100–109 mm carapace width (undersize, or pre-recruits) in 2002 and 2007, 110–119 mm (legal-size crabs) in 2003, 2004, 2008, 2009 and 2012, and 120–129 mm in 2005, 2006 and 2010. During 2006, there was also a relatively high abundance of very small pre-recruits (<79 mm), with an apparent bi-modal distribution suggestive of a large recruitment event. Further evidence of relatively high recruitment was apparent in the following year (2007), with high proportions of the sample at 90–109 mm, including the mode at 100-109 mm. The size structure in 2012 was similar to 2008. Overall, there was a good representation of all size classes across the years.

3.2.2. Commercial logbook data

3.2.2.1. Catch and effort

Annual trends

For the 2012/13 fishing year, the Spencer Gulf pot fishing sector held 381.7 t (61%) of the TACC for the BCF (626.8 t), most of which (377.4 t, 99%) was landed. Catch from this sector has been stable since 2003/04 (**Figure 3.8**).

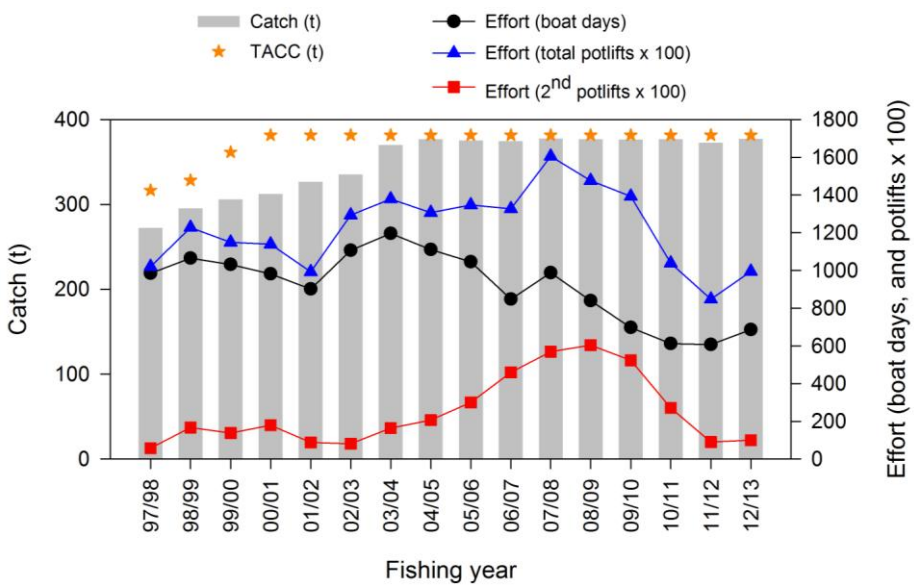

Figure 3.8. Total catch and effort for the Spencer Gulf pot fishing sector from 1997/98 to 2012/13.

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 3.8**). 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 most years to the historic low (since the introduction of

quota) of 612 boat days in 2010/11 and 607 boat days in 2011/12. In 2012/13, effort increased to 686 boat days.

The number of total potlifts in Spencer Gulf was stable between 2002/03 and 2006/07 with a mean of 133,057 potlifts. Effort increased in 2007/08 to 160,555 potlifts, and then reduced substantially over the next four seasons to the historic low of 84,756 potlifts in 2011/12 before increasing again to 99,513 potlifts in 2012/13 (**Figure 3.8**).

The number of second potlifts was at a low level (<18,000 potlifts) from 1997/98 to 2002/03, increased substantially to 60,398 potlifts in 2008/09, and has declined thereafter, returning to low levels of 8,983 potlifts in 2011/12 and 10,012 potlifts in 2012/13 (**Figure 3.8**). Relative to total number of potlifts, the proportion of second potlifts decreased from 41% in 2008/09 to 10% in 2012/13.

Spatial distribution of the annual catch

The number of blocks fished in Spencer Gulf has changed since 1997/98. No more than 20 blocks were fished in the four-year period following the introduction of quota (1997/98-2000/01). Since 2001/02, the total number of blocks fished increased, ranging between 27 and 33 in most years, except 2007/08 when 39 blocks were fished (**Figure 3.9**). Most of this increase and variation in number of blocks fished is attributed to the number of blocks with low total catches (<5 t), as the number of blocks with moderate (5-20 t) and high (>20 t) total catches have been relatively stable. These trends in total number of blocks fished and blocks with catches of less than 5 t is reflective of the overall increase in quota harvested by the Spencer Gulf pot fishing sector and exploratory fishing in new areas.

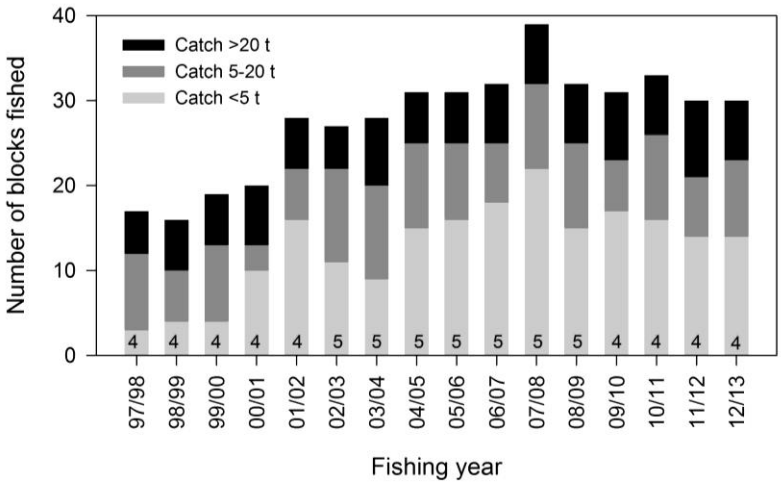

Figure 3.9. The number of blocks fished in the Spencer Gulf pot fishing sector from 1997/98 to 2012/13 with catches of <5 t, 5-20 t and >20 t. Labels indicate the number of licences fishing.

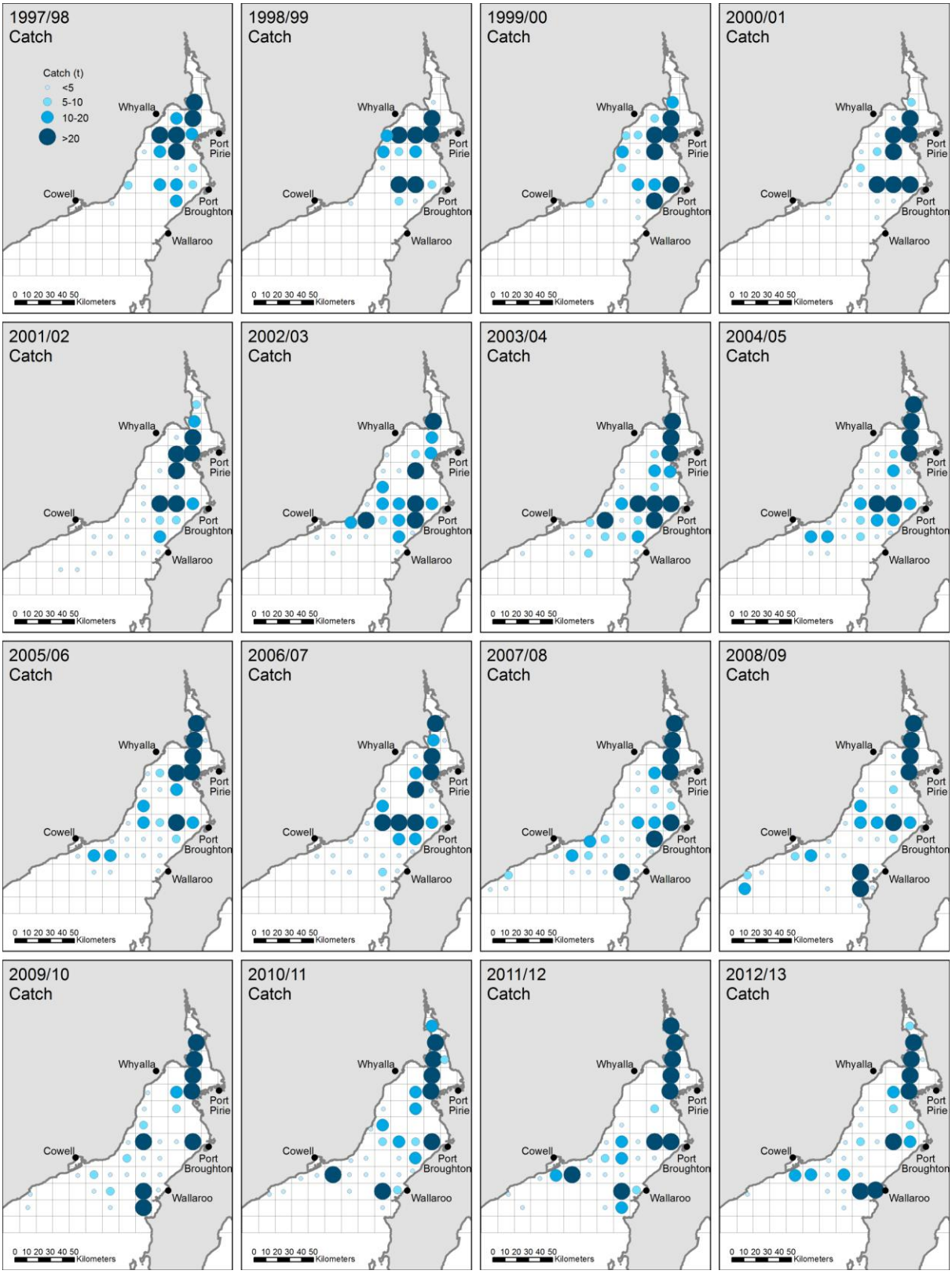

Figure 3.10. Spatial distribution of commercial catch by the Spencer Gulf pot fishing sector from 1997/98 to 2012/13. See 1997/98 map for legend.

The spatial distribution of catch in Spencer Gulf has varied considerably since the introduction of quota, with the exception of consistently high catches in four blocks aligned in a north-south direction in upper Spencer Gulf (Block 2, 3, 7 and 12) (**Figure 3.10**). Initially, high catches (>20 t) were restricted to several blocks in upper Spencer Gulf, but over time there has been a gradual spread of high catches further south. During 2012/13, the distribution of catches was similar to that of the previous five years (2007/08-2011/12).

Monthly catch and effort

Commercial pot fishing in Spencer Gulf occurs throughout the year, except for the two-month closure between 21 December and 19 February. Monthly effort has generally reflected the trend in catch (**Figure 3.13**). Between 1999/2000 and 2005/06, monthly catch and effort were often highest in March/April and lowest in June and February (when the fishery re-opens). Since 2006/07 (and including 2012/13), there has been an apparent shift in this trend, with catch and effort generally highest between July and November (winter and spring) and lowest between February and June. For 2012/13, monthly catch ranged from 7.5 t and 1,150 potlifts (February) to 55.8 t (September) and 15,394 potlifts (November), which is consistent with this recent trend.

3.2.2.2. Catch per unit effort

Mean annual CPUE

The mean commercial CPUE was relatively stable in Spencer Gulf between 1997/98 and 2009/10, ranging between 2.39 and 3.34 kg/potlift. Thereafter, mean CPUE increased substantially to the highest levels recorded in 2011/12 and 2012/13, at 4.38 and 3.79 kg/potlift, respectively (**Figure 3.11**). Regression analysis showed a poor correlation exists between commercial CPUE and the survey CPUE of legal-size crabs at the start of the fishing year ($R^2 = 0.26^{ns}$, **Figure 3.12**).

Spatial distribution of mean annual CPUE

The spatial distribution of mean commercial CPUE was highly variable among fishing blocks in Spencer Gulf from 1997/98 to 2012/13. A high mean CPUE (>3 kg potlift) was recorded in 29 out of 30 blocks fished in 2011/12 and in 25 out of 30 blocks fished in 2012/13 (**Figure 3.14**). In other years, there were few consistent trends in the distribution of fishing blocks with high CPUE. The lower number of blocks with high mean CPUE from 2007/08 to 2009/10 likely reflects the increase in number of second potlifts during this period. The almost ubiquitous high CPUE throughout Spencer Gulf during 2011/12 and, to a lesser

extent 2010/11 and 2012/13, likely reflects improvements in efficiency of the gear and/or a high biomass in this gulf.

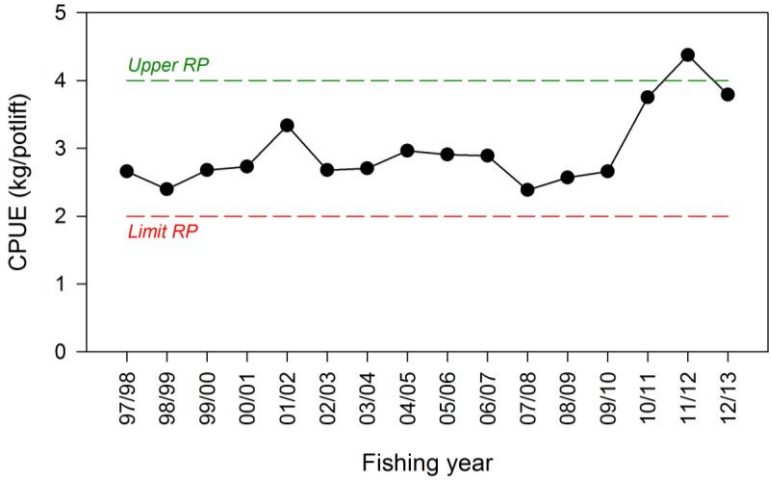

Figure 3.11. Mean commercial CPUE in the Spencer Gulf pot fishing sector from 1997/98 to 2012/13. Dashed lines indicate the limit and upper reference points for this performance indicator.

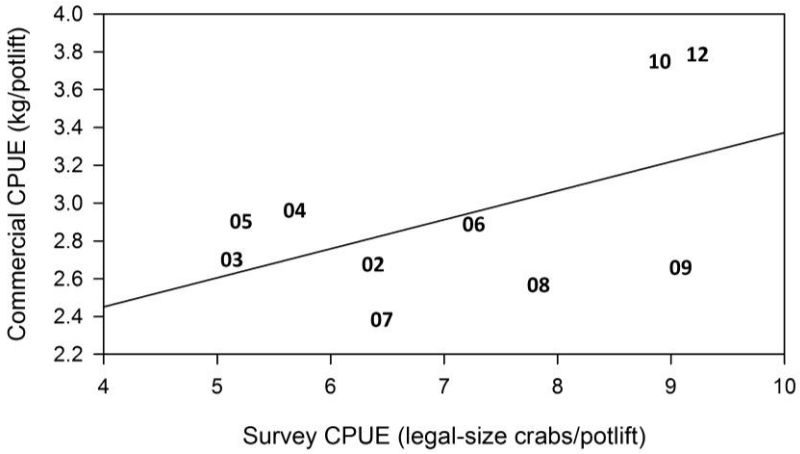

Figure 3.12. Linear regression between survey CPUE and commercial CPUE for the Spencer Gulf pot fishing sector. Values are represented by the year of the survey and start of the fishing year (e.g. '05' represents the 2005/06 fishing year).

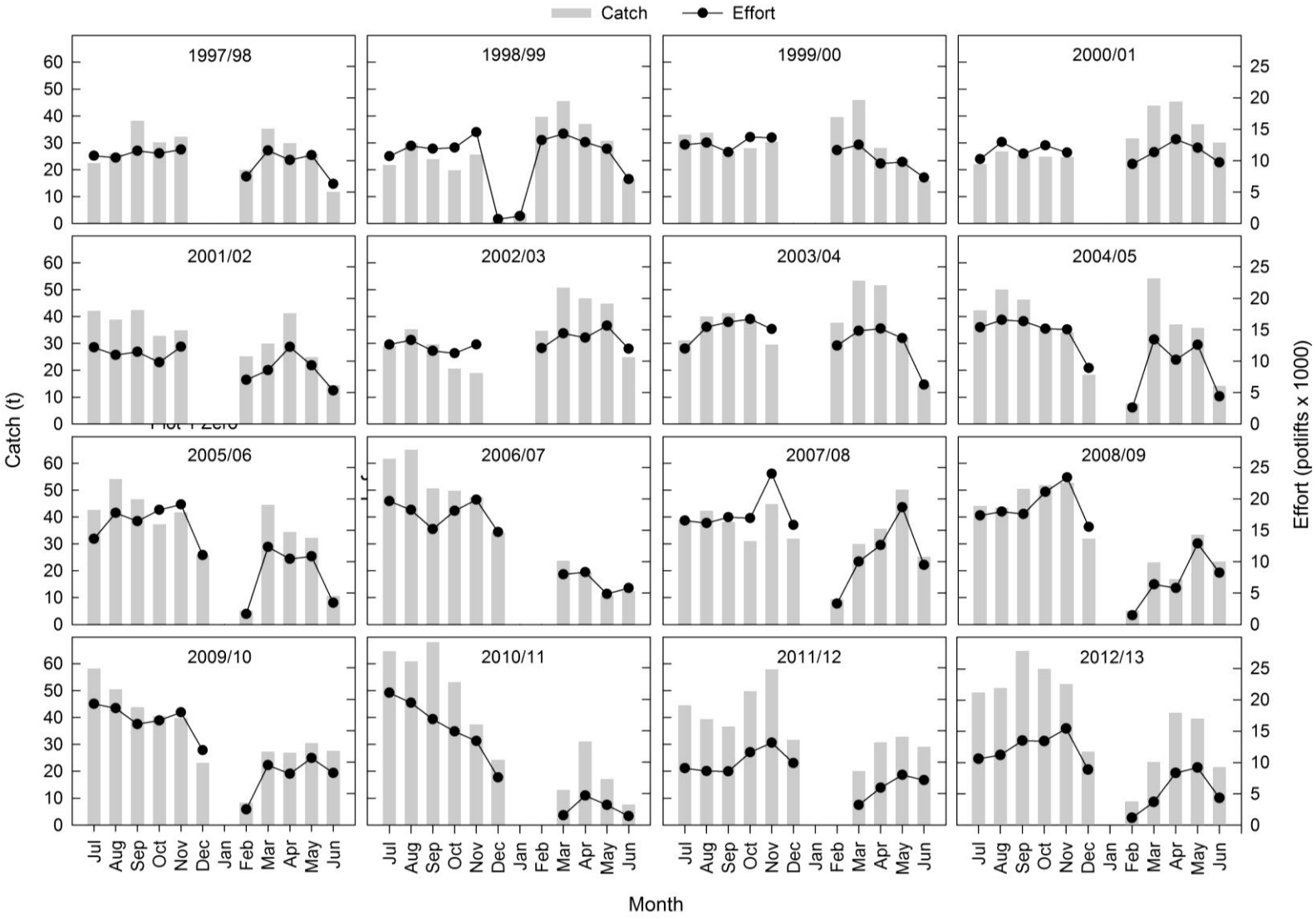

Figure 3.13. Monthly catch and effort for the Spencer Gulf pot fishing sector from 1997/98 to 2012/13.

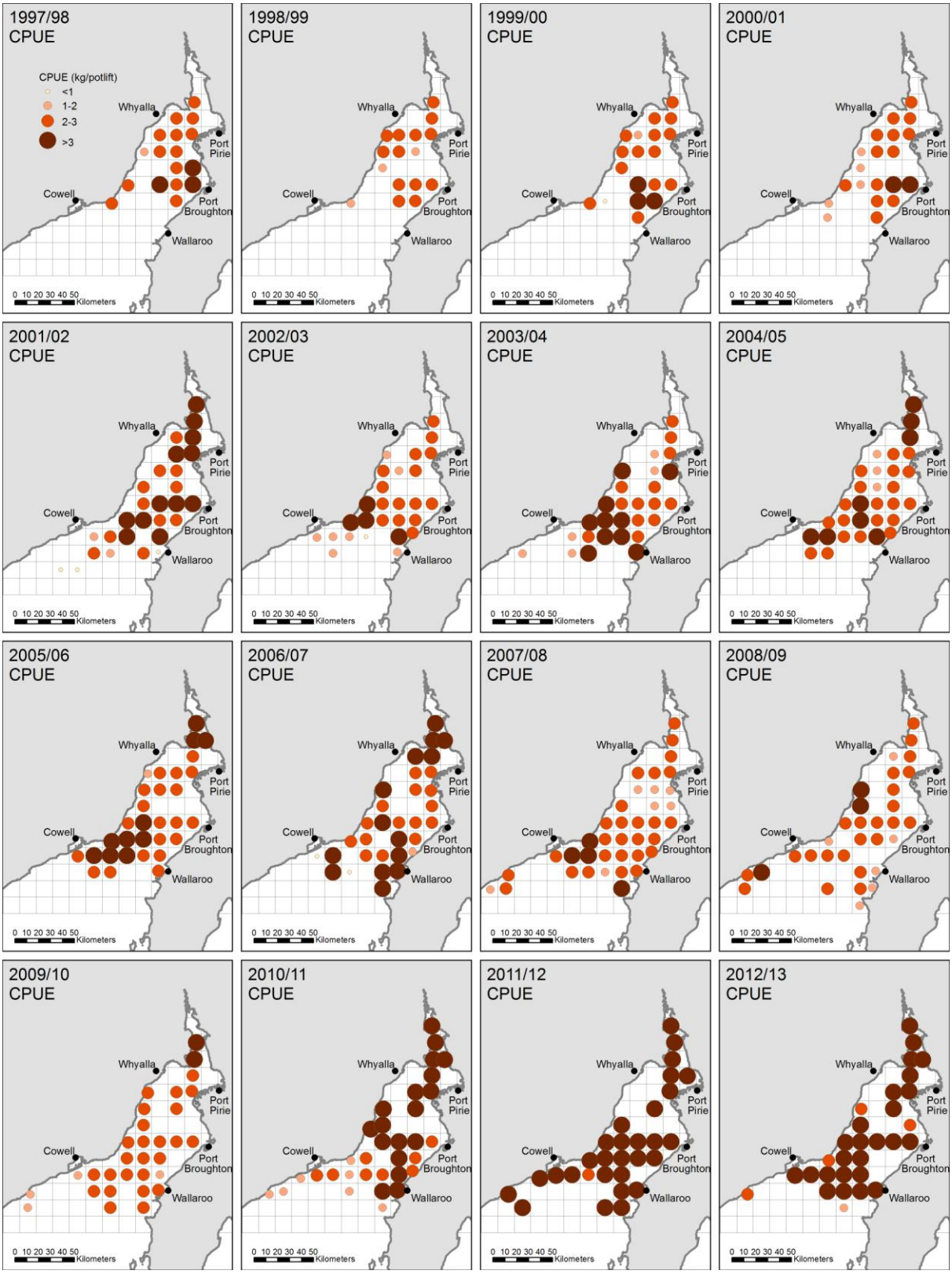

Figure 3.14. Spatial distribution of commercial CPUE of the Spencer Gulf pot fishing sector from 1997/98 to 2012/13. See 1997/98 map for legend.

Mean annual CPUE for first and second potlifts

Mean commercial CPUE for first potlifts was greater than that for the second potlifts in all years except 2009/10, and was the predominant driver of mean CPUE for total potlifts (**Figure 3.15**). Mean commercial CPUE for first potlifts has increased substantially in the last three years, from 2.6 kg/potlift in 2009/10 to 3.8 kg/potlift in 2012/13.

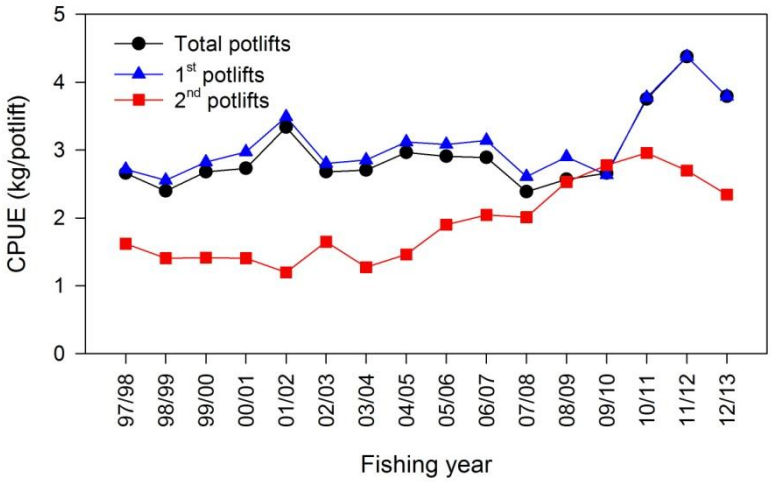

Figure 3.15. Mean commercial CPUE in the Spencer Gulf pot fishing sector (for first potlifts, second potlifts and total potlifts) from 1997/98 to 2012/13.

Mean monthly CPUE

A monthly trend in mean commercial CPUE for Spencer Gulf was observed since the introduction of quota (**Figure 3.16**). Generally, CPUE was high during the start of the quota period in July, and declined until the annual closure for the Spencer Gulf pot fishing sector in December. In most years, CPUE increased to the highest levels immediately after the closure in February and March, and then gradually declined until the end of the quota year in June. Over the last three years (2010/11-2012/13), the first months following the closure (February/March) were the only occasions since 1997/98 when the mean CPUE exceeded 6 kg/potlift.

Mean daily CPUE

Mean commercial daily CPUE for Spencer Gulf has increased considerably since the introduction of quota (**Figure 3.17**). The greatest increases have occurred since 2002/03 (303 kg/boat day), which coincides with an increase in number of second potlifts (**Figure 3.8**) and, more recently, with gear modifications of the fleet. The mean daily CPUE reached a high of 616 kg/boat day in 2010/11, and maintained this level in 2011/12 before decreasing to 550 kg/boat day in 2012/13.

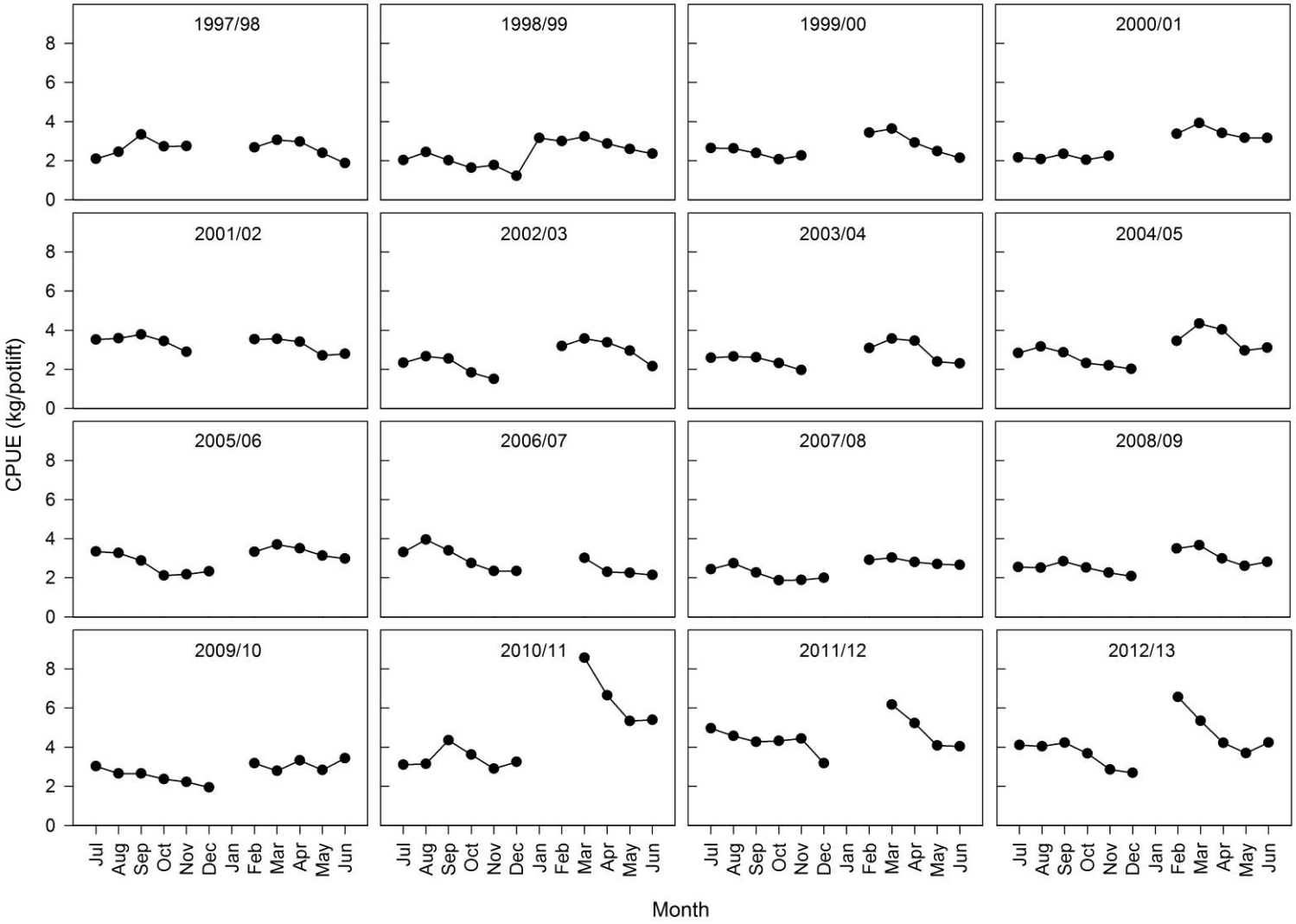

Figure 3.16. Mean monthly commercial CPUE for the Spencer Gulf pot fishing sector from 1997/98 to 2012/13.

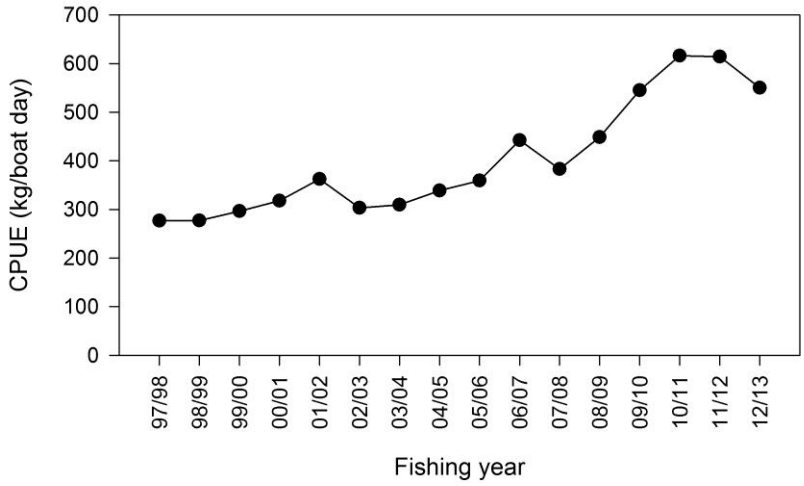

Figure 3.17. Mean daily commercial CPUE for the Spencer Gulf pot fishing sector from 1997/98 to 2012/13.

3.2.2.3. Sex ratio

Annual catches of blue swimmer crabs in Spencer Gulf are predominantly comprised of males by weight (**Figure 3.19**). Uncertainty in estimates of sex ratio arises from incomplete logbook data. Under the assumptions that missing data on sex in daily catch records were: 1) all male (lower female estimate); and 2) an equal proportion to available data for each month (upper female estimate), the percentage of females in the total annual catch between 1997/98 and 2012/13 ranged from at least 4-18% (mean: 10%) to 4-38% (mean: 20%), respectively. Additional data supplied by one fisher indicated that females comprised 31% and 30% of their catch (which represents more than 50% of the Spencer Gulf quota) in 2011/12 and 2012/13, respectively. This was well above the estimated range for available logbook data for corresponding years (5-10% and 4-20%, respectively), suggesting that the proportion of females harvested can vary considerably among fishers.

Catches of female blue swimmer crabs were generally highest between July and November (**Figure 3.18**). Relatively few females were caught during February, March and April in any year.

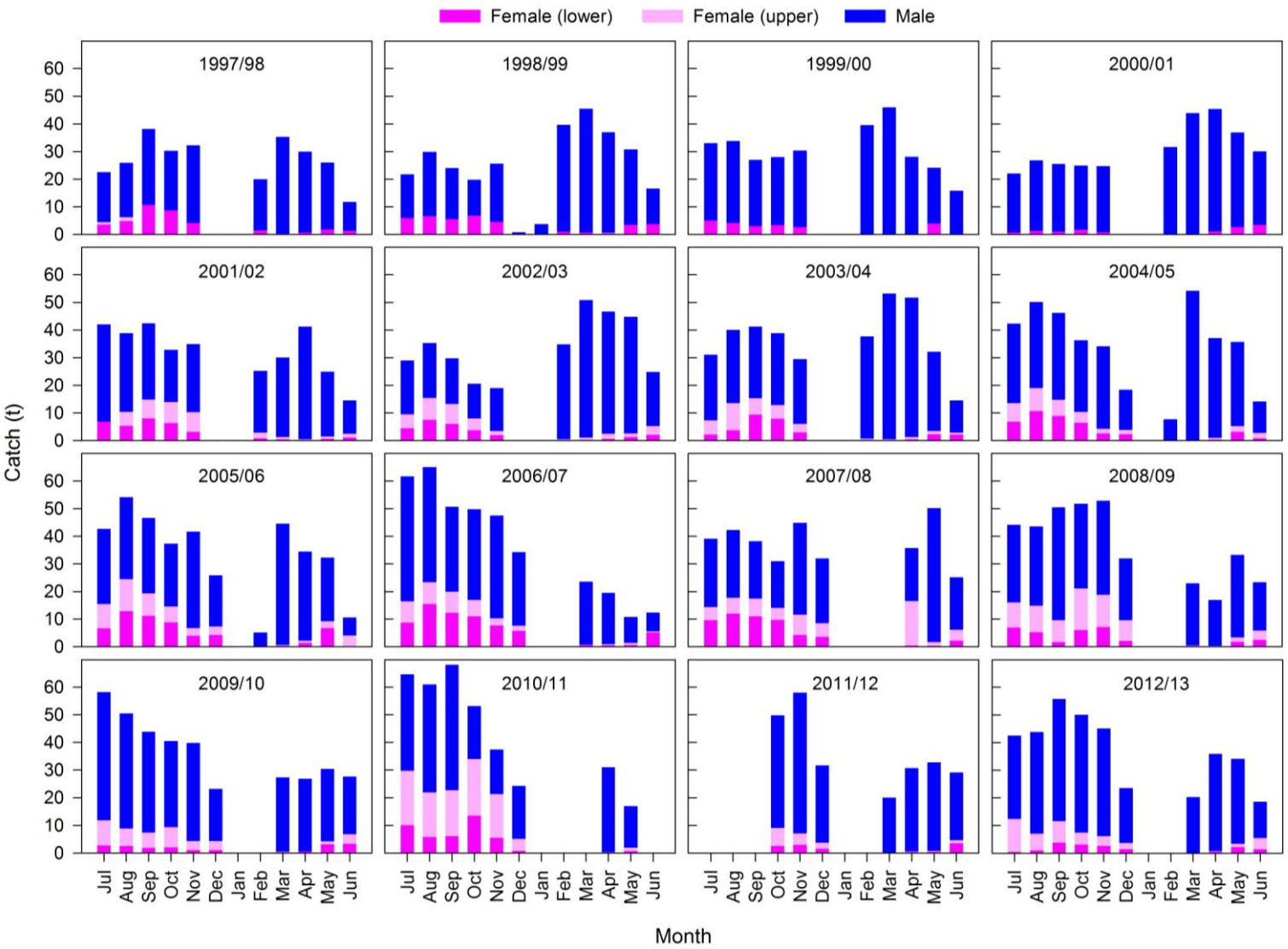

Figure 3.18. Monthly catches of female (upper and lower ranges) and male blue swimmer crabs by the Spencer Gulf pot fishing sector from 1997/98 to 2012/13.

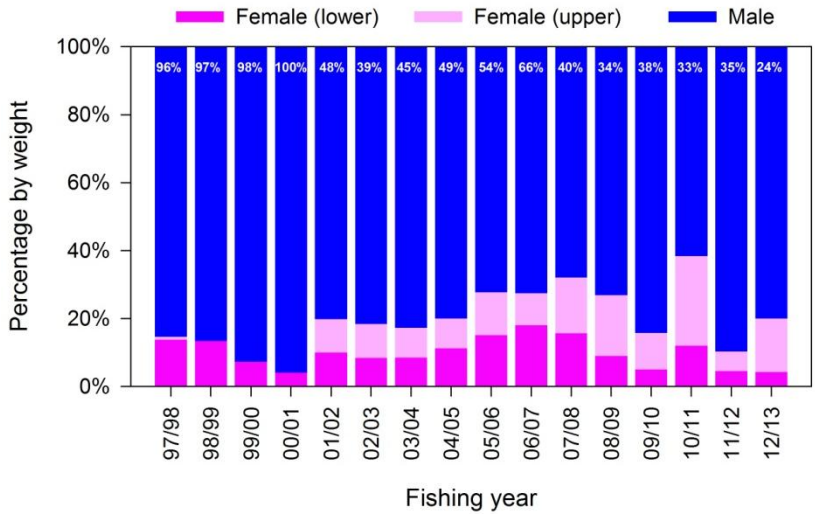

Figure 3.19. The percentage of female (upper and lower ranges) and male blue swimmer crabs by weight in Spencer Gulf from commercial logbook data from 1997/98 to 2012/13. Labels indicate the percentage of the total catch upon which estimates were based.

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 (a summary of these data is presented in **Table 3.1**). The mean CPUE of pre-recruits from pot-sampling during June and July has fluctuated since 2008, with the lowest CPUE recorded in 2011 (5.3 pre-recruits/potlift) and the highest in 2013 (11.4 pre-recruits/potlift) (**Figure 3.20**).

Table 3.1. Statistics on pot-sampling data collected by the Spencer Gulf pot fishing sector from 2006 to August 2013.

Statistic	2006	2007	2008	2009	2010	2011	2012	2013
No. of active licences*	5	5	5	5	4	4	4	4
No. of licences providing data	3	3	4	4	4	3	4	4
No. of boat days during the sampling period	989	858	971	696	734	526	664	378
No. of boat days sampled (and % total)	41	40	434	523	490	128	531	331
	4%	5%	45%	75%	67%	24%	80%	88%
No. of blocks sampled (and % of total fished)	6	18	27	26	27	8	29	20
	21%	51%	69%	90%	75%	35%	88%	80%
No. of crabs measured	845	1303	8526	8750	10204	2585	12550	8528

*Active licences are those licences where potlifts were recorded.

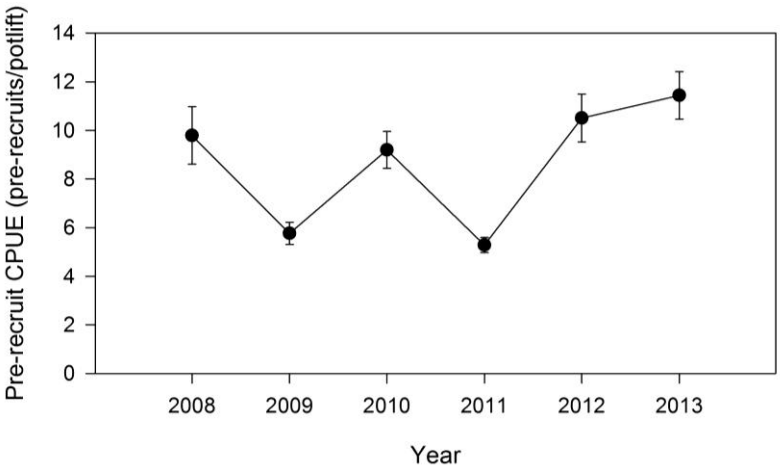

Figure 3.20. Mean (± SE) CPUE of pre-recruits from pot-sampling undertaken by the Spencer Gulf pot fishing sector during June and July from 2008 to 2013.

Although no trend is apparent between years, there is some evidence of a monthly trend in mean CPUE of pre-recruits from pot samples, with most peaks occurring in June or July (2010-2013) of each year (**Figure 3.21**). In 2013 (up to the end of July), the highest CPUE occurred in July at 12.9 pre-recruits/potlift.

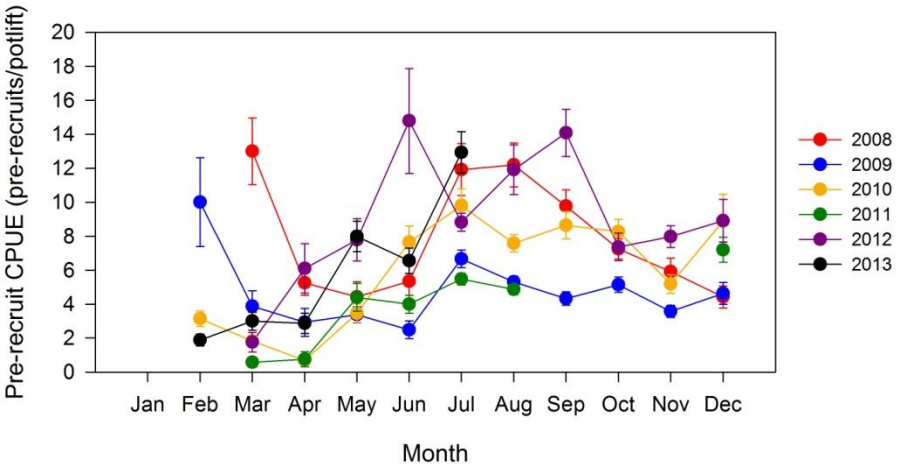

Figure 3.21. Mean (± SE) monthly CPUE of pre-recruits from pot-sampling undertaken by the Spencer Gulf pot fishing sector from 2008 to July 2013.

3.2.3.2. Frequency distributions by sex

Sex-specific frequency distributions from pot-sampling in Spencer Gulf were available for most months between March 2008 and June 2013 (**Figure 3.22**). Female blue swimmer crabs were caught in relatively high proportions from July to December, occasionally exceeding 50% of the catch by number. Females were rarely caught during February and March, but began to appear in small proportions from April to June. These trends were consistent among years.

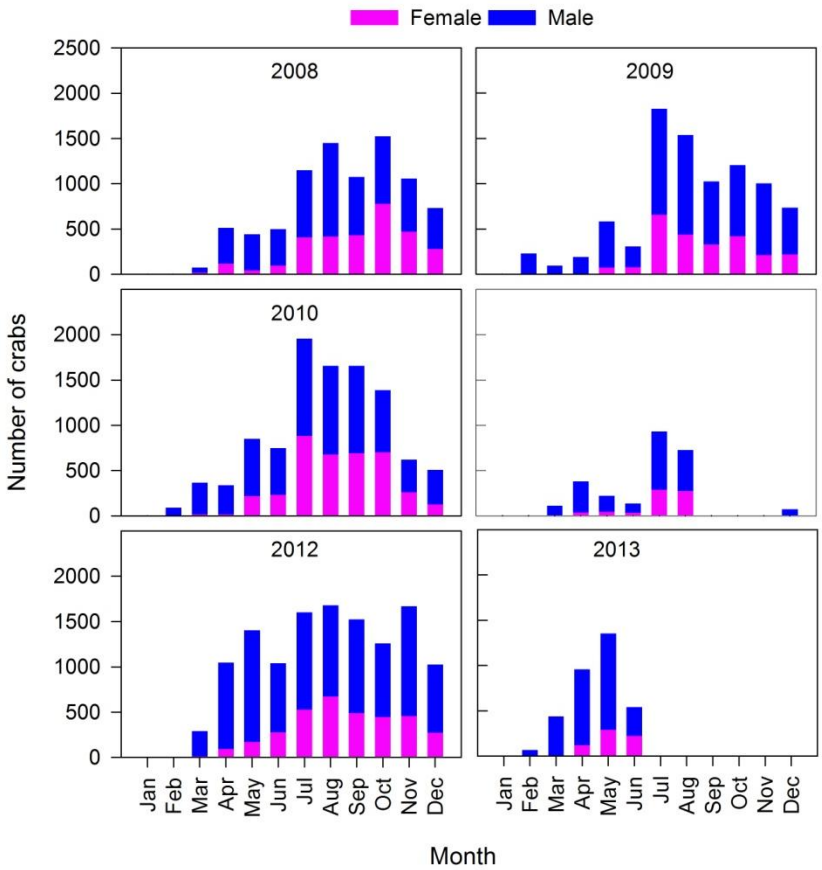

Figure 3.22. Number of female and male blue swimmer crabs caught in small-mesh pots by Spencer Gulf pot fishing sector during pot-sampling from 2008 to June 2013.

3.2.4. Performance indicators

As there was no stock assessment survey conducted in Spencer Gulf in 2013, information is only available for one of the three performance indicators for this sector, i.e. commercial CPUE of legal-size crabs. The mean commercial CPUE of legal-size crabs decreased from 4.38 kg/potlift in 2011/12 to 3.79 kg/potlift in 2012/13 (**Table 3.2**). Despite this reduction, these last two years represent the highest CPUEs recorded since quota was introduced. The 2012/13 value is between the limit (2 kg/potlift) and upper (4 kg/potlift) reference points for this indicator.

Table 3.2. Summary of the performance of the Spencer Gulf pot fishing sector for 2012/13 against the key biological performance indicators, including a comparison with the previous year and the stock status. Dashes (-) indicate that no survey was conducted in 2013.

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

3.3. Gulf St Vincent

3.3.1. Fishery-independent surveys

3.3.1.1. Relative biomass of legal-size crabs

Relative biomass of legal-size crabs in Gulf St Vincent fluctuated in the first few years in which fishery-independent surveys were conducted, i.e. since 2002, until it reached its highest level in 2006 (mean: 4.75 legal-size crabs/potlift) (**Figure 3.23**). The mean survey CPUE of legal-size crabs has generally declined each year thereafter (except for an increase in 2010), falling to 1.45 legal-size crabs/potlift in 2013, which represents the lowest recorded for the gulf. The current estimate is only marginally below the limit reference point (1.5 legal-size crabs/potlift).

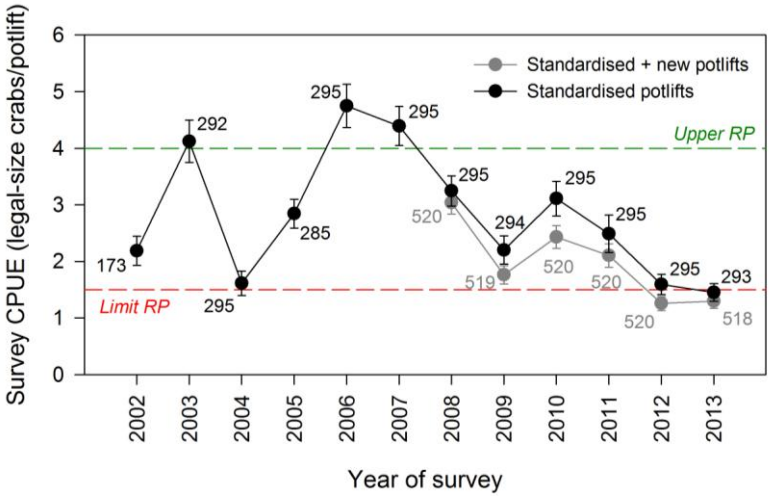

Figure 3.23. Mean (± SE) survey CPUE of legal-size crabs for standardised potlifts (2002-current) and standardised + new potlifts (2008-current) in Gulf St Vincent during June and July from 2002 to 2013. Labels indicate the number of potlifts.

3.3.1.2. Relative biomass of pre-recruits

The relative biomass of pre-recruits in Gulf St Vincent since 2004 has followed a similar trend as that for legal-size crabs. The lowest mean survey CPUE of pre-recruits in 2004 (0.44 pre-recruits/potlift) preceded the highest in 2006 (10.72 pre-recruits/potlift) (**Figure 3.24**). Consecutive declines in the mean survey CPUE of pre-recruits occurred from 2006 to 2009 (to 1.30 pre-recruits/potlift) before substantially increasing in 2010 (to 7.25 pre-recruits/potlift), and then declining again in 2011 and 2012 to 2.13 and 0.78 pre-recruits/potlift, respectively. A slight increase in mean survey CPUE of pre-recruits in the gulf was recorded in 2013 to 1.23 pre-recruits/potlift. With the inclusion of new potlifts (2008-current), the CPUE of pre-recruits 1.81 pre-recruits/potlift. This 48% higher mean density is mainly attributable to relatively high densities at new potlifts in the upper region of the gulf,

particularly at two new sites north of Ardrossan (Appendix, **Figure A 2**). Nevertheless, the current estimate using standardised potlifts only is below the limit reference point (1.5 pre-recruits/potlift).

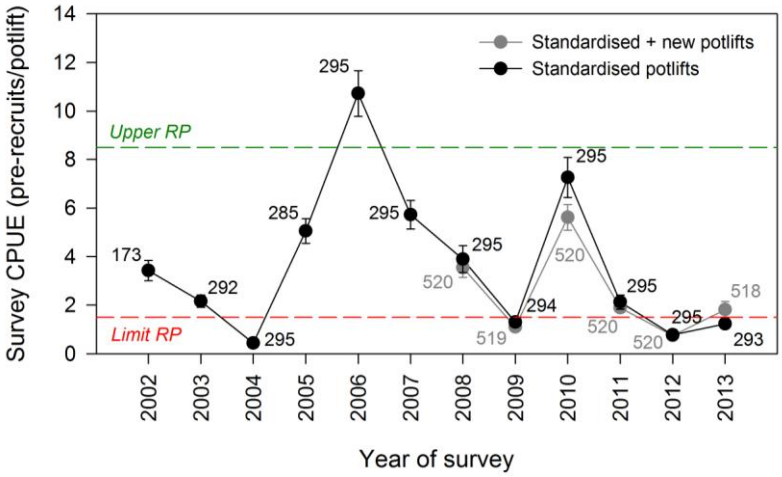

Figure 3.24. Mean (± SE) survey CPUE of pre-recruits for standardised potlifts (2002-current) and standardised + new potlifts (2008-current) in Gulf St Vincent during June and July from 2002 to 2013. Labels indicate the number of potlifts.

3.3.1.3. Spatial distribution of legal-size crabs

The distribution of legal-size crabs in Gulf St Vincent was spatially and temporally variable since 2002 (**Figure 3.25**). However, in the last few years (2011-2013) there were notably fewer blocks yielding densities of more than 5 legal-size crabs/potlift compared to previous years (2003-2010).

Block 27 and 35, west of Outer Harbor, consistently yielded a very high or high mean survey CPUE (>10 and 5-10 legal-size crabs/potlift) for eight years of the twelve year period in which surveys have been conducted. A very high mean survey CPUE was recorded in Block 27 on four occasions (2003 and 2005–2007), in Block 35 on three occasions (2008, 2009 and 2011), and in several blocks on one occasion each (Block 13, 17, 18, 33 and 34). There were no blocks north of Pine Point (i.e. above Block 13) with a very high mean survey CPUE during any year.

During 2013, a high mean survey CPUE (5-10 legal-size crabs/potlift) was recorded in Block 35 only, and a medium CPUE (2-5 legal-size crabs/potlift) in Block 10, 21 and 27. All remaining blocks averaged a low mean CPUE (<2 legal-size crabs/potlift). The overall spatial distribution and densities of legal-size crabs in the gulf in 2013 appears similar to 2012 (**Figure 3.25**).

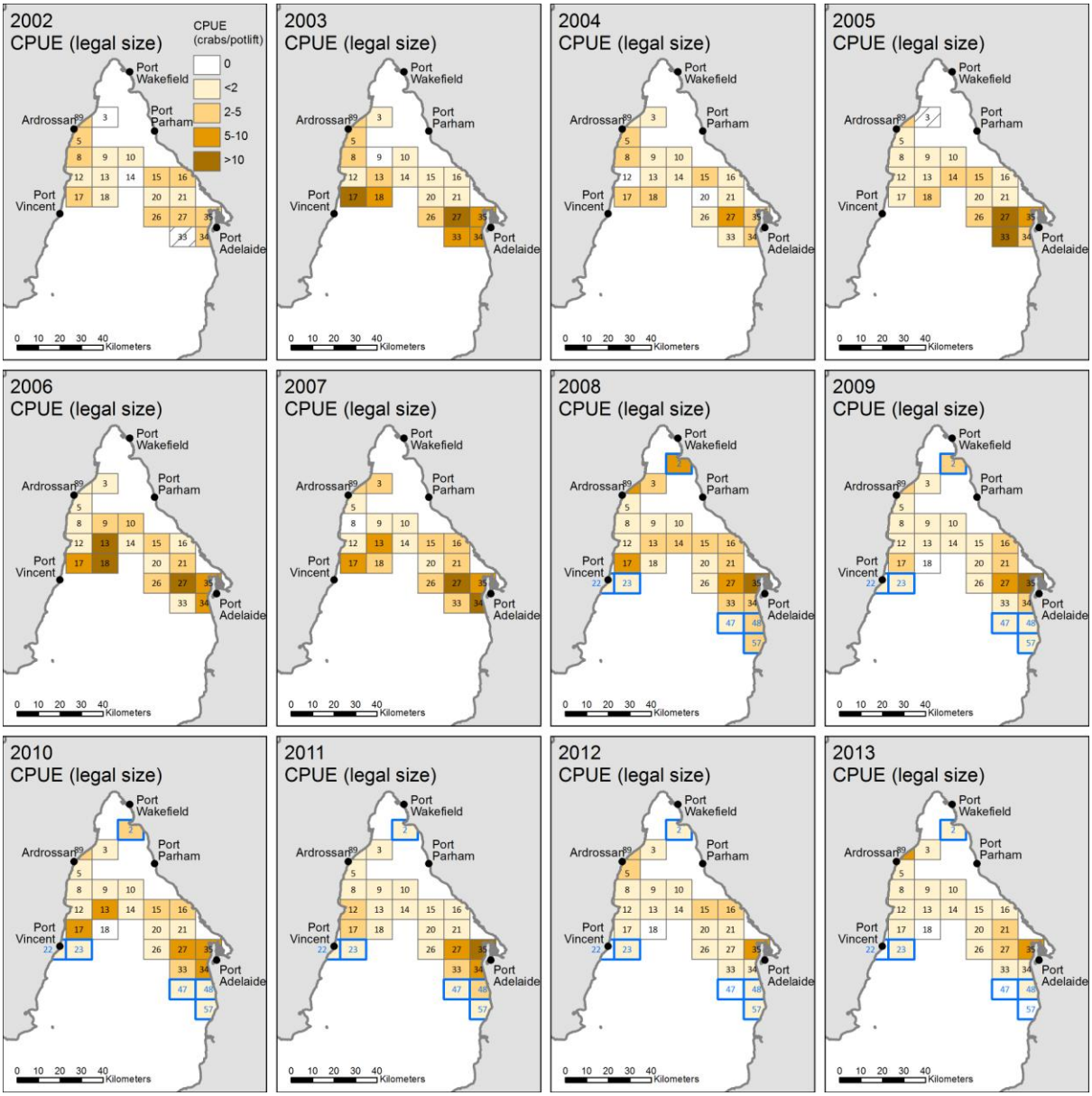

Figure 3.25. Spatial distribution of survey CPUE of legal-size crabs from standardised + new potlifts in Gulf St Vincent during June and July from 2002 to 2013. Note: 2008 to 2013 maps include new blocks surveyed (Block 2, 22, 23, 47, 48 and 57). See 2002 map for legend.

3.3.1.4. Spatial distribution of pre-recruits

The abundance index of pre-recruits varied substantially among blocks and between years (**Figure 3.26**). However, in the last few years (2011-2013) there were few blocks yielding densities of more than 5 pre-recruits/potlift compared to most previous years (2005-2010).

While few consistent trends were evident, the most productive blocks were Block 13, 27 and 35, each of which yielded a very high (>10 pre-recruits/potlift) or high (5-10 pre-recruits/potlift) mean survey CPUE of pre-recruits on most occasions up to 2010. Over the last three years (2011-2013), Block 35 was the only block in the gulf that yielded a mean of 5

or more pre-recruits/potlift each year. In 2013, there were no pre-recruits found in six out of 24 blocks surveyed (compared to nine blocks in 2012).

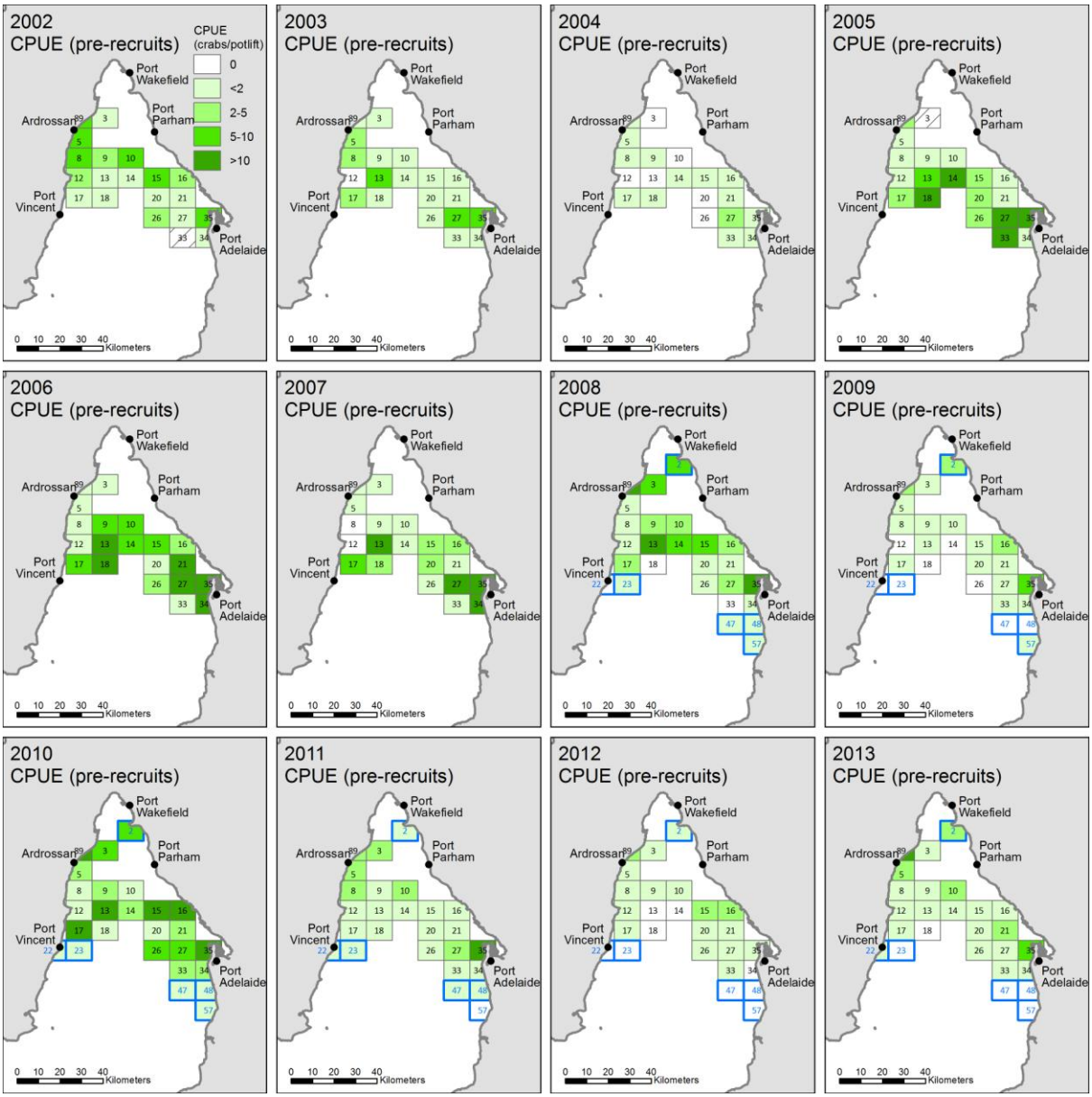

Figure 3.26. Spatial distribution of survey CPUE of pre-recruits from standardised + new potlifts in Gulf St Vincent during June and July from 2002 to 2013. Note: 2008 to 2013 maps include new blocks surveyed (Block 2, 22, 23, 47, 48 and 57). See 2002 map for legend.

A finer-scale 'heat map' of the average densities of legal-size and pre-recruit crabs from standardised potlifts in Gulf St Vincent reveals a similar spatial pattern between 2002-2007 and 2008-2013. However, in contrast to Spencer Gulf, there has been a general decrease in densities for both size classes in Gulf St Vincent during the latter period (**Figure 3.27**).

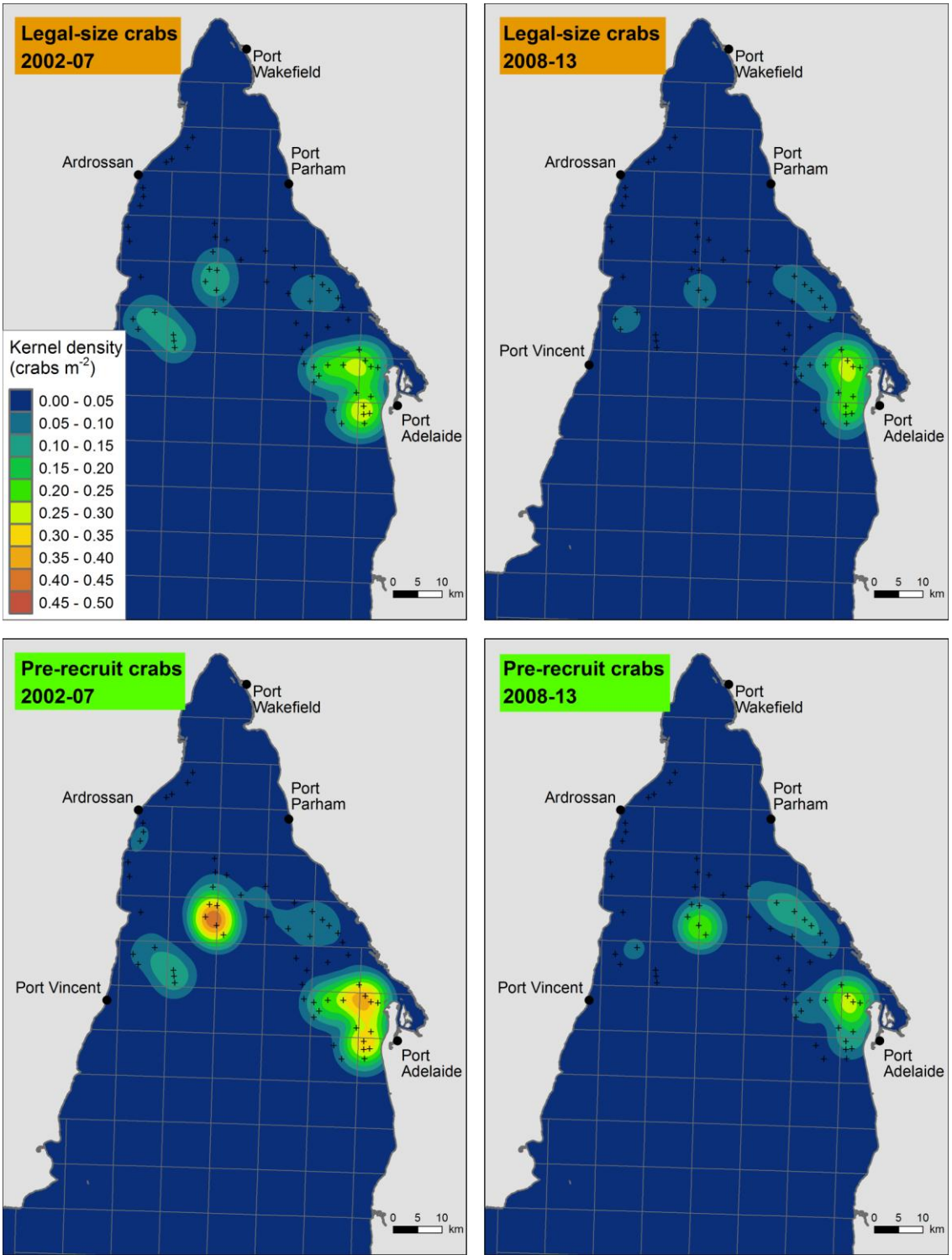

Figure 3.27. Kernel density maps showing average distribution of legal-size and pre-recruit crabs for standardised potlifts from surveys conducted in Gulf St Vincent for 2002-2007 and 2008-2013. See 2002-2007 map of legal-size crabs for legend.

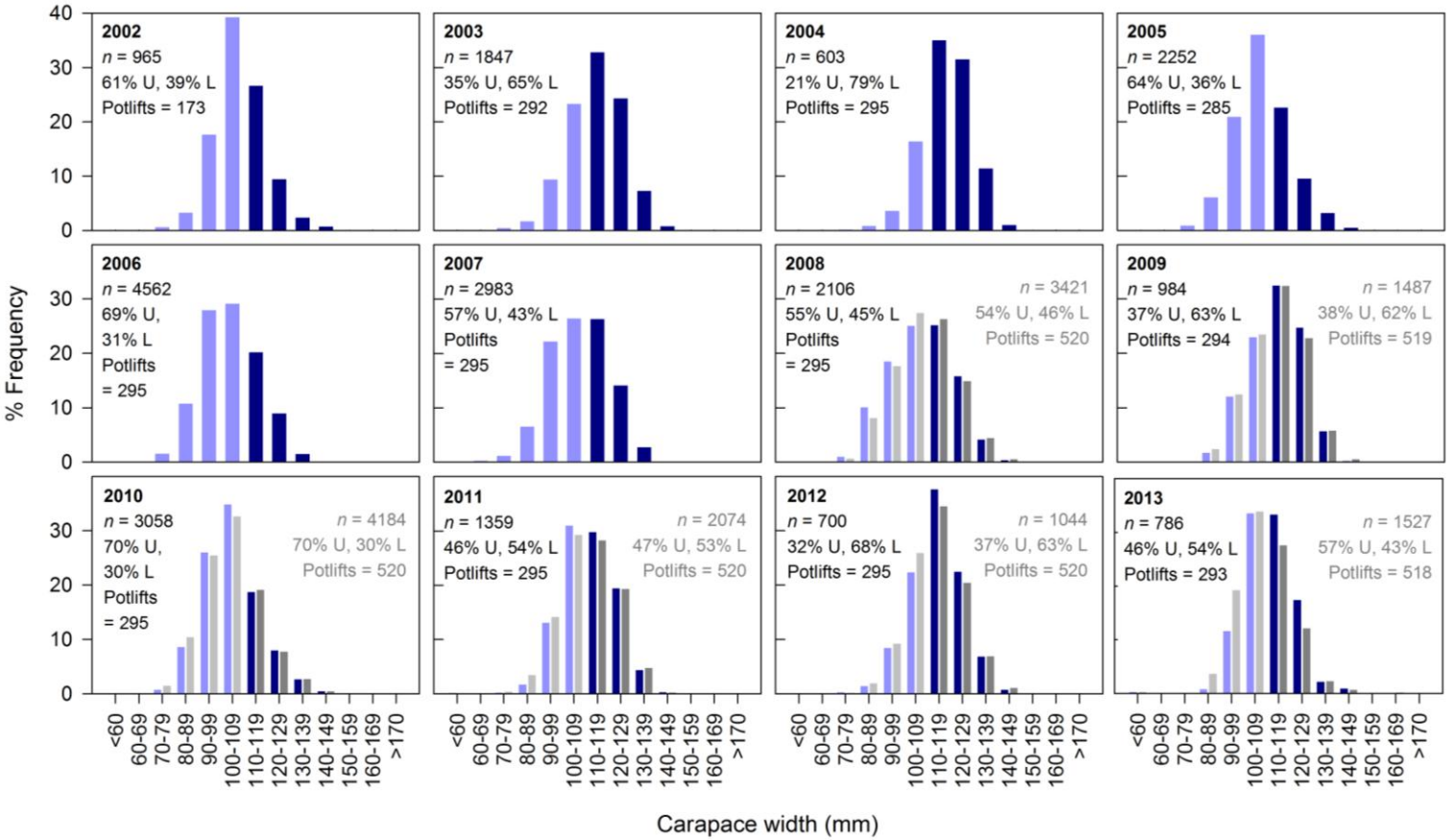

Figure 3.28. Size-frequency distribution of blue swimmer crabs caught during fishery-independent surveys conducted in Gulf St Vincent during June and July from 2002 to 2013. Light and dark blue bars represent pre-recruits and legal-size crabs, respectively, caught using standardised potlifts (2002-current), while grey bars and text represent those caught using standardised + new potlifts (2008-current).

3.3.1.5. Crab size

The size distribution of the surveyed population in Gulf St Vincent varied substantially among years (**Figure 3.28**). The modal size of blue swimmer crabs was 100-109 mm carapace width (undersize or pre-recruits) during 2002, 2005-2007, 2010 and 2011, and 110–119 mm (legal-size crabs) during 2003, 2004, 2008, 2009, 2012 and 2013. The proportion of pre-recruits ranged from 31% (2012) to 70% (2010) in all years except 2004, when the total caught was very low and pre-recruits comprised only 21% of the surveyed population. The proportion of pre-recruits in the size distribution increased from 31% in 2012 to 41% in 2013.

3.3.2. Commercial logbook data

3.3.2.1. Catch and effort

Annual trends

For the 2012/13 fishing year, the Gulf St Vincent pot fishing sector held 245.1 t (39%) of the TACC for the BCF (626.8 t), yet only landed just over half their allocation (129.0 t, 53%) (**Figure 3.29**). Consequently, 2012/13 was the fifth consecutive year that 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. The total catch of 129.0 t in 2012/13 was 45% lower than in 2011/12 (234.3 t), and was the lowest catch since 1997/98 (125.4 t).

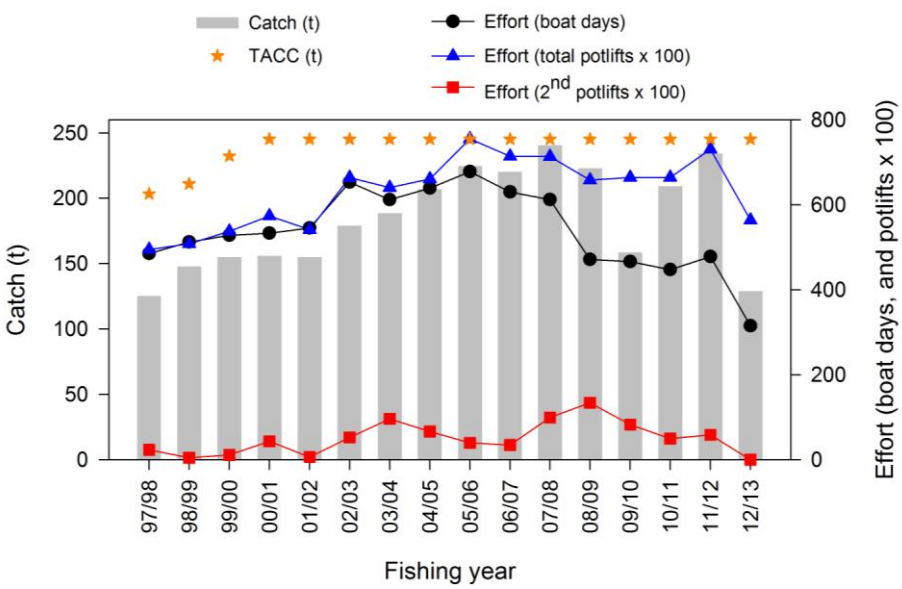

Figure 3.29. Total catch and effort for the Gulf St Vincent pot fishing sector from 1997/98 to 2012/13.

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 3.29**). Boat days increased 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), associated with the substantial reduction in total catch in the same year.

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 3.29**). 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).

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 3.29**). A low number of second potlifts (<1,000 potlifts) were recorded in 1998/99 (432 potlifts) and 2001/02 (620 potlifts); however, 2012/13 is the only year in which no second potlifts were recorded.

Spatial distribution of the annual catch

The number of blocks fished in Gulf St Vincent has changed since 1997/98. There were two licences for the first five years of quota (i.e. 1996/97-2000/01), and during this period, 11 to 15 blocks were fished (**Figure 3.30**). The introduction of a new licence in 2002/03 coincided with an increase in the number of blocks fished (16 blocks), particularly those with low catch (<5 t). Thereafter, fishing occurred in 12 to 17 blocks up to 2007/08, when another licence was issued in this gulf and the number of blocks with high catch (>20 t) doubled. Since 2008/09, there has been a substantially higher number of blocks fished, i.e. 22 to 25, particularly those of low catch. With the exception of 2011/12 (25 blocks), more blocks were fished in the gulf during 2012/13 (24 blocks) than any previous year.

The distribution of catch in Gulf St Vincent in 2012/13 was similar to the expansion in area fished that was reported for 2011/12, especially in the fishing blocks adjacent the western shoreline extending north of Port Vincent to south of Stansbury (**Figure 3.31**). However, the catches for 2012/13 were lower for most blocks fished across the gulf, which reflects the substantially reduced total catch for that year.

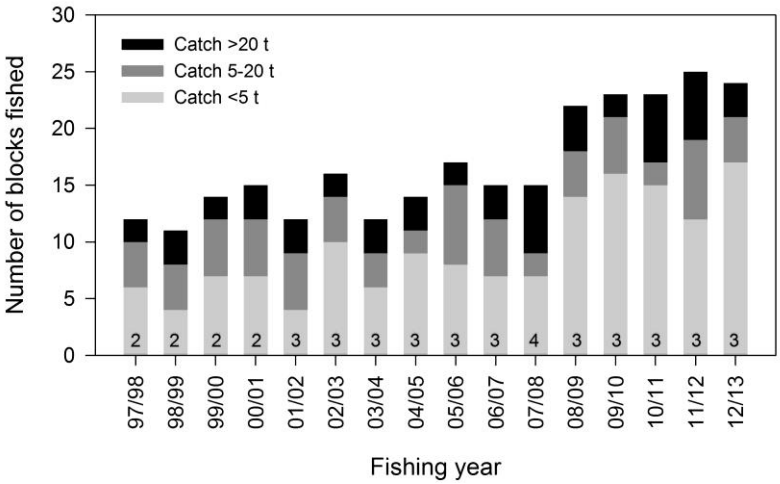

Figure 3.30. The number of blocks fished in the Gulf St Vincent pot fishing sector from 1997/98 to 2012/13 with catches of <5 t, 5-20 t and >20 t. Labels indicate the number of licences fishing.

Monthly catch and effort

Commercial pot fishing in Gulf St Vincent occurs throughout the year, except for the closure between 1 November and 15 January. Monthly effort generally reflected the trend in catch (**Figure 3.32**). Monthly catch and effort were more variable between January and June. Generally, monthly catches were highest in February (immediately following the closure), with catches declining thereafter. For 2012/13, monthly catch and effort ranged from 8.6 t (June) and 4,410 potlifts (September) to 25.4 t and 9,660 potlifts (February), which is consistent with this recent trend.

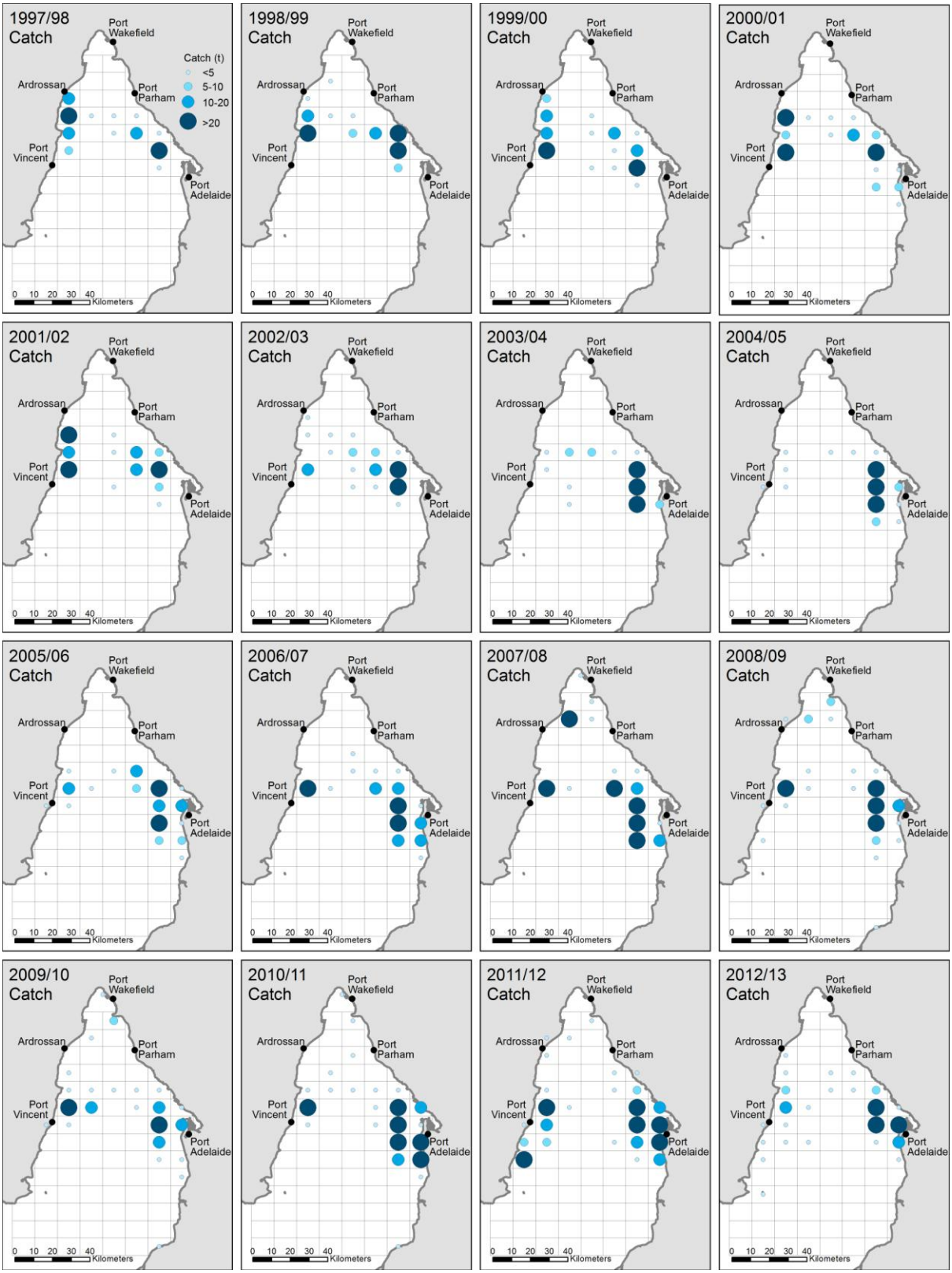

Figure 3.31. Spatial distribution of commercial catch by the Gulf St Vincent pot fishing sector from 1997/98 to 2012/13. See 1997/98 map for legend.

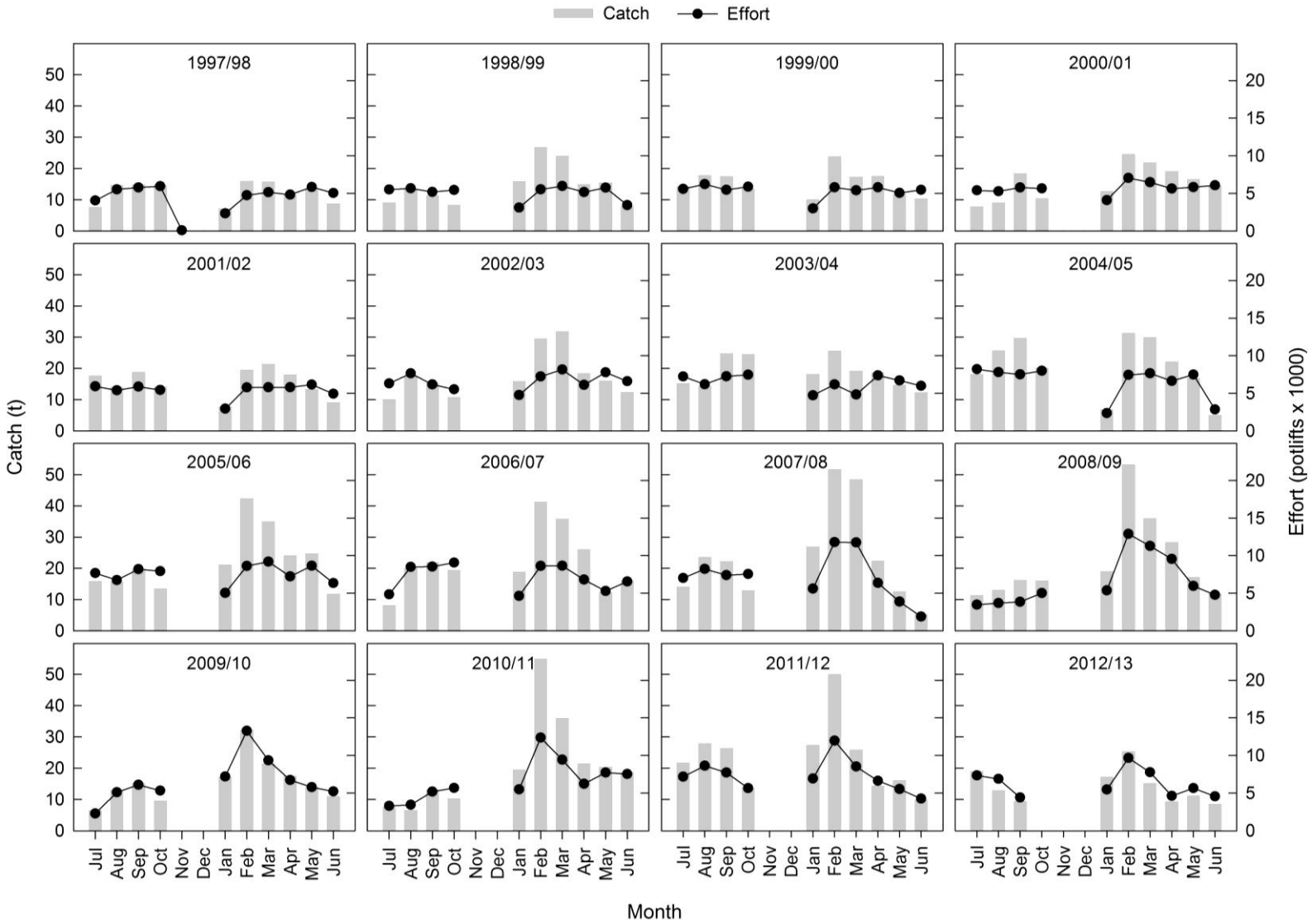

Figure 3.32. Monthly catch and effort for the Gulf St Vincent pot fishing sector from 1997/98 to 2012/13.

3.3.2.2. Catch per unit effort

Mean annual CPUE

The mean commercial CPUE gradually increased in Gulf St Vincent since quota was introduced, except 2009/10 and 2012/13, when CPUE substantially reduced (**Figure 3.33**). Over the last two years, mean commercial CPUE dropped from the highest recorded at 3.36 kg/potlift in 2011/12 to the lowest at 2.33 kg/potlift in 2012/13. Regression analysis showed a poor correlation exists between survey CPUE and commercial CPUE of legal-size crabs at the start of the fishing year ($R^2 = 0.28^{ns}$, **Figure 3.34**).

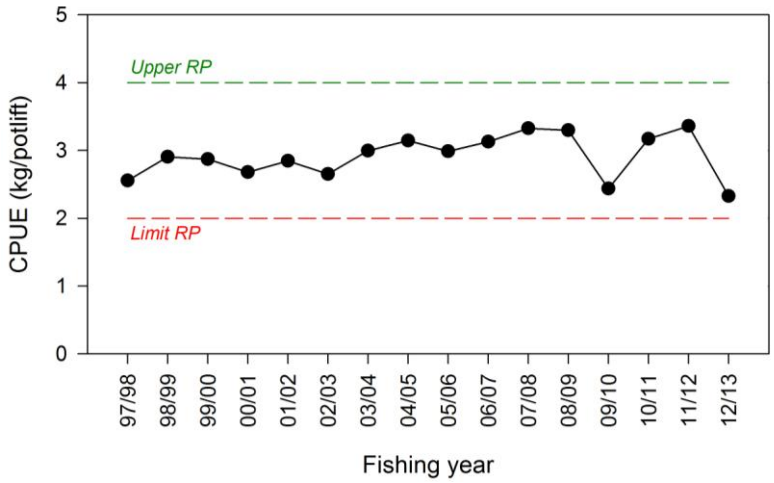

Figure 3.33. Mean commercial CPUE in the Gulf St Vincent pot fishing sector from 1997/98 to 2012/13. Dashed lines indicate the limit and upper reference points for this performance indicator.

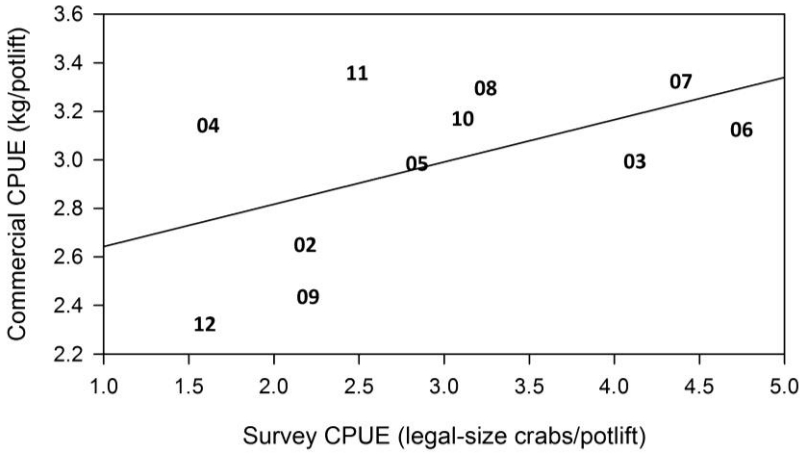

Figure 3.34. Linear regression between survey CPUE and commercial CPUE for the Gulf St Vincent pot fishing sector. Values are represented by the year of the survey and start of the fishing year (e.g. '05' represents the 2005/06 fishing year).

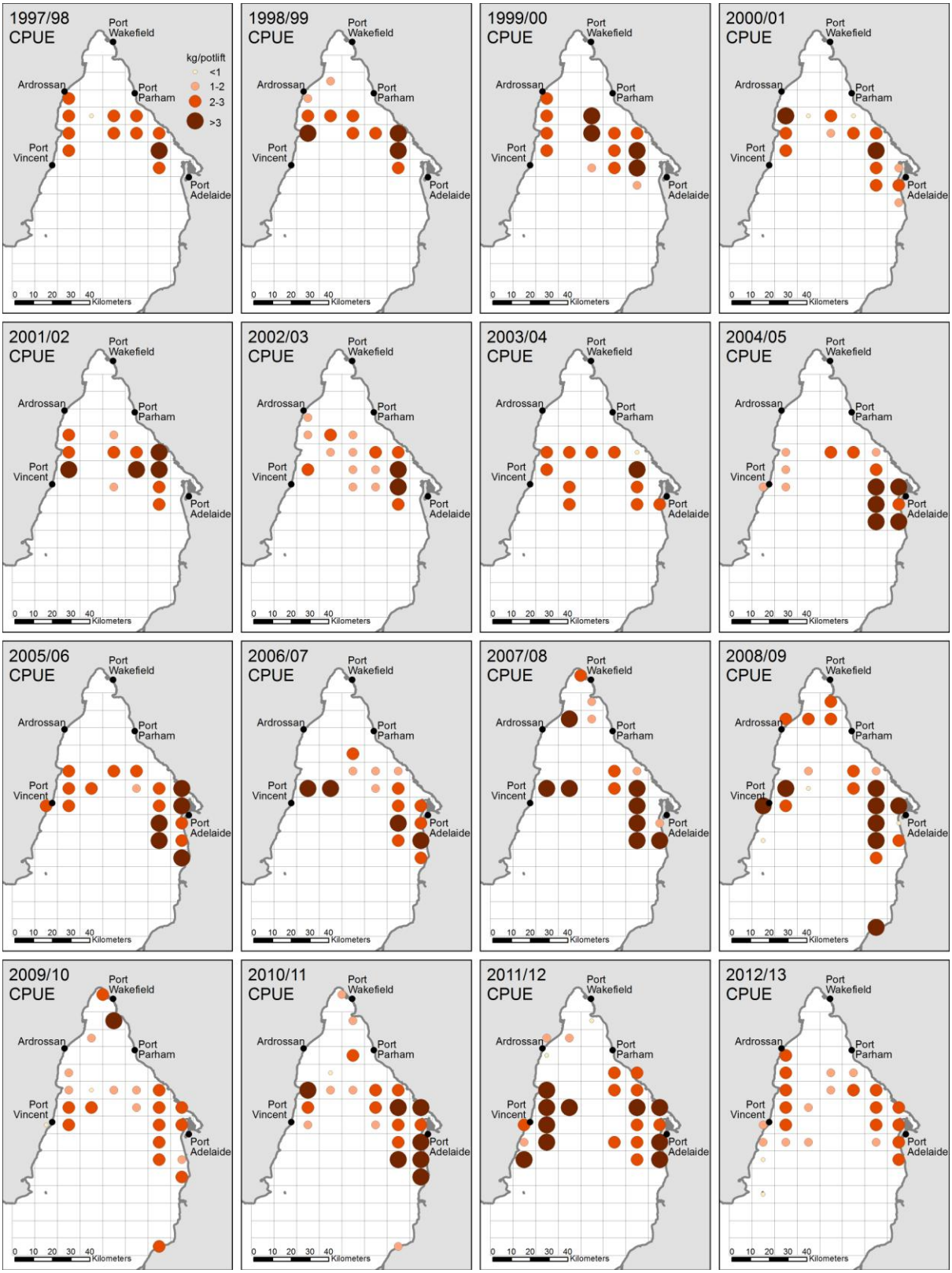

Figure 3.35. Spatial distribution of commercial CPUE of the Gulf St Vincent pot fishing sector from 1997/98 to 2012/13. See 1997/98 map for legend.

Spatial distribution of mean annual CPUE

The distribution of mean commercial CPUE in Gulf St Vincent was spatially and temporally variable from 1997/98 to 2012/13 (**Figure 3.35**). Prior to 2011/12, most blocks with a high mean CPUE (>3 kg/potlift) were located in the eastern region of the gulf adjacent the shoreline extending from Port Gawler to southern metropolitan Adelaide. In 2011/12, additional blocks were identified with high CPUE adjacent the western shoreline and south of Stansbury. Some fishing continued in this expanded area in 2012/13, but at lower CPUE. Two other blocks with medium CPUE levels (2-3 kg/potlift) were identified in the upper region of the gulf (Block 5 and 7) that had not shown densities this high since 1999/00. A high mean CPUE was not recorded for any fishing block during 2012/13.

Mean annual CPUE for first and second potlifts

Mean commercial CPUE for first potlifts was greater than for second potlifts in all years except 2002/03, 2003/04 and 2010/11 (**Figure 3.36**). While this difference may appear to be due to the difference in soak time (generally 19-20 h for the first potlift and 4-5 h for the second potlift), second potlifts have a much higher catch rate if catch is expressed per hour of soak time. Interpretation of trends in CPUE is further complicated by the relatively low number of second potlifts compared to first potlifts. In 2012/13 the commercial CPUE was calculated only on first potlifts as there were no second potlifts.

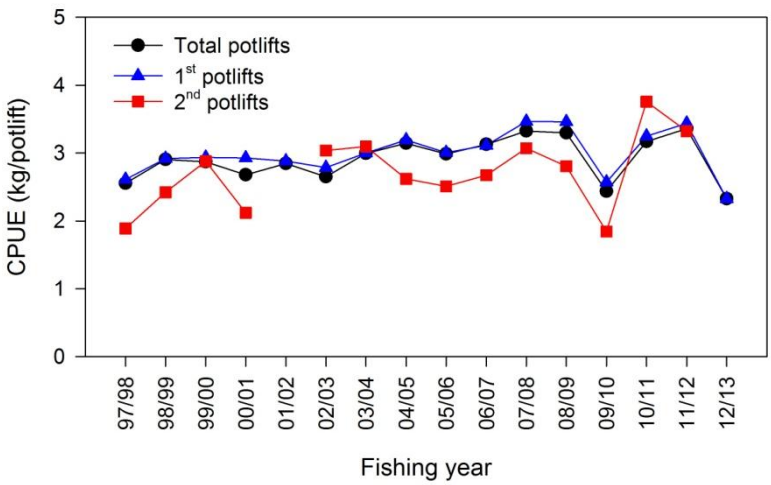

Figure 3.36. Mean commercial CPUE in the Gulf St Vincent pot fishing sector (for first potlifts, second potlifts and total potlifts) from 1997/98 to 2012/13.

Mean monthly CPUE

A monthly trend in mean commercial CPUE for Gulf St Vincent was observed in most years since the introduction of quota. Generally, CPUE was relatively low in July at the start of the quota period, after which it increased until September, and then declined rapidly in October

prior to the annual closure for the Gulf St Vincent pot fishing sector in November and December (**Figure 3.38**). In most years, mean CPUE was highest in February following the closure, before declining to the end of the quota period in June.

Mean daily CPUE

Mean commercial daily CPUE for Gulf St Vincent increased steadily from 259 kg/boat day in 1997/98 to 473 kg/boat day in 2008/09 (**Figure 3.37**). Although daily CPUE decreased in 2009/10, it increased again in 2010/11 before reaching its highest level in 2011/12 of 490 kg/boat day. A slight decrease was recorded in 2012/13, with a mean daily CPUE of 409 kg/boat day.

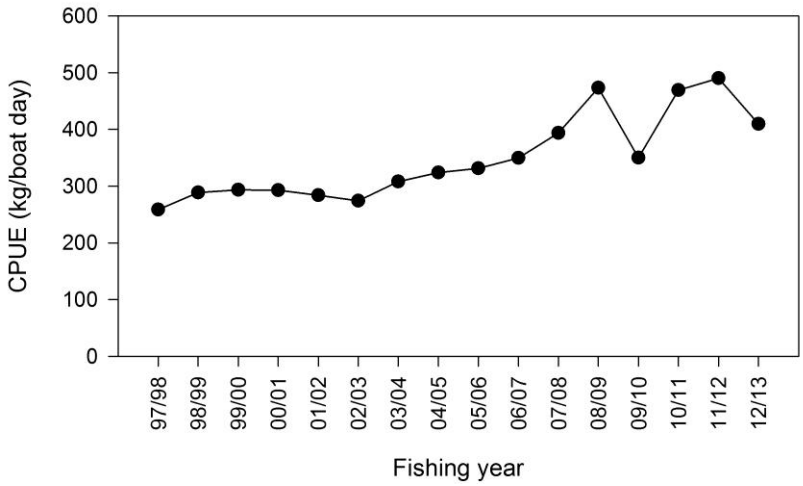

Figure 3.37. Mean commercial daily CPUE for the Gulf St Vincent pot fishing sector from 1997/98 to 2012/13.

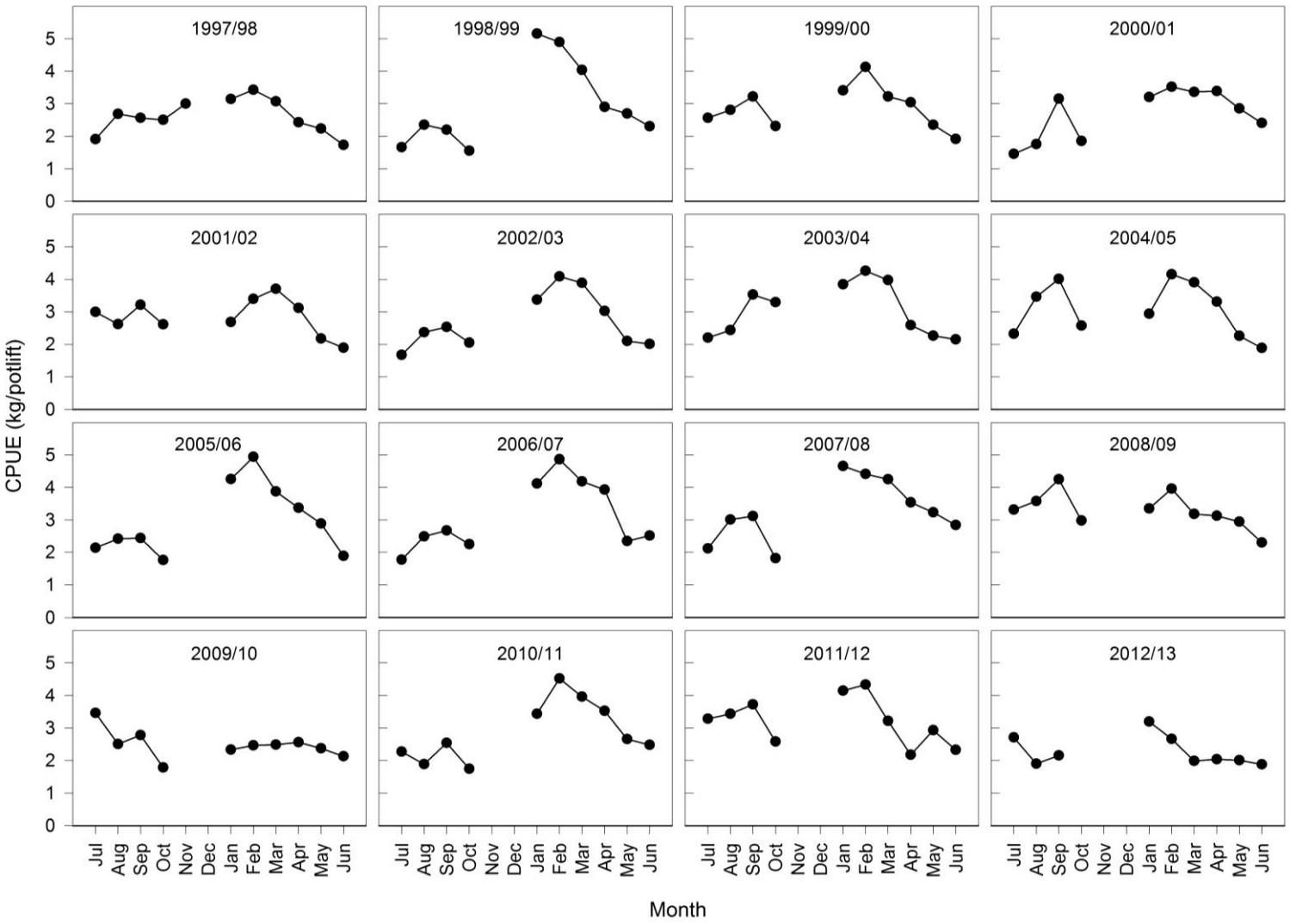

Figure 3.38. Mean monthly commercial CPUE for the Gulf St Vincent pot fishing sector from 1997/98 to 2012/13.

3.3.2.3. Sex ratio

Annual catches of blue swimmer crabs in Gulf St Vincent are predominantly comprised of males by weight (**Figure 3.39**). Uncertainty in estimates of sex ratio arises from incomplete logbook data. Under the assumptions that missing data on sex in daily catch records were: 1) all male (lower female estimate); and 2) an equal proportion to available data for each month (upper female estimate), the percentage of females in the total annual catch between 1997/98 and 2012/13 ranged from at least 5-46% (mean: 18%) to 8-46% (mean: 21%), respectively. The highest proportion of females was recorded in 2012/13, increasing from 27-28% in 2011/12 to 46%, and representing the fifth consecutive increase in proportion of the commercial catch since 2007/08 (13-14%).

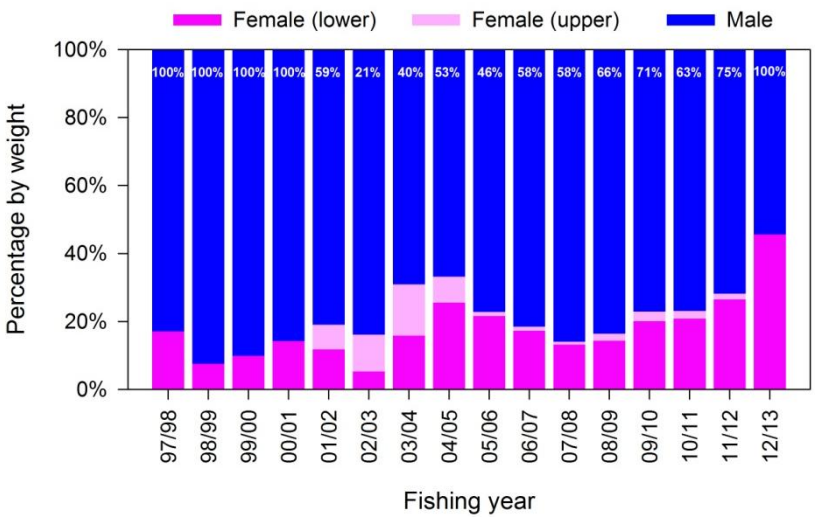

Figure 3.39. The percentage of female (upper and lower ranges) and male blue swimmer crabs by weight in Gulf St Vincent from commercial logbook data from 1997/98 to 2012/13. Labels indicate the percentage of the total catch upon which estimates were based.

Catches of female blue swimmer crabs were generally highest between May and October (**Figure 3.40**), while few females were caught between January and April in any year. Like Spencer Gulf, the timing of capture exerts a strong influence over the proportion of females harvested in any year. As in most other years, the highest catch of male blue swimmer crabs in 2012/13 was in February.

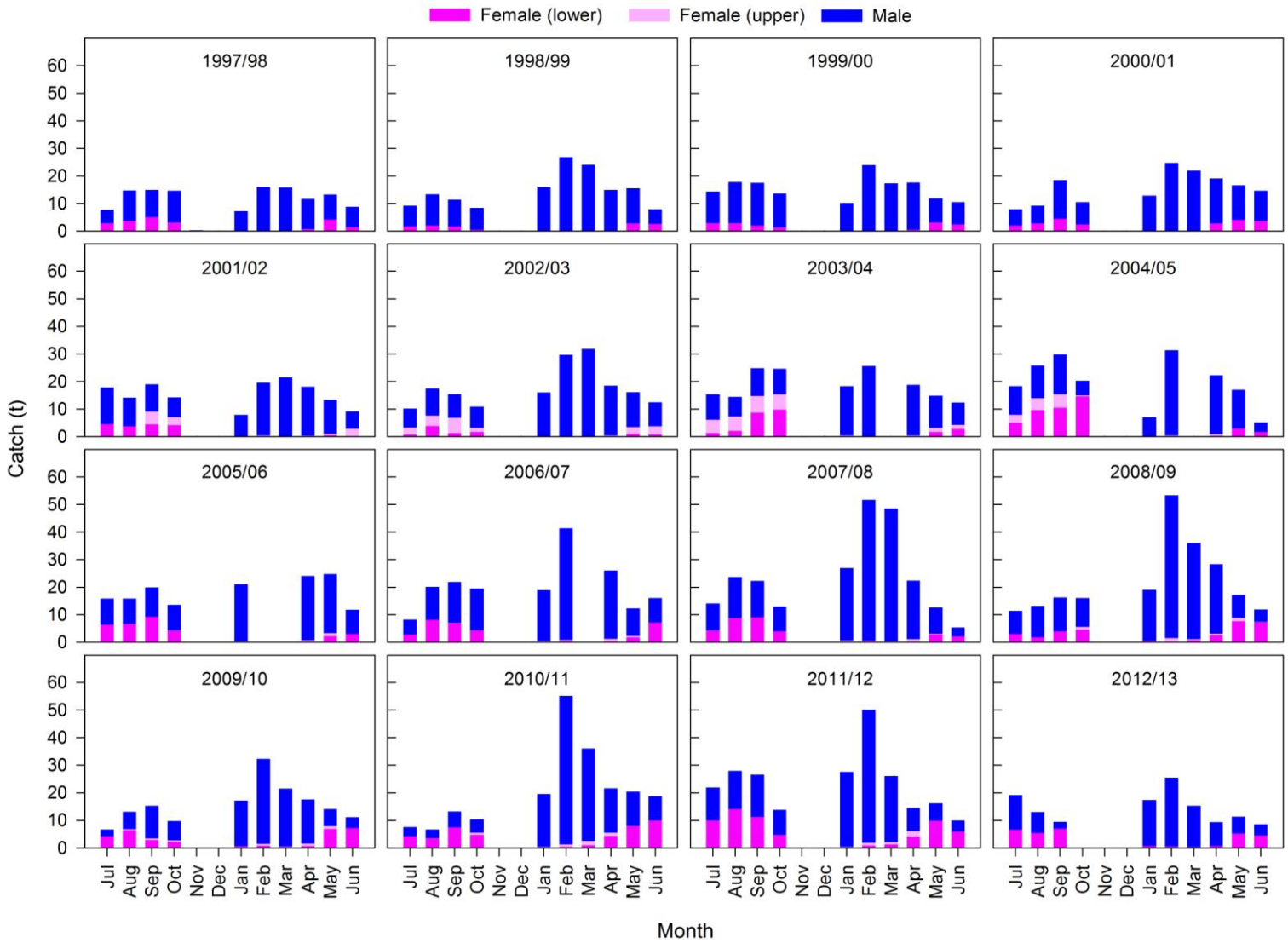

Figure 3.40. Monthly catches of female (upper and lower ranges) and male blue swimmer crabs by the Gulf St Vincent pot fishing sector from 1997/98 to 2012/13.

3.3.3. Pot-sampling data

3.3.3.1. Pre-recruit abundance

Reliable pot-sampling data for Gulf St Vincent have been collected since 2008 (a summary of these data is presented in **Table 3.3**). 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, before an increase was recorded in 2013 at 5.4 pre-recruits/potlift (**Figure 3.41**).

Table 3.3. Statistics on pot-sampling data collected by the Gulf St Vincent pot fishing sector from 2006 to June 2013.

Statistic	2006	2007	2008	2009	2010	2011	2012	2013
No. of active licences*	3	4	4	3	3	3	3	3
No. of licences providing data	1	3	3	3	3	3	3	3
No. of boat days during the sampling period	674	640	443	492	425	512	407	203
No. (and % total) of boat days sampled	13	32	169	327	348	353	300	188
	2%	5%	38%	66%	82%	69%	74%	93%
No. (and % of total fished) of blocks sampled	3	8	10	13	18	15	21	14
	20%	53%	67%	59%	67%	63%	72%	70%
No. of crabs measured	336	789	3485	5473	7308	6845	6423	4960

*Active licences are those licences where potlifts were recorded.

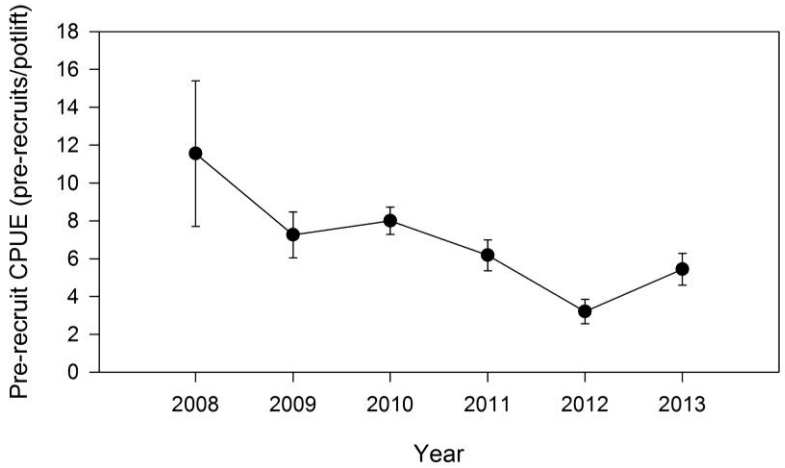

Figure 3.41. Mean (± SE) CPUE of pre-recruits from pot-sampling undertaken by the Gulf St Vincent pot fishing sector during June and July from 2008 to 2013.

Monthly pre-recruit estimates were variable among years (**Figure 3.42**), particularly from July to October in both 2008 and 2010, when mean CPUE of pre-recruits was relatively high. The CPUE of pre-recruits was marginally higher in June compared to July in all years. Although relatively low throughout 2012, mean monthly CPUE of pre-recruits increased in 2013 (up to June) to highest levels recorded for most months.

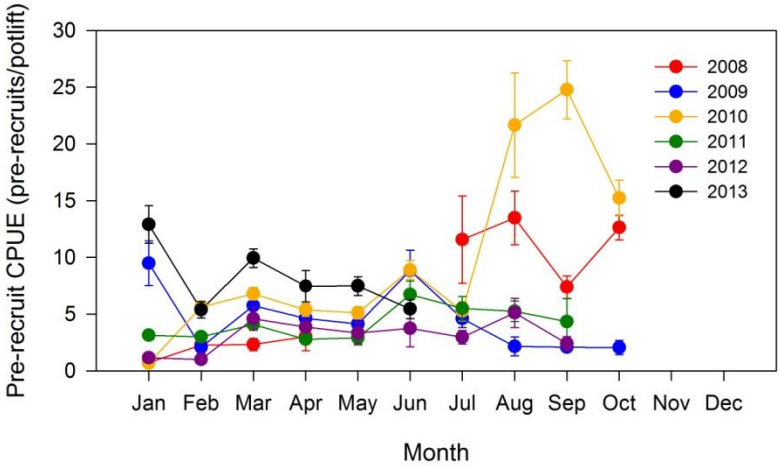

Figure 3.42. Mean (± SE) monthly CPUE of pre-recruits from pot-sampling undertaken by the Gulf St Vincent pot fishing sector from 2008 to July 2013.

3.3.3.2. Frequency distributions by sex

Sex-specific frequency distributions from pot-sampling in Gulf St Vincent were available for most months between January 2008 and June 2013 (**Figure 3.43**). Female blue swimmer crabs were rarely caught from January to March but their proportion increased between May and October, reaching 50% of the catch by number on some occasions. As in 2012, the highest catch of females from pot-sampling in 2013 was recorded in May, while the highest catch of males was recorded in February.

3.3.4. Performance indicators

Data were available for all three performance indicators for the Gulf St Vincent pot fishing sector in 2012/13. Compared to 2011/12, the mean survey CPUE of legal-size crabs decreased slightly from 1.59 to 1.45 legal-size crabs/potlift, which is only marginally below the limit reference point (1.5 pre-recruits/potlift) for this indicator (**Table 3.4**). Although the mean CPUE of pre-recruits from the 2013 survey of 1.23 pre-recruits/potlift was still below the limit reference point, this represents an increase from 0.78 pre-recruits/potlift for the 2012 survey. The mean commercial CPUE of legal-size crabs decreased from 3.36 kg/potlift in 2011/12 to the lowest recorded in 2012/13, at 2.33 kg/potlift. Despite this reduction, this indicator remains within the reference range (2-4 kg/potlift).

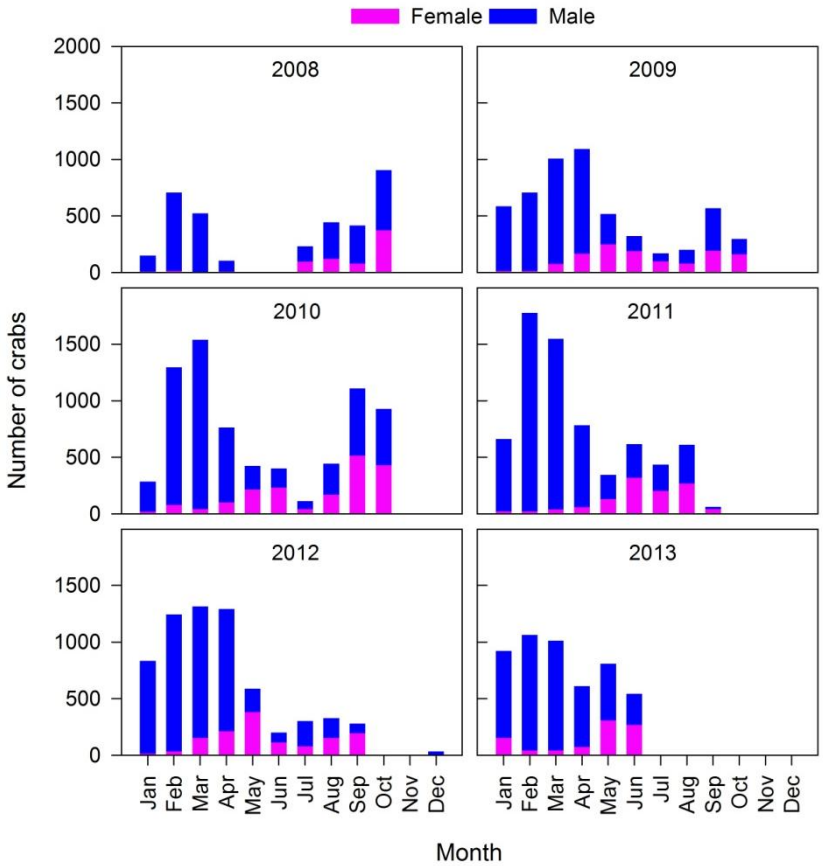

Figure 3.43. Number of female and male blue swimmer crabs caught in small-mesh pots by Gulf St Vincent pot fishing sector during pot-sampling from 2008 to June 2013.

Table 3.4. Summary of the performance of the Gulf St Vincent pot fishing sector for 2012/13 against the key biological performance indicators, including a comparison with the previous year and the stock status. 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
		Lower	Upper		
1. Fishery-independent survey	CPUE of legal-size crabs (legal-size crabs/potlift)	1.5	4	1.59	**1.45**
2. Fishery-independent survey	CPUE of pre-recruits (pre-recruits/potlift)	1.5	8.5	**0.78**	**1.23**
3. Commercial catch and effort	CPUE of legal-size crabs (kg/potlift)	2	4	3.36	2.33
Stock status: 'Transitional-recovering'					

4. DISCUSSION

4.1. Information sources used for assessment

This assessment relied on three sources of information: 1) fishery-independent survey data; 2) fishery-dependent commercial logbook data; and 3) fishery-dependent pot-sampling data.

4.1.1. Fishery-independent surveys

Fishery-independent surveys provide robust measures of relative biomass of legal-size and/or pre-recruit crabs across the extent of the fishery. These are considered the most reliable and primary source of information for assessment of the blue swimmer crab resource due to: 1) their representativeness of relative biomass and changes in biomass in each gulf; 2) the relatively consistent timing of the survey (i.e. around the period of peak recruitment, in June and July); 3) the standardised sampling design with respect to pot type, sampling method, numbers of potlifts, and site locations; and 4) their repeatability. All of these attributes of fishery-independent surveys help to overcome some of the biases and variability associated with targeted fishing of commercial operations, and hence fishery-dependent CPUE.

Two of the three key biological performance indicators are determined from surveys: 1) survey CPUE of legal-size crabs; and 2) survey CPUE of pre-recruits. The main uncertainty in the interpretation of survey CPUE of pre-recruits results from differences in the timing of surveys relative to the timing of peak recruitment to the fishery, as the year-round pot-sampling program has shown this to be variable in some years. Other uncertainties include the influence of environmental factors such as weather and water temperature on catch rates. Whilst surveys provide reliable measures of relative biomass, these measures could potentially be improved by standardisation of CPUE (see review by Maunder and Punt, 2004) to remove the influence of other factors that are not related to abundance, but may otherwise influence catch rates and their interpretation.

4.1.2. Fishery-dependent commercial logbooks

The commercial CPUE of legal-size crabs is the third key biological performance indicator, used as an index of abundance of legal-size crabs. However, the reliability of this measure is uncertain (there is a lack of correlation with survey CPUE), and considered secondary to fishery-independent surveys. The main uncertainty associated with logbook data is in regard to the interpretation of abundance from commercial CPUE data, which may be influenced or impeded by: 1) changes in fisher demographics and experience; 2) temporal and spatial shifts in catch and effort; 3) changes in potlift behavior; 4) improvements in catching efficiency

through gear modification and vessel technology; and 5) selectivity of commercial pots. The net effect of these changes is considered to be a positive bias in CPUE, although this has not yet been quantified.

4.1.3. Fishery-dependent pot-sampling program

There is currently no performance indicator for the fishery from pot-sampling. The pot-sampling program avoids some of the biases (e.g. selectivity) associated with commercial large-mesh pots and thereby provides a potentially useful fishery-dependent index of abundance of pre-recruits throughout the season. However, the current frequency of sampling (one or two potlifts per day) is considered low, especially since there are only a few operators in the fishery. Increasing the number of research pots sampled during each day's fishing could further improve the reliability and value of these data, although survey-derived relative biomass of legal-size and pre-recruit crabs should remain the key biological performance indicators for the fishery.

4.2. Determination of stock status

The national framework for stock status reporting (Flood *et al.*, 2012) has been adopted by PIRSA Fisheries and Aquaculture for determining stock status of all South Australian fisheries. Where key performance indicators are available for assessment of a fishery, limit reference points for these indicators are developed to explicitly identify the level below which the stock is classified as overfished.

The primary indicators for the BCF are relative biomass of legal-size and pre-recruit crabs derived from fishery-independent surveys. Limit and upper reference points for each of these indicators in the current Management Plan were selected to represent a range of desirable fishery performance in terms of biological and economic objectives (PIRSA, 2012) rather than for the determination of stock status. The development of reference points to link to stock status and management actions is identified as a priority in the review of the harvest strategy for the fishery (see Section 4.4).

Nevertheless, until a limit reference point is developed for the BCF that identifies the level below which the stock would be classified as overfished, the currently-used limit reference points for legal-size and pre-recruit crabs were used in this assessment to determine stock status. The limit reference points for legal-size and pre-recruit crabs (1.5 crabs/potlift) for the Gulf St Vincent fishing zone are lower than those for the Spencer Gulf fishing zone (limit reference points: 5 legal-size crabs/potlift and 2 pre-recruits/potlift), reflecting the lower productivity and biomass levels in this gulf. These limit reference points were assumed in this assessment as a proxy for determining when the stock is recruitment overfished.

4.3. Status of the Blue Crab Fishery

The assessment of the BCF for the 2012/13 fishing year provides strong evidence that the current biomass differs greatly between Spencer Gulf and Gulf St Vincent stocks. This is because whilst fishery-independent surveys indicate that the relative biomass of legal-size and pre-recruit crabs in Spencer Gulf in recent years were among the highest since surveys began in 2002, these same surveys in Gulf St Vincent show that the relative biomass of both size classes for the last two years (2012 and 2013) were at their lowest levels recorded. Based on the latest information available on the primary indicators, and using the national framework for stock status reporting (Flood *et al.*, 2012), the Spencer Gulf and Gulf St Vincent fishing zones of the BCF would be classified as 'sustainable' and 'transitional-recovering', respectively.

4.3.1. Spencer Gulf

There is limited information available to assess the Spencer Gulf fishing zone for 2012/13 because, as a result of the CPUE of pre-recruits in the 2012 survey exceeding the ten-year average, a survey was not conducted in Spencer Gulf in 2013 (see PIRSA, 2012). The next survey will be conducted in 2014. Therefore, there are no fishery-independent data to determine if relative biomass has changed between years.

In 2012/13, almost the entire Spencer Gulf component of the TACC for the BCF was caught for the ninth consecutive fishing year and mean commercial CPUE was the second highest recorded, at the upper end of the reference range. High catch rates were also recorded in most of the blocks fished throughout the gulf. However, as identified previously (Dixon *et al.*, 2012; 2013), there are a number of influencing factors that preclude commercial CPUE from being a reliable measure of relative biomass.

The previous assessment concluded that the Spencer Gulf stock was in a strong position due to multiple lines of evidence that the relative biomass of legal-size crabs and pre-recruits were among the highest recorded (Dixon *et al.*, 2013). As there are no data from 2012/13 to contradict that assessment, the Spencer Gulf fishing zone of the BCF remains 'sustainable'.

4.3.2. Gulf St Vincent

There are multiple lines of evidence that the relative biomass of blue swimmer crabs in Gulf St Vincent in 2012/13 is low. This evidence is: 1) the survey CPUE of legal-size crabs decreased slightly between 2012 and 2013 to the lowest value on record and just below the limit reference point; 2) although the pre-recruit CPUE from the 2013 survey increased from 2012, values for both years were below the limit reference point and among the lowest on

record; 3) there has been a substantial reduction in the number of blocks with medium or high average survey CPUE for both size classes; 4) only half the Gulf St Vincent component of the TACC was caught in 2012/13, which is consistent with industry advising at last year's TACC meetings (in April/May 2013) that a substantial amount of quota would deliberately be left in the water in response to the recent decline in biomass; 5) it is the fifth consecutive year (since 2007/08) that the TACC for this zone was not caught in full; 6) more blocks were fished in 2011/12 and 2012/13 than any other year (and at low catches); and 7) low catch rates were distributed throughout the gulf.

In response to the decline in biomass of pre-recruits reported in the 2011/12 fishery assessment (Dixon *et al.*, 2013), a number of initiatives have been taken to promote recovery of the stock: 1) the commercial catch in 2012/13 was substantially less (almost half) than the TACC; 2) the 2013/14 TACC was reduced by 20% (from 245.1 to 196.1 t); 3) industry voluntarily closed the gulf to commercial fishing for more than six months (1 July 2013 to 15 January 2014) to allow pre-recruits to grow into the fishery and protect spawning females during the peak spawning time; and 4) recreational bag and boat limits were halved for 2012/13. Whilst it is not yet known whether these management actions will be sufficient to arrest the decline of the biomass and promote its recovery, and any increases in abundance are unlikely to be evident prior to the assessment of the 2013/14 fishing year, the fishery-dependent pot-sampling data from January to June 2013 indicate that the abundance index of pre-recruits was higher than in previous years. This is consistent with: 1) updated pot-sampling information (to end April 2013) presented at last year's TACC meetings, which indicated an increase in juvenile abundance; and 2) advice from industry that the abundance of juveniles in research (small-mesh) pots was increasing.

The primary indicators and other supporting evidence indicate that the relative biomass in Gulf St Vincent in 2012/13 was low. However, given that a number of management measures are in place to promote stock recovery, and there is evidence that recovery may be occurring (specifically for pre-recruits), the Gulf St Vincent fishing zone of the BCF is considered to be 'transitional-recovering'.

4.4. Review of the harvest strategy

A review of the harvest strategy is scheduled to take place in 2014. This review should: 1) evaluate the reliability of each of the existing performance indicators for determining stock status; 2) develop a limit reference point 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. standardised or standardised plus new potlifts); 4) identify other potential indicators; and 5)

consider reinstating annual surveys as the primary source of information for determining stock status and an appropriate trade-off for potential increases in TACC.

Two of the three performance indicators for the fishery, CPUE of legal-size and pre-recruit crabs from fishery-independent surveys are considered to be reliable indicators of relative biomass. The third indicator is commercial CPUE. Among the several factors identified that can influence commercial catch rates that are not related to abundance, changes to gear (primarily an increase in the size of the pots) were made by some of the fleet during 2010/11. With only a small number of licence holders in each zone, changes such as these can have a substantial effect on the overall catching efficiency of the fleet. This makes it difficult to reliably interpret changes in abundance of blue swimmer crabs from commercial CPUE. Some of this uncertainty may be addressed through standardisation of commercial CPUE data or examination of catch rate trends for individual fishers. Consequently, continued use of commercial CPUE as a performance indicator for this fishery requires scrutiny.

There are several options for replacing commercial CPUE as a performance indicator. For example, the CPUE of pre-recruits from pot-sampling (from research pots by commercial fishers) has been identified as a potentially useful fishery-dependent index of abundance. However, industry members have expressed concern that the primary limitation of conducting pot-sampling is the time taken to measure the carapace widths of all crabs in a pot. Whilst size should continue to be measured, approaches that minimise any imposition on crews while improving the reliability of results obtained from the pot-sampling program should be considered. A second option would be to develop a length-structured model for these fisheries, from which model-derived performance indicators could be determined (e.g. exploitation rate).

Revision of the harvest strategy will require the development of a limit 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. This needs to be resolved because the uncertainty of identifying when a stock is recruitment overfished is a major limitation of the current harvest strategy.

The review of the harvest strategy also needs to consider reinstating annual surveys. Given the short life-history of the blue swimmer crab and the large-scale changes that can occur in a relatively short period (e.g. between years), the option of biennial surveys in the current Management Plan (when the abundance of pre-recruits is above an historic average) could make TACC decision-making difficult because there are no current data to provide information on changes in biomass. Therefore, as part of the harvest strategy review, allowing for a TACC increase (should the stock assessment warrant it) may be an appropriate trade-off for ensuring

that the primary indicators of stock status (through survey indices) are monitored on an annual basis.

4.5. Future research needs

The most important future research needs for the BCF in South Australia are: 1) to understand the drivers of biomass and inter-annual variability in biomass of blue swimmer crab in the gulfs; 2) interpretation of commercial CPUE; and 3) evaluate alternative performance indicators (e.g. abundance indices derived from pot-sampling, prawn survey and sex-specific CPUE data).

There is a need to evaluate the relative importance of geography (e.g. latitude, spatial extent and bathymetry), ecosystem changes (e.g. changes in snapper abundance; Dixon *et al.* 2013; Lloyd 2010), exploitation rate and other potential factors driving the general decline in biomass of blue swimmer crabs in Gulf St Vincent, which are in stark contrast to trends in Spencer Gulf. An FRDC project is currently underway at SARDI to investigate some of these causal relationships through development of a trophic model for Gulf St Vincent. A main objective of that project is to understand the impact of changes in the abundance of snapper on the Gulf St Vincent ecosystem, with particular emphasis on the blue crab and prawn fisheries.

Much of the uncertainty with interpretation of commercial CPUE is a result of gear modifications. It would therefore be prudent to investigate the efficacy of different pot designs that have been used in the fishery over the years with respect to catchability. At the same time, this may be a good opportunity to investigate the effect of different pot designs and soak times on in-pot mortality rates of blue swimmer crabs.

Although there is limited information available from the pot-sampling program, the CPUE of pre-recruits derived from pot-sampling follows a similar trend to CPUE of pre-recruits from surveys, both of which use small-mesh pots. This demonstrates the potential for the development of a year-round fishery-dependent measure of abundance of pre-recruits to supplement the established fishery-independent measure (surveys).

Historically, the Spencer Gulf and Gulf St Vincent prawn fisheries have conducted regular, fishery-independent trawl surveys throughout each gulf. Blue swimmer crabs are caught during these surveys as by-catch, thus presenting an opportunity to investigate the efficacy of prawn trawl surveys as a cost-effective data source for the assessment of blue swimmer crabs. Juvenile prawn surveys have also been conducted in the upper parts of each gulf using the ‘jet net’ method, which uses a small beam trawl fitted with water jets that penetrate the sand/mud substrate to suspend the juvenile prawns for collection (Roberts *et al.*, 2005). Although the

abundance of juvenile blue swimmer crabs among these samples was relatively low (SARDI unpublished data), alternative sites and sampling times could be investigated to evaluate the effectiveness of the jet net method for sampling juveniles. Anecdotal evidence suggests that high abundances of juvenile blue swimmer crabs occur periodically in the intertidal zone of each gulf. If an appropriate sampling method and design could be developed for the collection of juvenile blue swimmer crabs, it may be possible to develop another indicator of pre-recruit abundance.

Differences in proportion of females in the catch suggest that the timing of capture exerts a strong influence over the proportion of females harvested at monthly and annual scales. However, the importance of sex ratio in the catch is not well understood. The ability to easily distinguish and record the sex and berried females in commercial logbooks provides a good opportunity to investigate the potential development of an appropriate performance indicator and associated reference points that aim to ensure egg production is at acceptable levels for future stock sustainability. Historical information on sex ratio in logbooks and/or processor records should be investigated to assist this initiative.

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APPENDIX

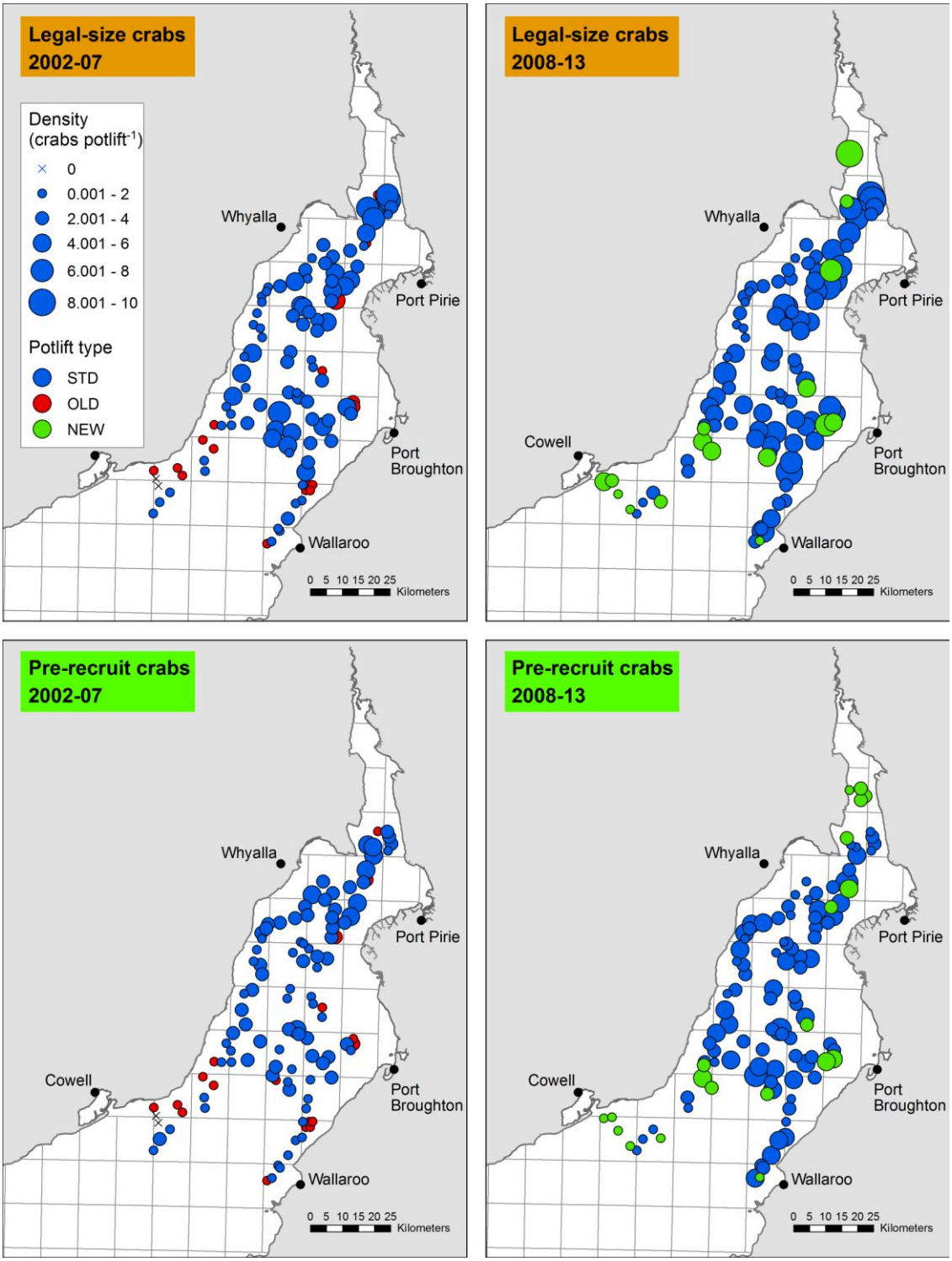

Figure A 1. Point density maps showing average distribution of legal-size and pre-recruit crabs for all potlift types (standardised, STD: 2002-current; old: 2002-2007; new: 2008-current) from surveys conducted in Spencer Gulf for 2002-2007 and 2008-2013. See 2002-2007 map of legal-size crabs for legend.

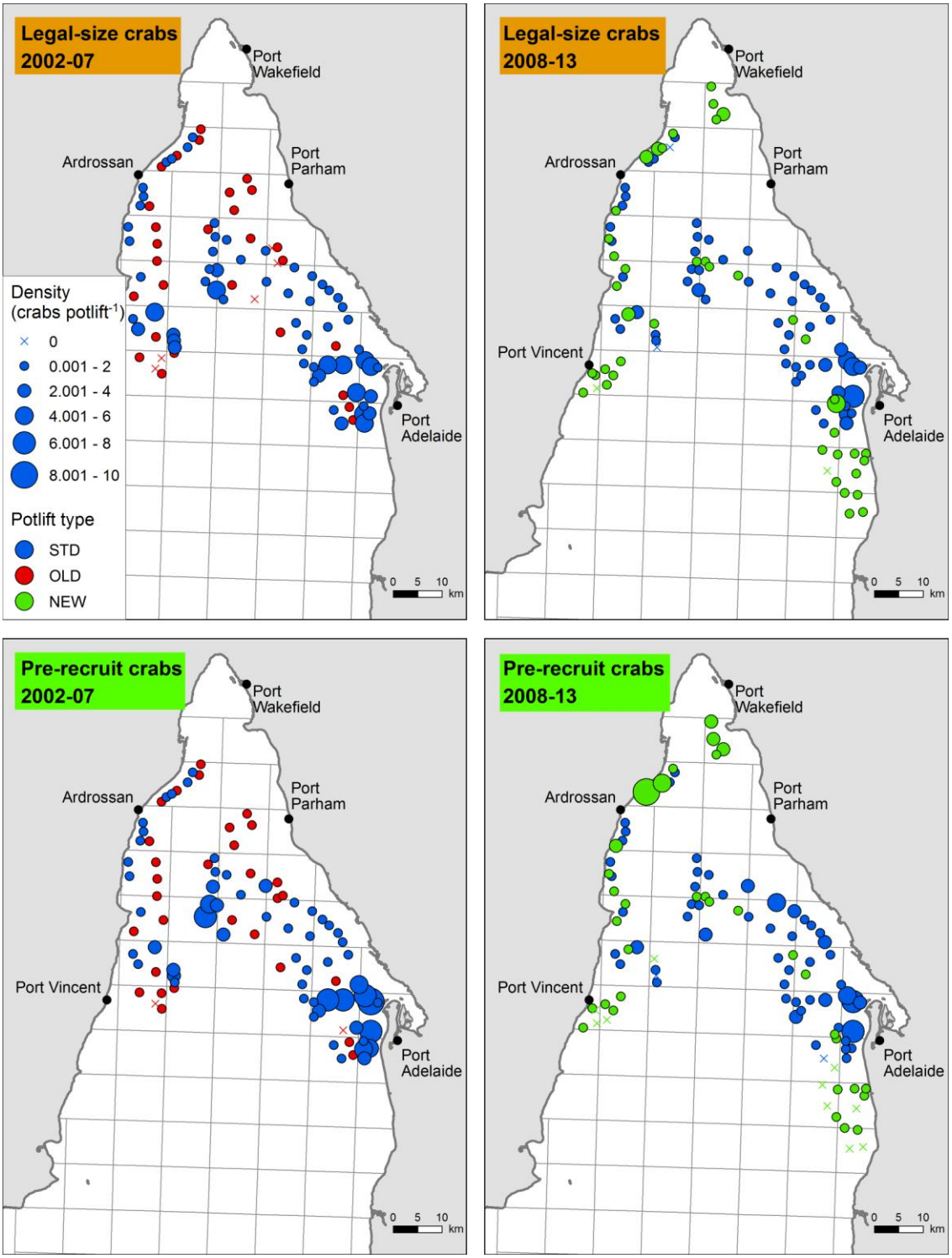

Figure A 2. Point density maps showing average distribution of legal-size and pre-recruit crabs for all potlift types (standardised, STD: 2002-current; old: 2002-2007; new: 2008-current) from surveys conducted in Spencer Gulf for 2002-2007 and 2008-2013. See 2002-2007 map of legal-size crabs for legend.