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Blue Crab (*Portunus armatus*) Fishery 2015/16

C. L. Beckmann and G. E. Hooper

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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

April 2017

Fishery Assessment Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

SOUTH AUSTRALIA

Government of South Australia
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SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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

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

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Author(s):	C. L. Beckmann and G. E. Hooper
Reviewer(s):	O. Burnell, J. Earl (SARDI) and K. Rowling (PIRSA)
Approved by:	S. Mayfield Science Leader – Fisheries
Signed:	
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EXECUTIVE SUMMARY

This stock assessment determined the current status of South Australia's Blue Swimmer Crab resource through analysis of data collected by several long-term monitoring programs. The current harvest strategy for the Blue Crab Fishery (BCF) does not define when the stock is considered 'recruitment-overfished' and performance indicators (PIs) are not explicitly linked to a definition of stock status. During 2015/16 reduced fishery-independent surveys (FIS) were undertaken in both gulfs during June/July. As a result, the PIs based on survey catch per unit effort (CPUE) could not be assessed against the existing reference points (RPs) under the current harvest strategy. A draft interim harvest strategy has been developed and PIs have been assessed against RPs based on the reduced survey design undertaken in June/July. As the Management Plan and revised harvest strategy have not yet been finalised, this assessment uses a 'weight of evidence' method to determine stock status.

In 2015/16, almost the entire Spencer Gulf (SG) component of the total allowable commercial catch (TACC) for the fishery was caught for the twelfth consecutive year. Commercial CPUE was the sixth highest recorded since 1996/97 and was between the upper and lower limit RPs specified in the Management Plan. Data from the June/July FIS indicated that legal-size CPUE was between the target and trigger RPs specified in the draft interim harvest strategy in 2016, and was above the target RP for the previous four surveys. Pre-recruit CPUE has been above the threshold RP specified in the draft interim harvest strategy in the past four surveys. On the basis of this information, the biological stock is unlikely to be recruitment overfished and the current level of fishing mortality is unlikely to cause the biological stock to become recruitment overfished. Consequently, using the national framework for stock status reporting, the SG fishing zone of the BCF is classified as **'sustainable'.**

Following improvement in the stock status of the Gulf St Vincent (GSV) zone of the BCF in 2014/15, the TACC was restored to the baseline of 245.1 t in 2015/16; all of which was harvested. In 2015/16, commercial CPUE was the second highest recorded since 1996/97 and between the upper and lower limit RPs specified in the Management Plan. CPUE of legal-size crabs during the June 2016 FIS was the highest on record and legal-size CPUE has been above the target RP specified in the draft interim harvest strategy for the past two years. Pre-recruit CPUE measured during the FIS decreased from 1.2 kg.potlift^{-1} in 2015 to 0.5 kg.potlift^{-1} in 2016 and was below the threshold level specified in the draft interim harvest strategy. Despite this, pot sampling data, collected after the 2016 survey, indicated that pre-recruit abundance was high from July to October. On the basis of this information, the biological stock is unlikely to be recruitment overfished and the current level of fishing mortality is unlikely to cause the biological stock to become recruitment overfished. Consequently, using

the national framework for stock status reporting, the GSV fishing zone of the BCF is classified as **'sustainable'.**

There were insufficient data to confidently classify stock status for the West Coast (WC) zone; consequently, using the national framework for stock status reporting, this zone of the BCF is classified as **'undefined'.**

Table 1. Key Blue Crab Fishery (BCF) statistics for the 2015/16 season.

Statistic	Spencer Gulf	Gulf St Vincent	West Coast
TACC	382 t	245 t	NA
Catch	381 t (99.8%)	245 t (100%)	31 t
Effort	779 boat days	568 boat days	497 boat days
PF CPUE	3.5 ± 0.1 kg.potlift^{-1} (511 kg.boat day^{-1})	3.5 ± 0.1 kg.potlift^{-1} (432 kg.boat day^{-1})	62 kg.boat day^{-1}
Legal-size FIS CPUE	2.1 ± 0.1 kg.potlift^{-1} (8.0 ± 0.3 legal-size.potlift^{-1})	2.9 ± 0.1 kg.potlift^{-1} (10.5 ± 0.5 legal-size.potlift^{-1})	NA
Pre-recruit FIS CPUE	1.9 ± 0.1 kg.potlift^{-1} (13.1 ± 0.6 pre-recruits.potlift^{-1})	0.5 ± 0.0 kg.potlift^{-1} (2.7 ± 0.2 pre-recruits.potlift^{-1})	NA
Status	Sustainable	Sustainable	Undefined

Abbreviations- total allowable commercial catch (TACC), catch per unit effort (CPUE), Fishery-independent survey (FIS), Pot fishery (PF).

1. INTRODUCTION

1.1. Overview

Stock assessments for the South Australian Blue Swimmer Crab *Portunus armatus,* (previously *P. pelagicus*, Lai *et al.* 2010, hereafter referred to as 'Blue Crab') fishery have been produced annually since 2004 (Svane and Hooper 2004) as part of the South Australian Research and Development Institute (SARDI) Aquatic Sciences' ongoing assessment program. This report has four aims: 1) to present information from the fishery and biology of the species; 2) to assesses the current status of the Blue Crab resource in Spencer Gulf (SG), Gulf St. Vincent (GSV) and the West Coast (WC), and consider the uncertainty associated with each assessment; 3) to comment on the current biological performance indicators (PIs) and reference points (RPs) for the fishery; and 4) to identify future directions for the research program.

1.2. Description of the fishery

1.2.1. Access

Blue Crabs support an important inshore fishery in South Australia, with 656 t harvested in 2015/16 at an approximate value of $5.3M (SARDI unpublished data). This harvested value includes small commercial quantities of Blue Crabs taken from the WC, which is not part of the total allowable commercial catch (TACC) for the Blue Crab Fishery (BCF).

There are three major stakeholders: the commercial pot fishery (Figure 1.1), the commercial Marine Scalefish Fishery (MSF; Figure 1.2) and the recreational fishery. Access to take Blue Crabs is provided via a BCF or a MSF licence endorsed with quota entitlements. MSF licences are also permitted to take Blue Crabs on the WC of South Australia (west of longitude 135°E) outside of the quota management system. BCF licence holders (pot fishers) generally fish in waters deeper than those fished by MSF and recreational fishers. The ability to access deeper water provides for an extended season as fishers can access Blue Crabs in waters where they continue to be caught during the cooler months.

Commercial pot fishers generally haul their gear once or twice every 24 hours using specifically designed crab pots covered with mesh. MSF licence holders use hoop/drop nets and on the WC they may also use crab pots, rakes or dab nets. Recreational fishers mostly use crab nets (hoop or drop nets) or hand held rakes. Current output controls for Blue Crabs caught in South Australia include restrictions on the total commercial catch through a quota system, spatial and temporal commercial closures, bag and boat limits for recreational fishers,

a minimum legal size limit (MLS: 110 mm carapace width measured from the anterior base of the first spine) and restrictions on taking berried females.

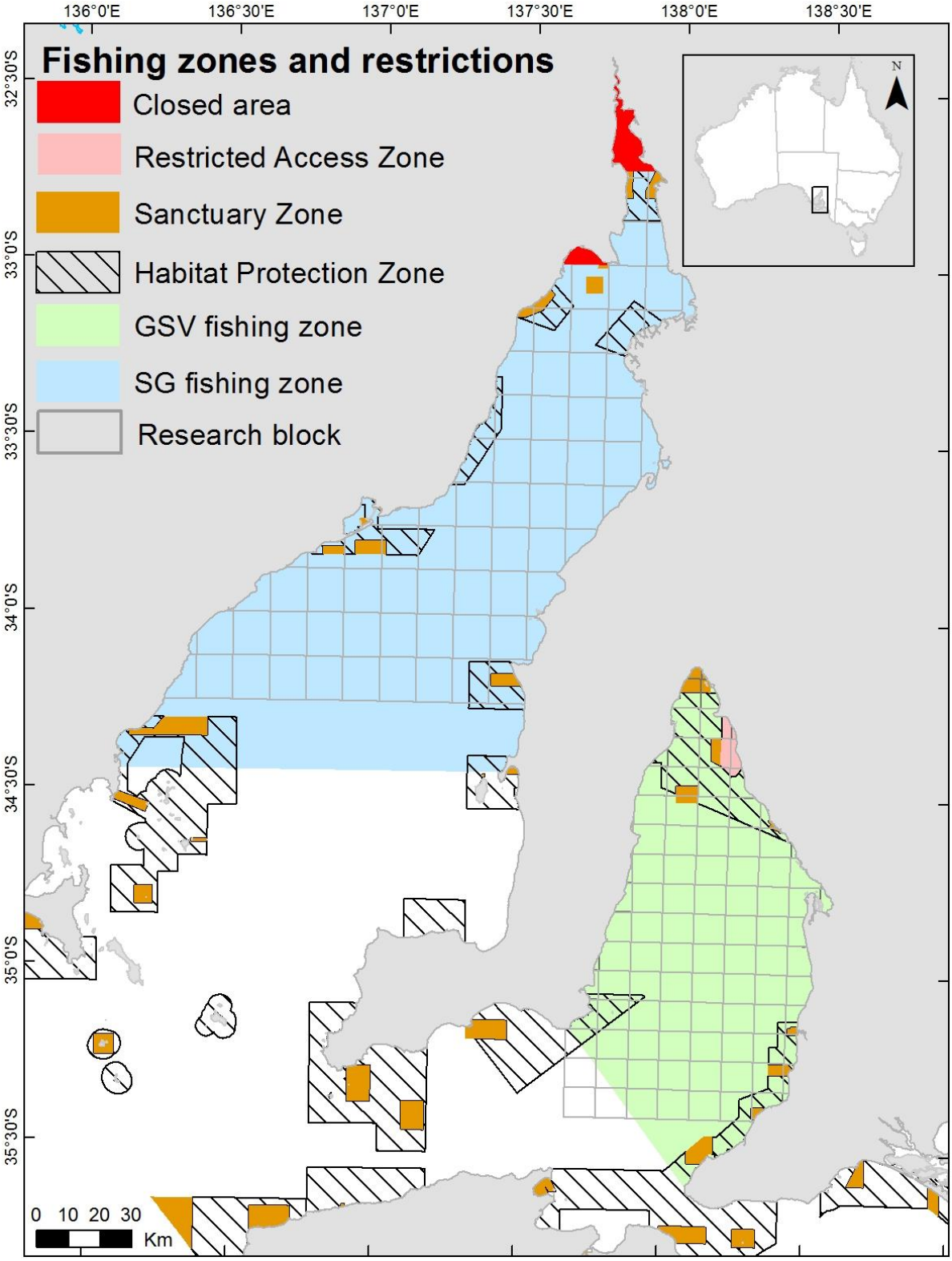

Figure 1.1 The South Australian Blue Crab Fishery (BCF) with Spencer Gulf (SG) and Gulf St Vincent (GSV) fishing zones, research blocks, closures and Marine Parks.

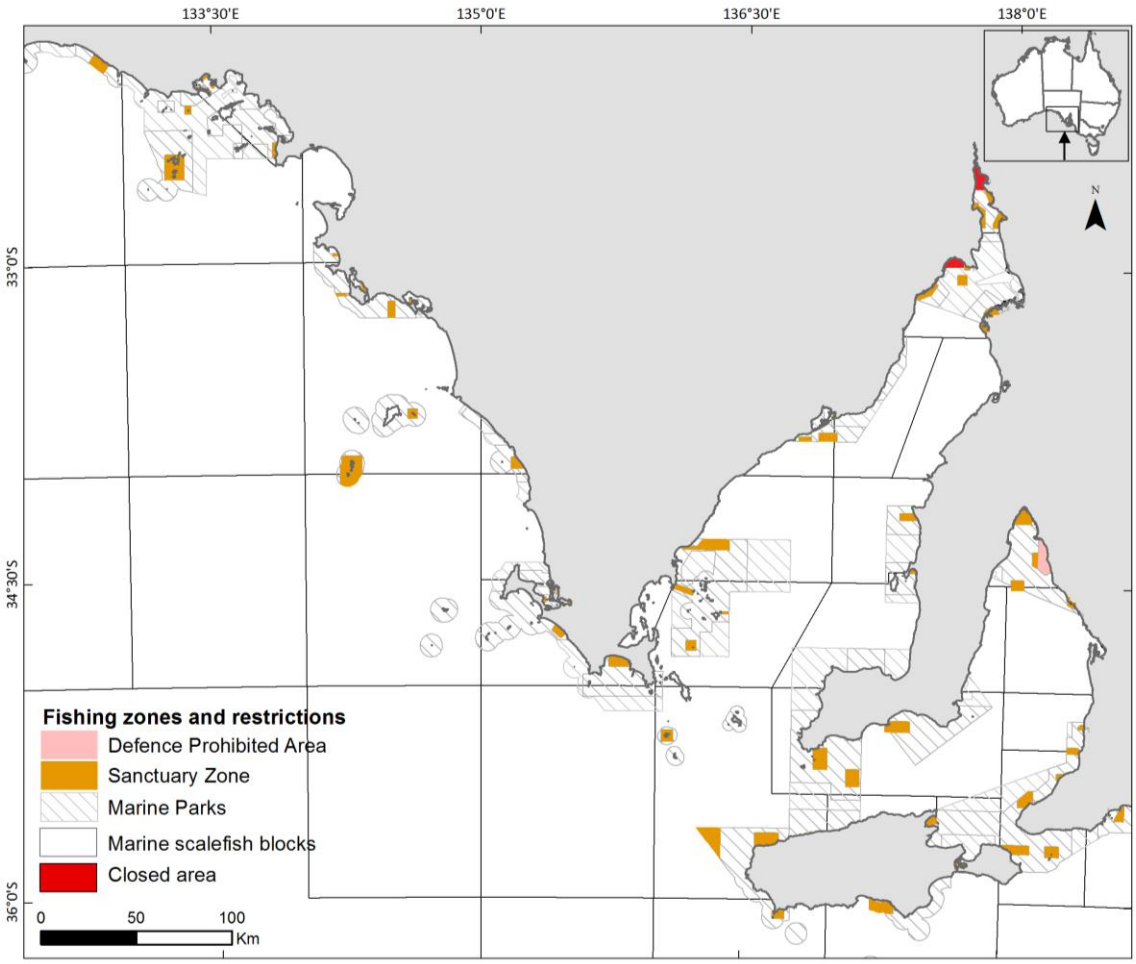

Figure 1.2 South Australian Marine Scalefish Fishery (MSF) research blocks. The West Coast (WC) zone (not subject to quota) operates in all waters west of longitude 135° East.

1.2.2. Management arrangements

As with all of South Australia's fisheries and aquatic resources, the *Fisheries Management Act 2007* ('the Act') provides the statutory framework for management of the South Australian Blue Crab resource. The schemes of management for the fishery are prescribed in the *Fisheries Management (Blue Crab Fishery) Regulations 2013* and the *Fisheries Management (Marine Scale Fisheries) Regulations 2006*, while general regulations pertaining to commercial and recreational take of Blue Crabs from State waters are described in the *Fisheries Management (General) Regulations 2007*.

The BCF was established in 1996, with formalised management arrangements that included pot restrictions, formation of two fishing zones in SG and GSV 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. Since the introduction of quota in the BCF, there has been a transfer of fishing effort from the MSF to the pot fishing

sector, with the number of MSF licences holding Blue Crab quota steadily decreasing from 29 in 1996 to 3 licence holders in 2014.

The State-wide TACC for the BCF was initially set by Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture at 520 t for the 1996/97 fishing season (325 t in SG and 194 t GSV). Over the next four quota years the TACC gradually increased to 627 t in 2000/01, where it remained until 2012/13. In 2013/14 and 2014/15, the TACC for the GSV zone was reduced by 20% from 245 t to 196 t, which resulted in a reduction of the fishery-wide baseline quota to 578 t (SG: 382 t; GSV: 196 t). A voluntary commercial closure in GSV was also implemented from 1 July 2013 to 15 January 2014. In 2015/16, the TACC for the GSV zone was increased to the baseline of 245 t, resulting in an overall TACC of 627 t.

Temporary spatial commercial closures have been in place in recent years in GSV to allow greater recreational access to Blue Crabs during the peak recreational period (i.e. December, January and Easter). The commercial closures operate between St Kilda Beach to the northern Outer Harbor breakwater; and the southern Outer Harbor breakwater to Marino Rocks. The temporary commercial fishery closure also applies to a 2 nm area adjacent to the Ardrossan, Black Point, Port Vincent, and Stansbury boat ramps.

The BCF fishing zones are also subject to annual temporal closures, when the abundance of spawning females is highest. The closure in SG was modified from 2004/05 to take advantage of higher market prices in the lead up to Christmas and extends from 21 December to 19 February. The GSV zone is closed between 1 November and 15 January. The GSV closure was modified from 2014/15 to allow a temporary fishing trial during the closure period. The conditions of this trial were: 1) all commercial pot fishery licence holders were given access excluding weekends and public holidays; 2) the existing spatial closure arrangements for the commercial sector in the metropolitan area and outer harbour were maintained; 3) no commercial fishing was permitted in all inshore waters from St Kilda to Stansbury, from the high water mark, out to 2 nm; 4) no more than 10% of a licence holders annual quota could be taken during this period; 5) collection and reporting using the current research framework for the fishery was continued, with additional finer scale spatial information including latitude and longitude of catch and effort information incorporated into the data collection; and 6) additional economic information on the value of catch was compiled and reported on by the South Australian Blue Crab Pot Fishers Association SABCPFA at the end of the trial to enable assessment of the economic benefits.

From December 2016, recreational fishers are restricted to a bag limit of 20 crabs (Blue Crabs and/or Sand Crabs combined) per person per day and a boat limit of 60 crabs per day (where 3 or more people are on board).

1.3. Biology of the Blue Crab

1.3.1. Distribution

Blue Crabs are distributed within near-shore, marine embayments and estuarine systems in Australia and New Caledonia (Lai *et al*. 2010). In the relatively cool, temperate waters of South Australia, rates of growth and reproduction increase in response to rising water temperatures during the warmer months of the year, and reduce during the colder winter months.

Blue 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 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 Crabs into shallow inshore waters during the warmer months of September to April, and out to deeper offshore waters during the cooler months of May to August (Smith 1982).

1.3.2. Reproductive biology

Early understanding of the biology of Blue Crabs in South Australia was based on a research program which commenced in 1977 (Smith 1982). This work was updated in the late 1990s with an extensive study that sampled fishery catches throughout GSV and SG (Kumar *et al.* 2000; 2003; Xiao and Kumar 2004).

Male and female Blue Crabs generally reach sexual maturity at carapace widths of similar sizes between 70 and 90 mm (Smith 1982). 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 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) found that the fecundity of female Blue Crabs was size-dependent, increasing up to a carapace width of 134 mm and decreasing thereafter, with females producing between 650,000 and 1,760,000 eggs per spawning. From 105 mm to 125 mm, fecundity was shown to increase by 83.9%, indicating that a single large female can produce as many eggs as two small females (Kumar *et al.* 2003).

In South Australia, late stages of ovarian development were observed in Blue Crabs during late October to November in conjunction with rising seawater temperatures (Kumar *et al.*

2000). 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 Crab. Egg extrusion is independent of the timing of copulation.

1.3.3. Early life history

A plankton-sampling program for Blue Crabs was conducted in GSV in 1994/95 (Bryars and Havenhand 2004). Larvae are hatched mainly offshore during November to March and wind (strength and direction) and temperature influence the dispersal of larvae. Laboratory experiments suggest that the effects of constant and varying temperatures have marked effects on larval development (Bryars and Havenhand 2006). In years of average seasonal temperature changes, the larval developmental period was predicted to range from 26 to 45 days depending on the date of hatching with peak post-larval settlement occurring between mid-January and mid-March.

1.3.4. Stock structure

Using allozyme markers, Bryars and Adams (1999) determined that the populations of *P. armatus* within SG, GSV and WC 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 limited and likely to be determined by local factors.

1.4. Research program

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 (FIS) data, and provided assessment against the PIs of the Management Plan for the fishery (PIRSA 2012). Since 2008, the report has presented information and conclusions for each fishing zone separately and included information gathered from the fishery-dependent pot-sampling program.

The current research program for the BCF conducted by SARDI Aquatic Sciences comprises four components: 1) a FIS during winter to inform fishing strategy decisions and assess the fishery against the PIs defined in the Management Plan; 2) management of fishery-dependent

commercial logbook data; 3) collation and analyses of fishery-dependent pot-sampling data; and 4) production of an annual stock assessment report for the fishery.

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

1.5. Information sources used for assessment

1.5.1. Commercial catch and effort statistics

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

In addition to the two PIs from the stock assessment FIS, the only other indicator for the fishery, commercial catch per unit effort (CPUE), is derived from data reported in catch and effort logbooks for each fishing day, which is submitted at the end of each month.

1.5.2. Recreational catch and effort statistics

Quantifying the recreational sector's contribution to the State's total catch is important in determining the overall status of fish stocks and resolving resource allocation issues. There have been four extensive recreational fishing surveys carried out in South Australia over the past 20 years. The first was a creel survey that was undertaken throughout 1994 to 1996 (McGlennon and Kinloch 1997). State-wide telephone/diary surveys were undertaken in 2000/01 (Henry and Lyle 2003), 2007/08 (Jones 2009) and 2013/14 (Giri and Hall 2015). Of these four surveys, only the results from the three most recent can be reliably compared as their data were collected using similar methods.

1.5.3. Fishery-independent survey

Fishery-independent surveys (FIS') have been conducted for the BCF during June or July on an annual or biennial basis since 2002. The primary aim of the FIS is to determine the relative abundance and size composition of Blue Crabs in SG and GSV during winter (June/July), when juveniles generally recruit to the fishery. This also coincides with the end/beginning of the quota season.

Since 2015 in GSV and 2016 in SG, a program has been in place to transition from June/July surveys to March/April surveys, thereby reducing the time lag between surveys and annual quota setting. As a result of this process, the number of sites sampled during the FIS has been reduced to allow three paired surveys (June/July and March/April) to be undertaken and for PIs and associated RPs to be developed based on the March/April time series. The PIs under the draft interim harvest strategy are therefore based on a reduced suite of sites sampled in June/July in both gulfs since 2008. Data from 2002–2007 are not considered as new sampling locations were added from 2008.

1.5.4. Fishery-dependent pot-sampling

The pot-sampling program sampled small-mesh pots used in the fishery to estimate CPUE of pre-recruits (pre-recruits.potlift^{-1}) and quantify the size composition of Blue Crabs throughout the fishing season to provide information on recruitment strength and sex ratio. Pot-sampling data have been voluntarily collected by fishers since May 2006 in SG and July 2006 in GSV.

1.6. Harvest strategy

1.6.1. Management Plan

The Management Plan for the BCF (PIRSA, 2012) is in place as required under the *Fisheries Management Act* 2007.

The key objectives of the Management Plan are: (1) ensure the Blue Crab resource is harvested within ecologically sustainable limits; (2) allocate access to the Blue Crab resource to achieve optimum utilisation and equitable distribution to the benefit of the community; (3) minimise impacts on the ecosystem; and (4) deliver cost-effective and participative management of the fishery.

The Management Plan provides a strategic direction for management of the fishery. In addition to providing details of the current harvest strategy, it emphasises the need to improve the quality of both fishery-dependent and fishery-independent information collected for assessments of stock status, thereby building scientific knowledge and developing a future harvest strategy that comprises more robust fishery PIs and RPs that are explicitly linked to TACC decisions.

The Management Plan is currently undergoing review and a draft interim harvest strategy has been recommended by the Blue Crab Fishery Harvest Strategy Review Committee. This harvest strategy contains explicit TACC decision rules and should provide greater certainty on how the fishery will be sustainably managed under the quota management system. The draft interim harvest strategy includes arrangements to transition from June/July surveys to March/April surveys thereby reducing the time lag between surveys and annual quota setting.

1.6.2. Performance indicators

Under the Management Plan for the BCF (PIRSA 2012), key biological PIs and RPs are used to guide the annual TACC decision-making process. The Management Plan includes harvest decision rules that stipulate if the limit RP for any PI is not achieved, PIRSA Fisheries and Aquaculture and SABCPFA will review the TACC and consider the possibility of a decrease from the baseline TACC.

Table 1.1 Key biological performance indicators and reference points for the Blue Crab Fishery (BCF).

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

Abbreviation: Fishery-independent survey (FIS); catch per unit effort (CPUE); Spencer Gulf (SG); Gulf St Vincent (GSV).

As the full suite of standardised sampling locations was not sampled during 2016, new RPs were required to be developed under the draft interim harvest strategy (Table 1.2). The proposed primary indicator is legal-size CPUE (kg.potlift^{-1}) and the proposed secondary indicator is pre-recruit survey CPUE (kg.potlift^{-1}). Where legal-size CPUE is above the trigger RP, the relative biomass of legal-sized Blue Crabs is considered to be sustainable. Where the legal-size CPUE is below the trigger RP, the relative biomass of Blue Crabs is considered to be transitional, and significant TACC reductions are required to recover stocks from a recruitment overfished status (transitional-recovering) or to prevent a stock from moving into a recruitment overfished state (transitional-depleting). When legal-size CPUE is below the limit RP, the fishery is considered recruitment overfished.

Table 1.2 Key biological performance indicators and reference points for the Blue Crab Fishery (BCF) under the draft interim harvest strategy.

Gulf	Data source	Performance indicator	Reference Point			
			Limit	Trigger	Target	Threshold
SG	1. FIS	CPUE of legal-size crabs (kg.potlift^{-1})	0.7	1.7	2.7	-
	2. FIS	CPUE of pre-recruits (kg.potlift^{-1})	-	-	-	1
GSV	1. FIS	CPUE of legal-size crabs (kg.potlift^{-1})	0.4	0.8	1.2	-
	2. FIS	CPUE of pre-recruits (kg.potlift^{-1})	-	-	-	0.6

Abbreviation: Fishery-independent survey (FIS); catch per unit effort (CPUE); Spencer Gulf (SG); Gulf St Vincent (GSV).

1.7. Stock status classification

A national stock status classification system was recently developed for the consistent stock determination of key Australian fish stocks (Flood *et al.* 2014). It considers whether the current level of fishing pressure is adequately controlled to ensure that stock abundance is not reduced to a point where the production of juveniles is significantly compromised. The system combines information on both the current stock size and level of catch into a single

classification for each stock against defined biological RPs. Each stock is then classified as either: 'sustainable', 'transitional-recovering', 'transitional-depleting', 'overfished', 'environmentally limited', or 'undefined' (Table 1.3). PIRSA has adopted this classification system to determine the status of all South Australian fish stocks (PIRSA 2015). This assessment was undertaken at the management unit level for SG, GSV and WC, as each of these management units represent separate biological stocks

Table 1.3 Stock status terminology (Flood *et al.* 2014).

	Stock status	Description	Potential implications for management of the stock
	Sustainable	Stock for which biomass (or biomass proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (i.e. not recruitment overfished) and for which fishing pressure is adequately controlled to avoid the stock becoming recruitment overfished	Appropriate management is in place
↑	Transitional–recovering	Recovering stock—biomass is recruitment overfished, but management measures are in place to promote stock recovery, and recovery is occurring	Appropriate management is in place, and the stock biomass is recovering
↓	Transitional–depleting	Deteriorating stock—biomass is not yet recruitment overfished, but fishing pressure is too high and moving the stock in the direction of becoming recruitment overfished	Management is needed to reduce fishing pressure and ensure that the biomass does not deplete to an overfished state
	Overfished	Spawning stock biomass has been reduced through catch, so that average recruitment levels are significantly reduced (i.e. recruitment overfished). Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvements	Management is needed to recover this stock; if adequate management measures are already in place, more time may be required for them to take effect
	Environmentally limited	Spawning stock biomass has been reduced to the point where average recruitment levels are significantly reduced, primarily as a result of substantial environmental changes/impacts, or disease outbreaks (i.e. the stock is not recruitment overfished). Fisheries management has responded appropriately to the environmental change in productivity	Appropriate management is in place
	Undefined	Not enough information exists to determine stock status	Data required to assess stock status are needed

2. METHODS

2.1. Commercial catch and effort statistics

Commercial logbook catch and effort data are compulsorily recorded by licensed fishers in the SG and GSV pot fishing zones and the MSF. Detailed analyses of these data reported since the introduction of quota (1996/97) are provided in the results. Confidentiality agreements preclude the presentation of catch and effort data from a small number of MSF participants (<5 fishers) since 2007/08 in GSV, 2014/15 in SG and 1988/89–1989/90 in WC.

In addition to catch and effort data, daily records of fishing block, depth, and the number and sex of Blue Crabs caught are recorded by the pot fishing sector. With respect to catch and effort, additional information is recorded on second potlifts, when pot fishers have lifted and reset their gear on the same day. Under these circumstances, soak time is generally 18 to 20 hours for the first potlift, and 4 to 6 hours for the second potlift. Logbooks also provide for recording the numbers of undersized Blue Crabs (pre-recruits) and berried females before being returned to the water.

For analyses and presentation of commercial logbook data throughout this report, effort data are expressed in boat days (days fished per licence). Annual estimates of nominal commercial CPUE are expressed as the catch per boat day (kg.boat day^{-1}) since 1983/84 and the average of daily catch divided by the daily number of potlifts (kg.potlift^{-1}) since 1997/98.

2.2. Fishery-dependent pot-sampling program

The pot-sampling program collects fishery-dependent catch and effort data from small-mesh pots. The size and sex composition of Blue Crabs throughout the fishing season is recorded to provide supplementary information on recruitment strength. These data have been collected since May 2006 in SG and July 2006 in GSV (a summary of these data are presented in Appendix A).

Initially, sampling was voluntarily undertaken from one small-mesh pot and one commercial pot from each licence on each fishing day. The focus of the sampling program shifted towards the CPUE of pre-recruits, so data were collected exclusively from one small-mesh pot only from May 2008 to July 2010, and from up to two small-mesh pots from July 2010 onwards. Data collected from participating licensed fishers include date, licence number, fishing block, GPS coordinates of pot locations, depth, water temperature, and the sex and size of individual crabs. Nominal pot sampling CPUE is expressed as the annual and monthly mean number of pre-recruits per potlift.

2.3. Recreational catch and effort statistics

The specific details of the methods used in the three recreational surveys considered in this chapter can be found in their respective reports (2000/01: Henry and Lyle 2003; 2007/08: Jones 2009; 2013/14: Giri and Hall 2015).

2.4. Fishery-independent survey

Fishery-independent surveys (FIS') are conducted using industry vessels, skippers and crews, with independent observers placed on each vessel to collect data on Blue Crab size and CPUE. While there has been some inter-annual variability in the timing of the FIS, they have been generally undertaken during the winter months of June and July in both gulfs, and March and April from 2015 in GSV and 2016 in SG (Figure 2.1 and 2.2). Information on the March/April 2016 surveys is presented in Appendix B.

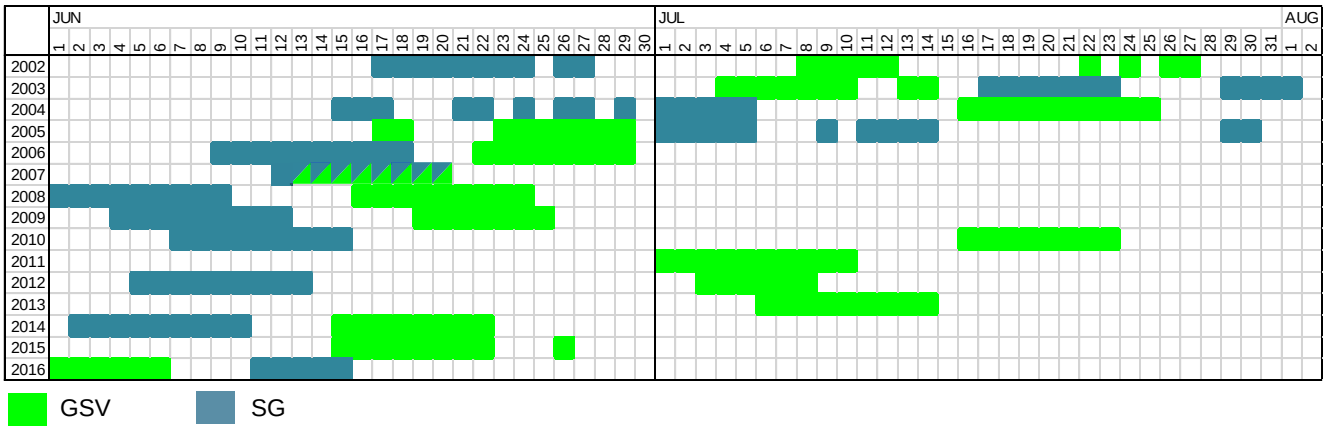

Figure 2.1 Fishery-independent survey (FIS) calendar for Spencer Gulf (SG) and Gulf St Vincent (GSV) during June and July from 2002 to 2016.

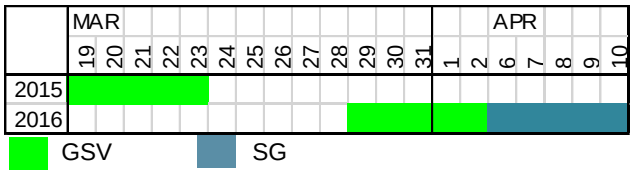

Figure 2.2 Fishery-independent survey (FIS) calendar for Spencer Gulf (SG) and Gulf St Vincent (GSV) during March and April from 2015 to 2016.

In the event that the FIS estimates CPUE of pre-recruits to be above the average for the previous 10-years in either gulf, the Management Plan provides the option for the FIS to be omitted for that gulf in the following year (PIRSA 2012). As a result of high CPUE of legal-size and pre-recruit crabs in SG determined from the 2010, 2012 and 2014 FIS, the decision was made by the SABCPFA and PIRSA Fisheries and Aquaculture to not conduct a FIS in that gulf in 2011, 2013 and 2015.

The area of the FIS encompasses waters with depths ranging from 3 to 22 m northwards of a line from Wallaroo to Cowell in SG and northwards of a line from Glenelg to Port Vincent in GSV (Figure 2.3). Sampling locations were determined based on fisher knowledge and historical catch and effort data. From these recommendations, four FIS sites were selected in each fishing block.

Fewer potlifts (approximately 22% less in SG and 41% less in GSV) were undertaken during June/July 2002 compared to subsequent surveys undertaken during 2003–2014. In June 2008, the FIS design was modified by SARDI, PIRSA Fisheries and Aquaculture and industry to provide a more representative measure of relative abundance of Blue Crab in each gulf. Changes included removing all sampling locations from some fishing blocks, adding new FIS locations to previously un-surveyed blocks, and relocating sampling locations within existing blocks.

In 2016, the survey design was rationalised by removing sites with consistently low abundances of legal-size and pre-recruit crabs and excluding some sites to minimise vessel travel time between sampling locations, thereby reducing the survey to 5 days (see Beckmann *et al.* 2016). The reduced survey was undertaken for the first time in GSV during March 2015 when 50 sites were sampled and in March 2016 an additional 10 sites were added. A similar procedure was undertaken in SG resulting in 60 sites sampled for the first time in April 2016. The reduced suite of sampling locations was sampled in both gulfs from June/July 2016. Figure 2.3 shows the ‘standard’ survey locations which have not changed since 2002 in blue, sampling locations specified under the draft interim harvest strategy (60 sites) and sampled from 2016 are denoted as circles and new sites which are included in the 60 sites but only sampled since 2008 are shown in green.

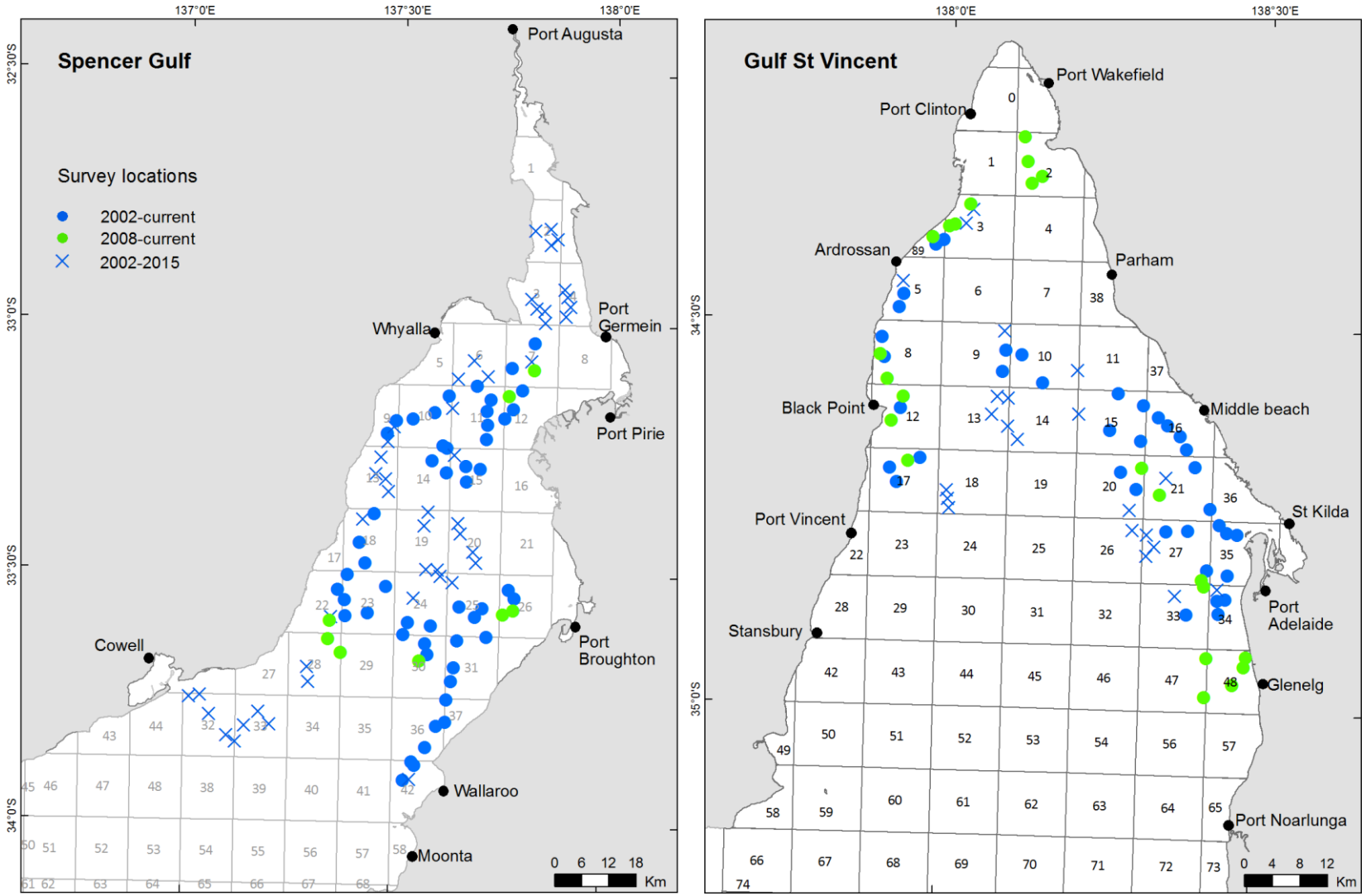

Figure 2.3 Commercial fishing blocks (grid) and fishery-independent survey (FIS) locations in the Spencer Gulf (SG) and Gulf St Vincent (GSV) zones of the Blue Crab Fishery (BCF). Circles represent the 60 sites chosen for the draft interim harvest strategy (green sampled since 2008, blue sampled since 2002), crosses represent standard sites removed from the design from 2016. Old sites sampled from 2002-08 not shown.

At each FIS location, commercial and small-mesh pots were set and hauled on a daily basis. Commercial pots have increased in size and larger mesh or escape gaps have become common since 2006/07. Most operators have also switched from single or double set pots to long lines since 2006/07 (Beckmann *et al.* 2015). Catch rates from commercial pots are presented in Appendix C. To standardise data collected in the FIS, research pots have remained unchanged with a diameter of 140 cm, a height of 50 cm, and a mesh size of 5.5 cm. At each FIS location, five sets of gear were deployed, each set comprising one commercial pot (except for GSV in July 2012 when only small mesh pots were used) 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. Since June 2014, pots in GSV have been set along a single line (long line) at each FIS location with each set of gear spaced at 76 m apart. Pots were baited with fresh Australian salmon, sardines or striped trumpeter, and hauled from dawn each day.

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

Nominal FIS CPUE is expressed as the average number of legal-size per potlift or pre-recruits per research potlift (small-mesh pots only) for each FIS and used as a measure of relative abundance. Under the draft interim harvest strategy, RPs have been expressed by weight (kg.potlift^{-1}) rather than abundance (crabs.potlift^{-1}). These conversions were performed using the length weight relationship (Figure 2.4) for each crab measured. CPUE has been presented for both gulfs utilising the standard FIS locations sampled from 2002–2015 and the reduced 60 site design as per the draft interim harvest strategy. Size frequency information is presented as the number of crabs in the specified size class per research potlift for the 60 sites sampled during the FIS from 2008–2015.

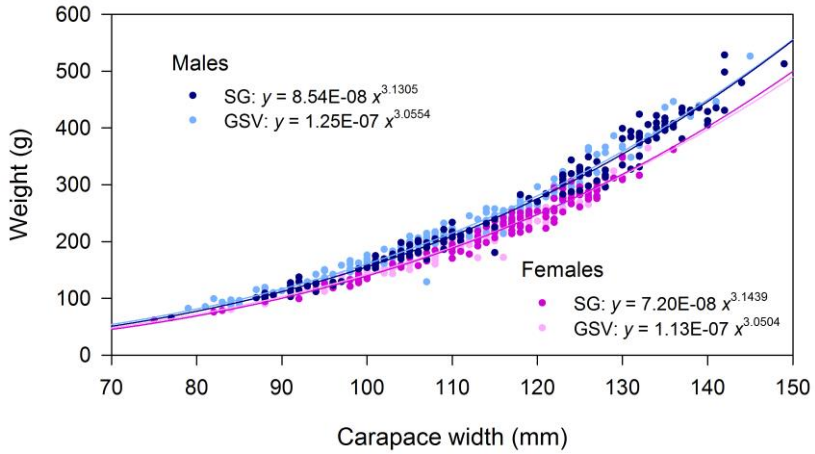

Figure 2.4 Length-weight relationships of male and female Blue Crabs from Spencer Gulf (SG) and Gulf St Vincent (GSV).

ArcGIS (ArcMap 10.1) software was used to depict the spatial patterns in crab abundance over time that were then evaluated visually. CPUE from each site was determined and the kernel density method was used to calculate the density of point features within each output raster cell (100 m * 100 m). Conceptually, a smoothly curved surface is fitted over each point, where the surface value is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the search radius. A search radius of 7,500 m was used to generate kernel density maps for both SG and GSV.

2.5. Fishery performance

Primary biological PIs are identified to provide measures of the status of the fishery in each zone and predictions about the future performance of the fishery. Analysis of these indicators is incorporated into the decision rules for the fishery, which are used to inform the annual TACC decisions for the fishery.

The limit RPs in the Management Plan are based on 108 sites sampled in June/July since 2002 in SG, 104 sites sampled since 2002 in GSV. The three key biological PIs specified in the Management Plan (PIRSA 2012) are:

1. Survey CPUE of pre-recruit crabs (crabs.potlift^{-1});
2. Survey CPUE of legal-sized crabs (crabs.potlift^{-1});
3. Commercial CPUE of legal-sized crabs (kg.potlift^{-1}).

The draft interim harvest strategy RPs are based on the 60 sites which have been sampled in June/July since 2008 in both gulfs. The two key biological PIs are:

1. Survey CPUE of legal-sized crabs (kg.potlift^{-1});
2. Survey CPUE of pre-recruit crabs (kg.potlift^{-1}).

2.6. Quality assurance of data

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

Data are extracted from the databases using established protocols. Accuracy of the data extracted is checked by comparing pivot table summaries with previous data extractions. The analyses in this report were carried out independently for multiple years at a time to confirm they were accurate compared to the results of previous reports. The results, their interpretation and conclusions provided in the report 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 at least two independent scientists at SARDI in accordance with the SARDI report review process.

3. RESULTS

3.1. State-wide

Since 1985/86, the majority of the State's Blue Crab catch has been harvested in SG and GSV. The State-wide commercial catch of Blue Crabs increased from 87 t in 1983/84 to 618 t in 1995/96 (Figure 3.1). Following the introduction of quota in the gulfs in 1996/97, State-wide catch was reduced by 29% and then catch increased until 2007/08 when the entire TACC of 627 t was caught. The total commercial catch remained below the TACC from 2008/09–2012/13, although most of the TACC was caught (>98%) in 2011/12. In 2013/14 and 2014/15, the GSV component of the TACC was reduced by 25% and nearly all (>99%) of the State-wide quota was harvested in both years. In 2015/16, the GSV compenent of the TACC was restored to 245 t, all of which was harvested by the pot fishing sector. During 2015/16 in SG, the pot fishing sector harvested 378 t and a further 2 t was harvested by the MSF sector. The combined catch from GSV and SG in 2015/16 was 626 t, which represents 100% of the TACC.

Although MSF licence holders are permitted to harvest Blue Crabs on the WC, the relative contribution of catches from that region to the harvest has been low since 1986/87 (Figure 3.1). In 2015/16, 31 t was harvested from the WC (5% of the total commercial harvest). This represents a 25% decrease from 2014/15 (41 t) and is the lowest catch since 2006/07 (21 t).

Estimates of recreational harvest have ranged from 390 t between May 2000 and April 2001 (Henry and Lyle, 2003), 283 t between November 2007 and October 2008 (Jones, 2009), and 376 t between December 2013 and November 2014 (Giri and Hall, 2015). Also, McGlennon and Kinloch (1997) estimated an annual recreational catch of 161 t, of which 116 t was taken in GSV and 45 t in SG. This estimate was derived from a 'creel survey' of recreational vessels only and does not include the recreational shore-based fishery, thus making it difficult to compare with the more comprehensive surveys of 2000/01, 2007/08 and 2013/14.

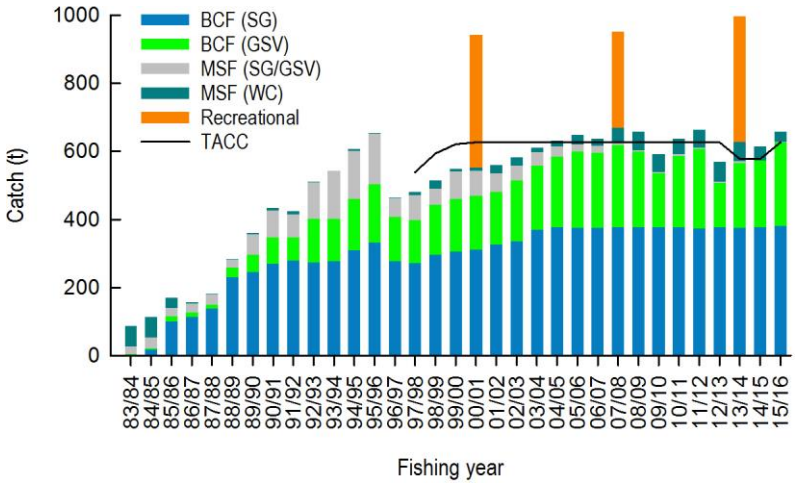

Figure 3.1 Commercial and recreational catch (t) of Blue Crabs from 1983/84 to 2015/16. Abbreviations– Blue Crab Fishery (BCF); Spencer Gulf (SG); Marine Scalefish Fishery (MSF); Gulf St Vincent (GSV); West Coast (WC); total allowable commercial catch (TACC).

3.2. Spencer Gulf

SG has been the most productive zone of the BCF since 1984/85. The highest recorded commercial catch was 382 t in 2007/08 and the lowest was 5 t in 1983/84 when the fishery began (Figure 3.2a). Following the introduction of quota, a 19% reduction in catch occurred from 367 t in 1996/97 to 297 t in 1997/98. Catch gradually increased from 1998/99, stabilised in 2003/04 with greater than 98% of the quota allocation thereafter. In 2015/16, 381 t was harvested from SG, equating to approximately 99.8% of the TACC (382 t).

Prior to the introduction of quota, there was a long-term trend of increasing fishing effort in SG, from 89 boat days in 1983/84 to 1,365 boat days in 1994/95 (Figure 3.2b). After the introduction of quota, effort declined from 1,255 boat days in 1996/97 to 663 boat days in 2010/11. Trends in effort were largely driven by the pot fishing sector which consistently contributed to more than 78% of fishing effort since 1985/86 and more than 90% of effort since 2002/03. In 2015/16, effort remained stable at 779 boat days and was below the 10-year mean (797 ± 38 days).

The number of total potlifts in SG has fluctuated through time (Figure 3.2c). Between 2002/03 and 2006/07, the number of potlifts was relatively stable with a mean of 133,057 ± 1,511 potlifts. A large reduction in effort was recorded between 2008/09 and 2011/12 with a historical low of 84,756 potlifts recorded in 2011/12. The total number of potlifts increased 24% from 84,756 potlifts in 2011/12 to 104,832 in 2015/16. Less than 18,000 second potlifts were recorded from 1997/98 to 2003/04. From 2003/04 to 2008/09, the number of second potlifts increased by 57% to 60,398 potlifts before declining in 2010/11 by 93% to 27,118 potlifts. Since 2011/12, the number of second potlifts has remained below 12,000. The proportion of total potlifts recorded as second potlifts also decreased from 41% in 2008/09 to 16% in 2015/16.

Commercial CPUE for the pot fishing sector ranged from 63 kg.boat day^{-1} in 1984/85 to 323 kg.boat day^{-1} in 1995/96 (Figure 3.2d). Following the introduction of quota in 1996/97, CPUE remained below 370 kg.boat day^{-1} until 2006/07, before peaking at 616 kg.boat day^{-1} in 2010/11. Since 2012/13, CPUE has remained below 600 kg.boat day$^{-1.}$ In 2015/16, CPUE was 511 kg.boat day^{-1} and below the 10-year mean (519 ± 24 kg.boat day^{-1}). Estimates of CPUE in the MSF sector have not exceeded 140 kg.boat day^{-1} in the history of the fishery and in 2015/16 the CPUE was 81.3 kg.boat day^{-1}. Average daily potlift CPUE ranged from 2.4 ± 0.0 kg.potlift^{-1} in 1998/99 to 4.4 ± 0.1 kg.potlift^{-1} in 2011/12 (Figure 3.2e). Since 2011/12, CPUE has remained relative stable (range: 3.5–4.0 kg.potlift^{-1}). In 2015/16, CPUE was 3.5 ± 0.1 kg.potlift^{-1}, which was 1% lower compared to 2014/15 (3.6 ± 0.1 kg.potlift^{-1}) and the lowest value since 2009/10 2.7 ± 0.0 kg.potlift^{-1}.

Annual estimates of pre-recruit CPUE from the pot-sampling program suggest that pre-recruit abundance has generally increased since 2009/10 (Figure 3.2f). CPUE of pre-recruits reached a low of 4.6 ± 0.2 pre-recruits.potlift^{-1} in 2009/10 (n=585 potlifts) before increasing to a historical high of 10.9 ± 0.4 pre-recruits.potlift^{-1} in 2013/14 (n=584 potlifts). CPUE of pre-recruits increased by 19% from 9.1 ± 0.4 pre-recruits.potlift^{-1} in 2014/15 (584 potlifts) to 10.8 ± 0.8 pre-recruits.potlift^{-1} in 2015/16 (165 potlifts).

There is some evidence of seasonal trends in CPUE of pre-recruits from the pot-sampling program, with peaks generally occurring in mid-winter and early-summer (Figure 3.3). In 2016, CPUE of pre-recruits was high in February, May and July, peaking at 17.9 ± 4.7 pre-recruits.potlift.$^{-1}$ in July (n = 15 potlifts). However, participation in the pot-sampling program for 2016 remained low with only 130 pots sampled over seven months of the year.

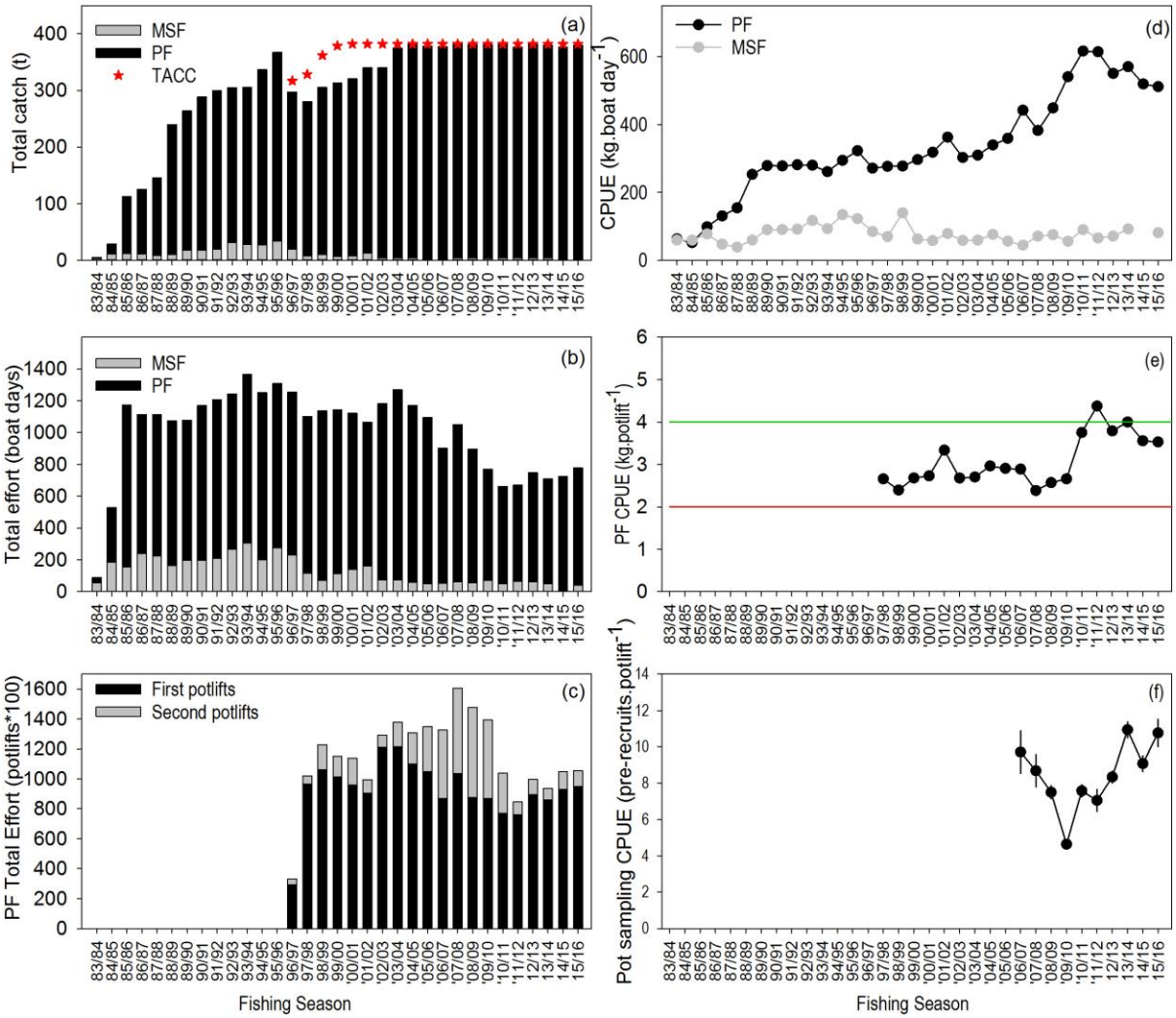

Figure 3.2 Key fishery-dependent outputs used to assess the status of the Spencer Gulf (SG) zone of the Blue Crab Fishery (BCF). (a) Trends in total catch (t) for pot fishing (PF) and Marine Scalefish Fishery (MSF) including total allowable commercial catch (TACC) limit; (b) total effort (boat days) for PF and MSF sector; (c) total effort from first and second potlifts for PF sector; (d) catch per unit effort (CPUE, kg.boat day^{-1}) for the PF and MSF sectors; (e) CPUE (kg.potlift) for the PF sector; (f) pre-recruit CPUE from the pot-sampling program (pre-recruits.potlift^{-1}). Green, and red lines represent the upper and lower limit reference points identified in Table 1.1; error bars, standard error.

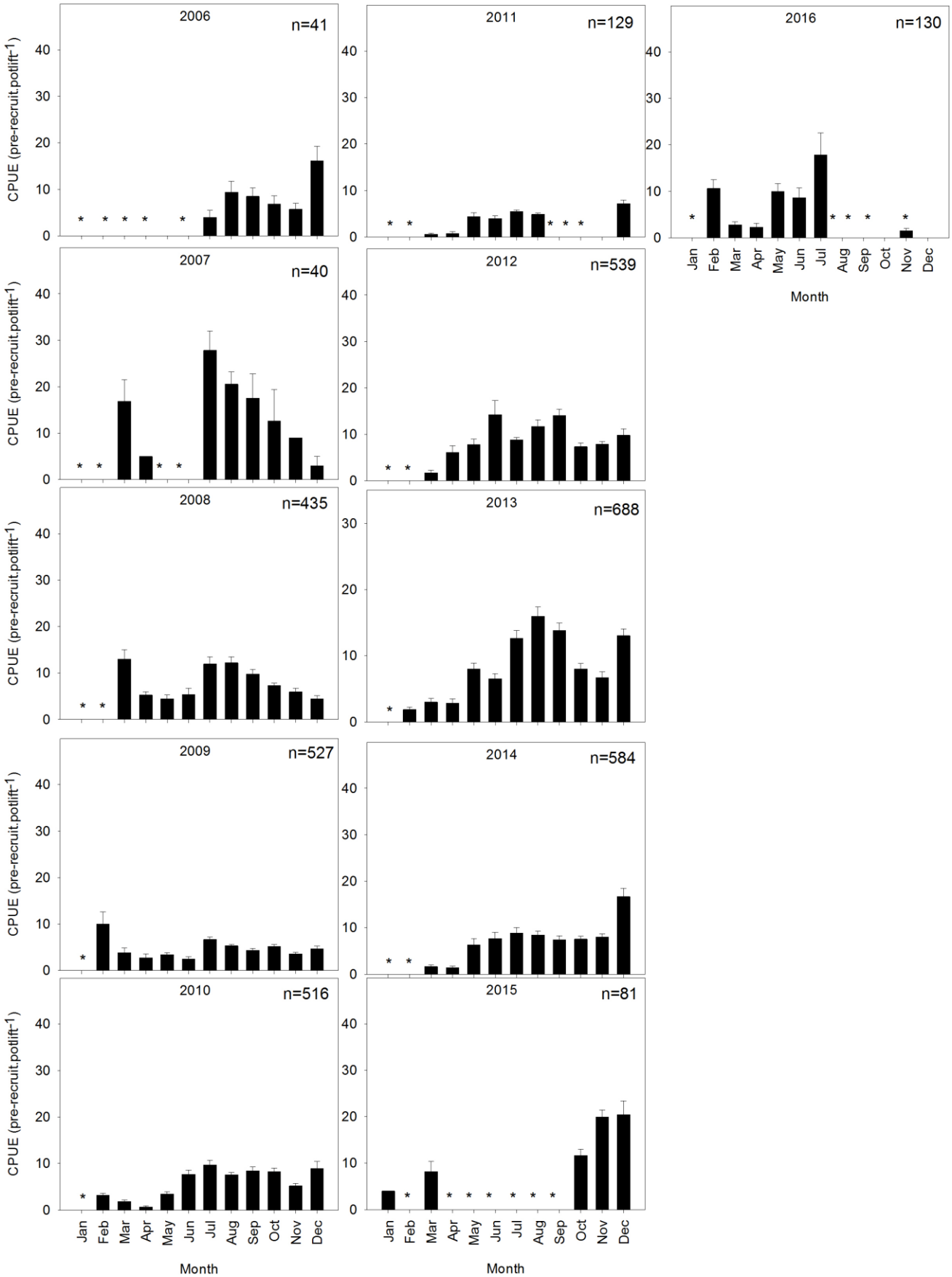

Figure 3.3 Monthly mean catch per unit effort (CPUE) of pre-recruits from pot-sampling undertaken by the Spencer Gulf (SG) pot fishing zone. Sample size (n), number of pots. Error bars, standard error. *No sampling during this month.

There has been a generally increasing trend in mean survey CPUE for legal-size crabs in SG since 2003. Mean legal-size survey CPUE measured at standard locations ranged from 5.1 ± 0.3 legal-size.potlift^{-1}in 2003 to 10.0 ± 0.3 legal-size.potlifit^{-1} in 2014 (Figure 3.4a). By weight, mean legal-size survey CPUE measured at standard locations ranged from 1.4 ± 0.1 kg.potlift^{-1} in 2003 to 2.7 ± 0.1 kg.potlift^{-1} in 2014 (Figure 3.4 b). A similar trend has been observed at standard locations and those selected under the draft interim harvest strategy and sampled since 2008. In 2016, the survey CPUE of legal-size crabs measured at the sites specified in the draft interim harvest strategy was 8.0 ± 0.3 legal-size.potlift^{-1} which was equivalent to 2.1 ± 0.1 kg.potlift^{-1}. These were the lowest values recorded under the draft interim harvest strategy sampling regime, but were above the values recorded at standard locations from 2002–2008 (range: 5.2–7.7 legal-size.potlift^{-1} and 1.4–2.3 kg.potlift^{-1}).

Pre-recruit CPUE recorded in the FIS have fluctuated since 2002. Between 2004 and 2006, pre-recruit CPUE at standard locations remained low by abundance (≤3.1 pre-recruits.potlift^{-1}, Figure 3.4c) and by weight (≤0.3 kg.potlift^{-1}, Figure 3.4d). Pre-recruit abundance experienced a three-fold increase from 3.1 ± 0.2 pre-recruits.potlift^{-1} in 2006 to 10.1 ± 0.3 pre-recruits.potlift^{-1} in 2007. When considered by weight, this was equivalent to a four-fold increase from 0.3 ± 0.0 kg.potlift^{-1} to 1.4 ± 0.0 kg.potlift^{-1} in 2007. Since 2008, pre-recruit CPUE at standard locations has followed a similar trend to locations selected under the draft interim harvest strategy. Considering the sites specified under the draft interim harvest strategy, the CPUE of pre-recruits declined from 7.6 ± 0.3 pre-recruits.potlift^{-1} in 2008 to 3.5 ± 0.2 pre-recruits.potlift^{-1}. By weight, the CPUE of pre-recruits declined from 1.2 ± 0.0 kg.potlift^{-1} in 2008 to 0.6 ± 0.0 kg.potlift^{-1} in 2009. From 2010, the CPUE of pre-recruits remained above 8.5 pre-recruits.potlift^{-1} and 1.2 kg.potlift$^{-1.}$ In 2016, pre-recruit abundance and weight peaked at 13.1 ± 0.6 pre-recruits.potlift^{-1} and 1.9 ± 0.1 kg.potlift^{-1}, respectively.

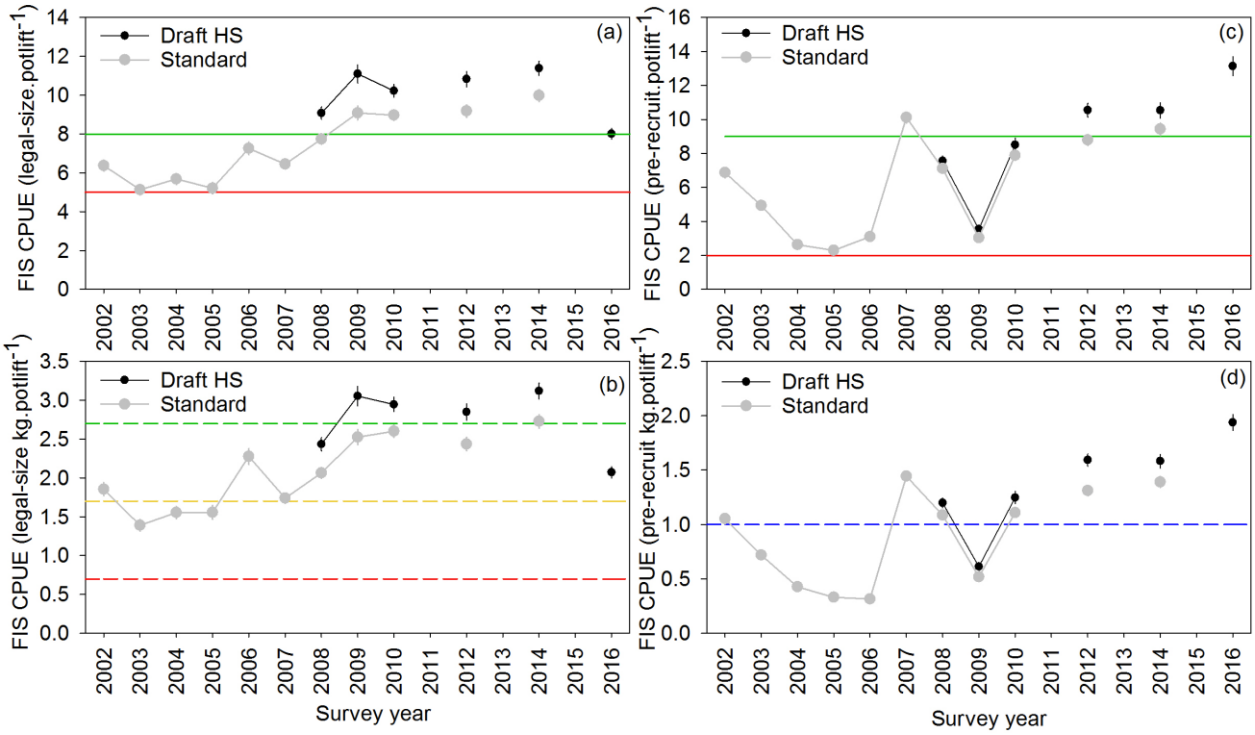

Figure 3.4 Key fishery-independent outputs used to assess the status of the Spencer Gulf (SG) zone of the Blue Crab Fishery (BCF). Fishery-independent (FIS) catch per unit effort (CPUE) by (a) abundance legal-size crabs (legal-size.potlift^{-1}), (b) weight of legal-size crabs (kg.potlift^{-1}), (c) abundance of pre-recruit crabs (pre-recruits.potlift^{-1}), and (d) weight of pre-recruit crabs (kg.potlift^{-1}). Standard sites refer to sites which have not changed since 2002 (excludes new sites) and draft HS sites refer to the subset of 60 sites sampled since 2008. Solid green, and red lines represent the upper and lower limit reference points identified in the Management Plan (PIRSA 2012), see Table 1.1. Dashed green, red and yellow lines represent the draft target, limit and trigger reference points and blue line represents the pre-recruit threshold identified in the draft interim harvest strategy, see Table 1.2. Error bars, standard error. Surveys were not conducted in 2011, 2013 or 2015.

Spatial mapping of density data obtained from the FIS indicate that the average relative densities of legal-size crabs measured in 2008–10, 2012, 2014 and 2016 were distributed widely throughout the gulf (Figure 3.5). High relative densities of legal-size crabs were concentrated in the northern gulf, near Port Pirie and Whyalla, in 2008, 2009 and 2010. In 2012, the density of legal-size crabs was high in the southern gulf while in 2014, legal-size crabs were broadly distributed with the highest densities occurring in the southern and central. In 2016, legal-size CPUE was below the 5-year average at 78% of sites sampled. Highest densities were recorded at sites in the southern and northern parts of the gulf.

Spatial mapping of density data obtained from the FIS indicate that pre-recruit crabs showed a similar distribution to legal-size crabs in most years (Figure 3.6). In 2008, the relative density of pre-recruits was concentrated in the northern gulf near Port Germein and Whyalla. Fewer pre-recruits were observed throughout the gulf in 2009, with the highest values observed in the southern gulf near Port Broughton and the northern gulf near Port Pirie. In 2010 and 2012,

pre-recruits were broadly distributed throughout the gulf. Increased pre-recruit density was observed throughout the gulf in 2014 with high densities observed south of Whyalla. In 2016, high densities of pre-recruits were again observed throughout the gulf with sites adjacent to Port Pirie, south of Whyalla and adjacent to Port Broughton recording the highest densities.

From 2008–2014, a large proportion (51–76%) of crabs sampled during the June/July FIS were legal-size (≥110 mm carapace width, CW) and in all years 63-76% of crabs were male (Figure 3.7). This was reflected in the modal size of male crabs sampled in 2008, 2012 and 2016 (110-114 mm CW), 2009 and 2014 (115–119 mm CW) and 2010 (120–124 mm CW). In 2016, only 38% of crabs sampled were of legal-size. The low proportion of legal-size crabs was driven by decreased abundance of crabs ≥120 mm CW. From 2008–2014, 18–34% of all crabs sampled were crabs ≥120 mm CW compared to only 11% in 2016. In 2016, a large proportion of female crabs were also under the legal-size limit resulting in a modal size for females of 105–109 mm CW. Similarly, the modal size of female crabs was below the legal-limit in 2008 and 2014 (105–109 mm CW) and 2010 (100-104 mm CW). The modal size of female crabs was only above the legal-size limit in 2009 and 2012 (110–114 mm CW).

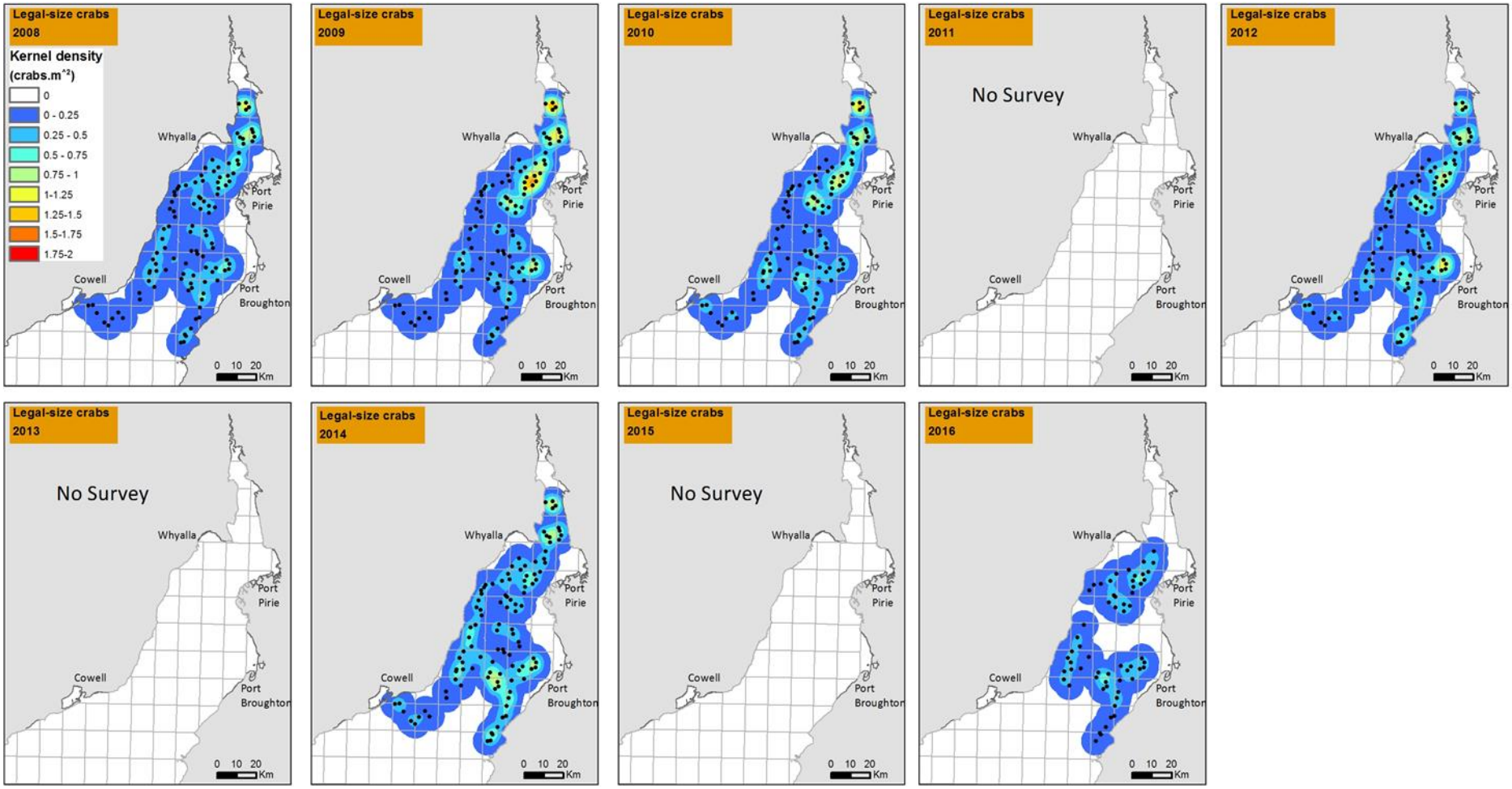

Figure 3.5 Kernel density maps showing the relative density (crabs per square metre) of legal-size crabs from June/July fishery-independent surveys (FIS) sampled at 108 locations from 2008–15 and 60 locations in 2016 in Spencer Gulf (SG). FIS were not conducted in 2011, 2013 or 2015. Sampling locations denoted by ●.

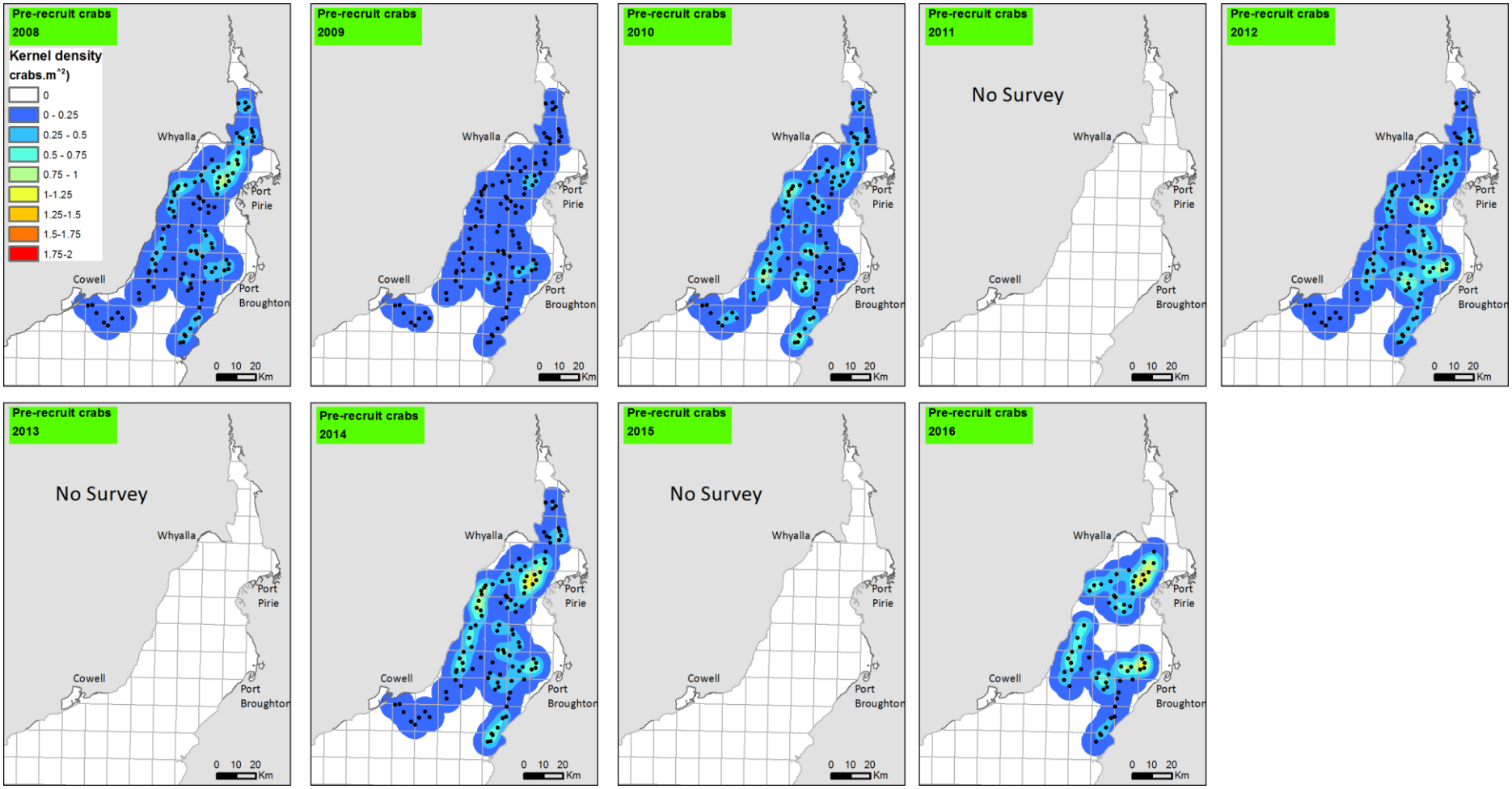

Figure 3.6 Kernel density maps showing the relative density (crabs per square metre) of pre-recruit crabs from June/July fishery-independent surveys (FIS) sampled at 108 locations from 2008–15 and 60 locations in 2016 in Spencer Gulf (SG). FIS were not conducted in 2011, 2013 or 2015. Sampling locations denoted by ●.

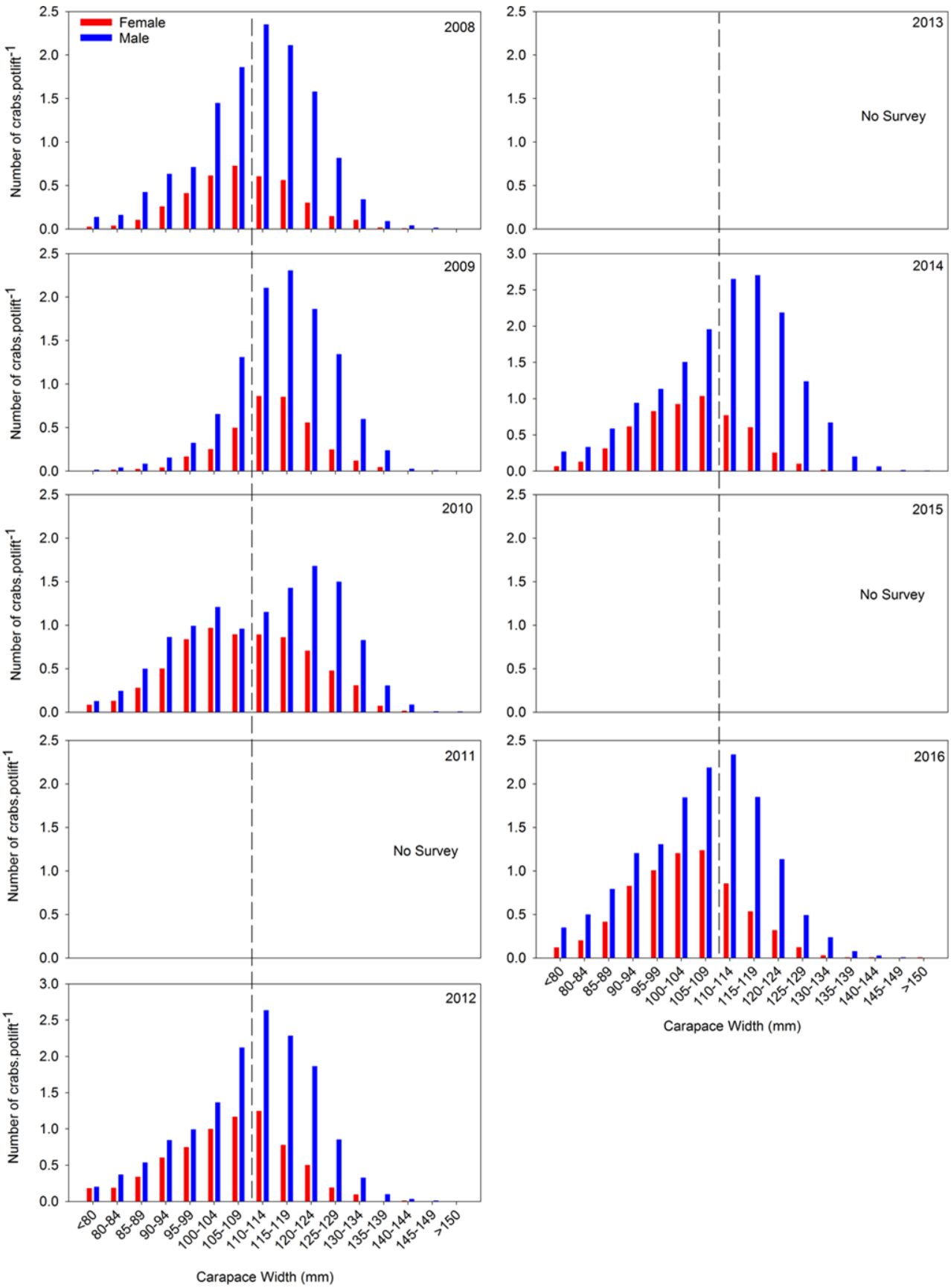

Figure 3.7 Length frequency distributions of male and female Blue Crabs from June/July fishery-independent surveys (FIS) in Spencer Gulf (SG) sampled at 60 sites selected under the draft interim harvest strategy from 2008–2016. Minimum size limit 110 mm carapace width, CW (---). FIS were not conducted in 2011, 2013 or 2015

3.3. Gulf St Vincent

In terms of catch, GSV is the second most productive zone of the BCF, producing more than 100 t of Blue Crabs per season since 1990/91. The highest recorded commercial catch was 285 t in 1995/96 and the lowest catch was 22 t in 1983/84 when the fishery began (Figure 3.8a). Following the introduction of quota in 1996/97, a 42% reduction in catch occurred from 285 t in 1996/97 to 165 t in 1997/98. Catch gradually increased from 1997/98, with 234 t harvested in 2007/08 comprising 99% of the TACC (245.1 t). Catch then fluctuated reaching a low of 129 t in 2012/13, when commercial catch was voluntarily reduced by almost 50%. The GSV component of the TACC was subsequently reduced by 20% to 196 t in 2013/14 and 2014/15. In 2014/15, the entire TACC for the GSV (196 t) was harvested for the first time. In 2015/16, the GSV component of the TACC was restored to 245 t and 100% of the TACC was harvested.

Prior to the introduction of quota there was a long-term trend of increasing fishing effort in this zone, from 441 boat days in 1983/84 to 2,111 boat days in 1995/96 (Figure 3.8b). After the introduction of quota, effort was largely transferred to the pot fishing sector resulting in a 55% decline in effort to 958 boat days in 1996/97. The MSF sector has not contributed to catch in GSV since 2008/09 and effort continued to decline reaching a minimum of 315 boat days in 2012/13. In 2015/16, pot fishing effort increased by 15% to 568 boat days compared to 492 boat days in 2014/15. This was the highest level of effort since 2007/08 (611 boat days) and was above the 10-year mean (487 ± 30 boat days).

The number of total potlifts and boat days in GSV followed similar trends from 1997/98 to 2004/05. Thereafter, the two measures of effort diverged, with the number of potlifts increasing relative to the number of boat days (Figure 3.8c). The number of total potlifts peaked at 75,508 in 2005/06 and decreased by 12% to 66,416 potlifts in 2010/11. In 2012/13, the number of total potlifts decreased a further 23% to 56,373. The total number of potlifts remained below 57,000 from 2012/13–2014/15 before increasing 17% from 56,264 potlifts in 2014/15 to 65,903 potlifts in 2015/16. The number of second potlifts has fluctuated since the introduction of quota, reaching a maximum number of potlifts (13,367 potlifts) in 2008/09. The proportion of total potlifts recorded as second potlifts was also the highest in 2008/09 (20%). A low number of second potlifts (<1,000 potlifts) were recorded in 1998/99 (432 potlifts), 2001/02 (620 potlifts) and 2013/14 (139 potlifts), while no second potlifts were recorded in 2012/13, 2014/15 and 2015/16.

Commercial CPUE for the pot fishing sector ranged from 33 kg.boat day^{-1} in 1983/84 to 323 kg.boat day^{-1} prior to the introduction of quota in 1995/96 (Figure 3.8d). From then, CPUE declined by 21% to 255 kg.boat day^{-1} in 1996/97 and remained below 300 kg.boat day^{-1} until 2003/04. CPUE gradually increased from 308 kg.boat day^{-1} in 2003/04 to 394 kg.boat day^{-1} in

2007/08. CPUE remained above 350 kg.boat day^{-1} from 2009/10–2015/16, reaching a maximum of 490 kg.boat day^{-1} in 2011/12. CPUE increased 8% from 399 kg.boat day^{-1} in 2014/15 to 432 kg.boat day^{-1} in 2015/16. This was the highest CPUE since 2013/14 and above the 10-year mean (432 ± 16 kg.boat day^{-1}). In the MSF sector, CPUE remained below 150 kg.boat day^{-1} until 2005/06 and 2006/07, when CPUE reached 269 and 216 kg.boat day^{-1}, respectively. Since 2008/09 there have been no MSF catches of Blue Crabs recorded in this region.

Following the introduction of quota in 1995/96, average potlift CPUE remained below 3.2 kg.potlift^{-1} until 2006/07 (Figure 3.8e). Since 2007/08, CPUE has remained above 3.2 kg.potlift^{-1} with the exception of 2009/10 and 2012/13 where CPUE declined to 2.6 ± 0.0 kg.potlift^{-1} and 2.3 ± 0.0 kg.potlift^{-1}, respectively. In 2013/14, CPUE was 3.9 ± 0.1 kg.potlift^{-1}, which was the highest on record. CPUE increased 6% from 3.3 ± 0.1 kg.potlift^{-1} in 2014/15 to 3.5 ± 0.1 kg.potlift^{-1} in 2015/16, which was the highest value observed since 2013/14.

Estimates of pre-recruit CPUE from the pot-sampling program indicate that levels of recruitment have fluctuated since 2006/07 (Figure 3.8f). Pre-recruit CPUE ranged from 8.3 ± 1.8 pre-recruits.potlift^{-1} in 2006/07 (n = 23 potlifts) to 3.2 ± 0.2 pre-recruits.potlift^{-1} in 2011/12 (n = 393 potlifts). Since 2012/13, pre-recruit CPUE has exceeded 5.8 pre-recruits.potlift^{-1}. In 2015/16 the CPUE of pre-recruits was 15.2 ± 0.7 pre-recruits.potlift^{-1} (n = 578 potlifts), a 56% increase compared to 2014/15 (9.7 ± 0.5 pre-recruits.potlift^{-1}, n = 539 potlifts) and the highest value on record.

Monthly estimates of the CPUE of pre-recruits were variable between years (Figure 3.9), particularly between July and October. Following several years of low recruitment values, no fishing was undertaken in the latter half of 2013. When fishing recommenced in 2014, CPUE of pre-recruits increased to a high of 17.1 ± 3.5 pre-recruits.potlift^{-1} in September (n = 47 potlifts). In 2015, the CPUE of pre-recruits peaked in August, reaching a historical high of 24.9 ± 2.3 pre-recruits.potlift^{-1} (n = 90 potlifts). In 2016, pre-recruit CPUE was lowest in May at 5.7 ± 1.5 pre-recruits.potlift^{-1} (n = 16 potlifts) and remained above 10 pre-recruits.potlift^{-1} from June–December, peaking at 19.1 ± 2.3 pre-recruits.potlift^{-1} in November (n = 21 potlifts).

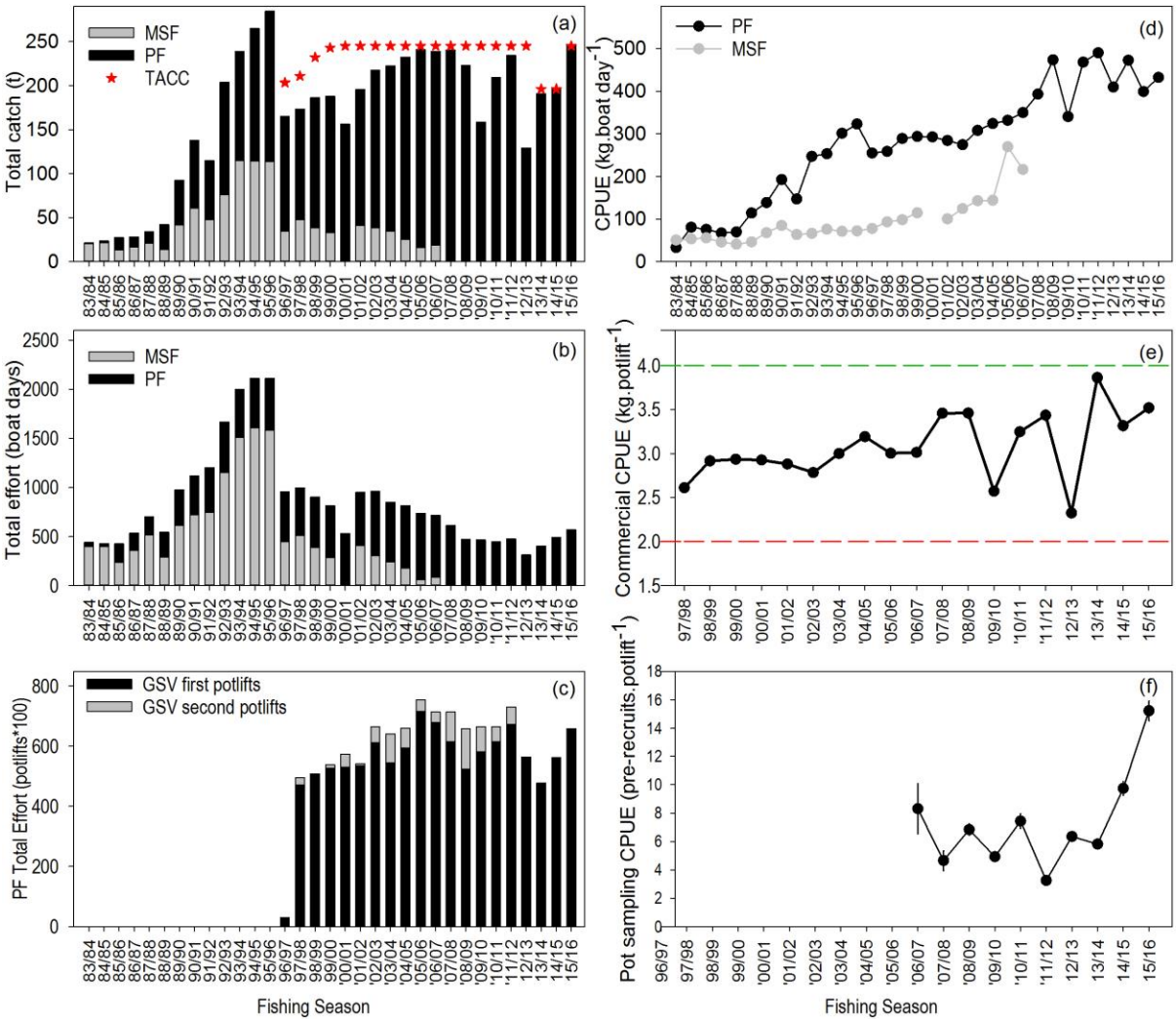

Figure 3.8 Key fishery-dependent outputs used to assess the status of the Gulf St Vincent (GSV) zone of the Blue Crab Fishery (BCF). (a) Trends in total catch (t) for pot fishing (PF) and Marine Scalefish Fishery (MSF) including total allowable commercial catch (TACC) limit; (b) total effort (boat days) for PF and MSF sector; (c) total effort from first and second potlifts for PF sector; (d) catch per unit effort (CPUE, kg/boat day) for the PF and MSF sectors; (e) CPUE (kg.potlift) for the PF sector; (f) pre-recruit CPUE from the pot-sampling program (pre-recruits.potlift^{-1}). Green, and red lines represent the upper and lower limit reference points identified in Table 1.1; error bars, standard error.

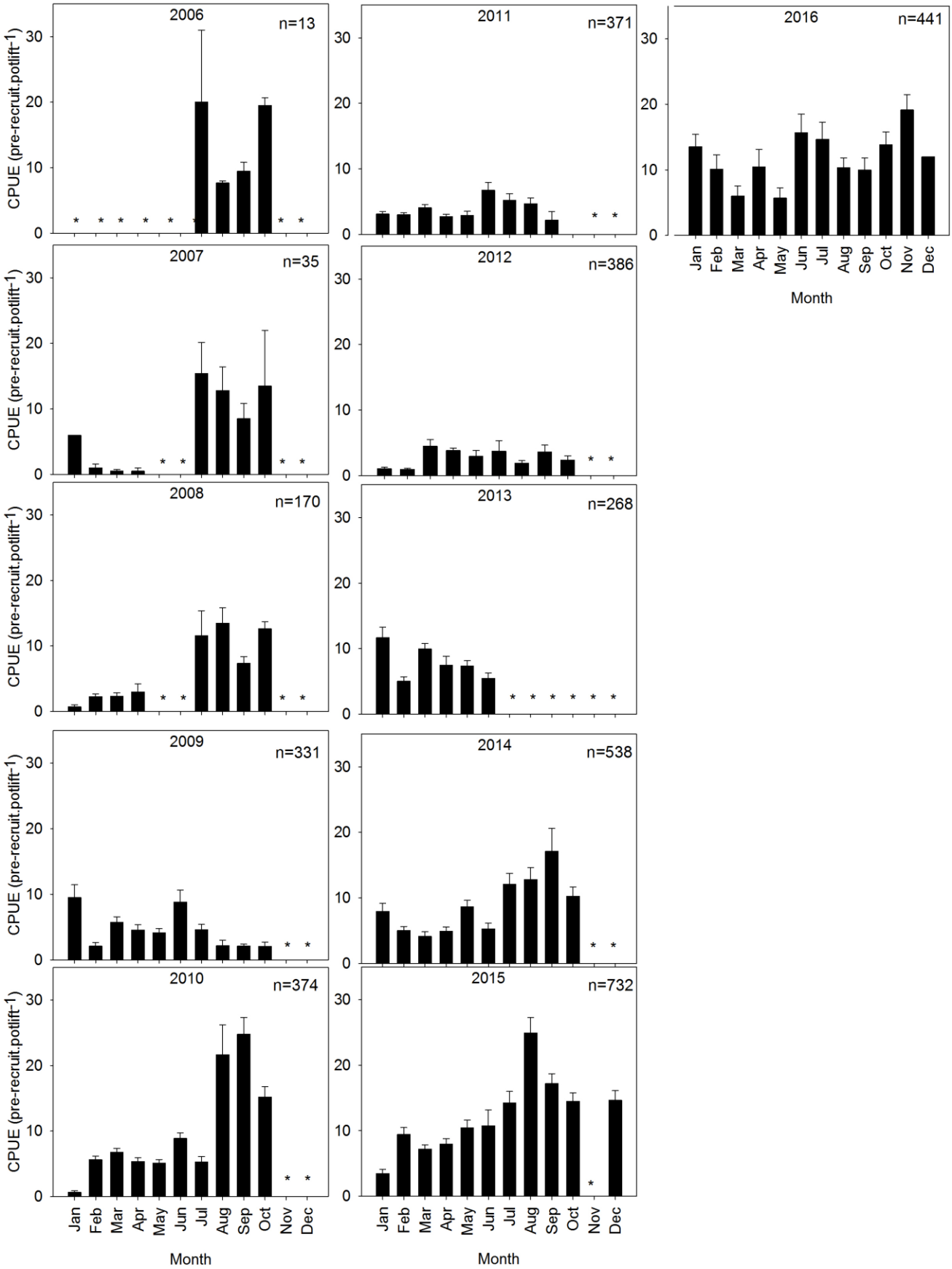

Figure 3.9 Monthly mean catch per unit effort (CPUE) of pre-recruits from pot-sampling undertaken in Gulf St Vincent (GSV). Sample size (n), pots sampled. Error bars, standard error. * No sampling in this month.

The mean CPUE of legal-size crabs recorded by the FIS has fluctuated through time, with similar trends observed at standard and draft HS locations from 2008–2015 (Figure 3.10a and b). The survey CPUE of legal-size crabs was relatively low by abundance (<2 legal-size.potlift^{-1}) and by weight (<0.5 kg.potlift^{-1}) in 2004, 2012 and 2013. In 2012 a minimum of 1.4 ± 0.2 legal-size.potlift^{-1} equivalent to 0.4 ± 0.0 kg.potlift^{-1}at standard locations was observed. Relatively high survey CPUE was observed by weight (>4 legal-size.potlift^{-1}) abundance (>1.1 kg.potlift^{-1}) in 2003, 2006, 2007 and 2015 at standard locations. Under the draft interim harvest strategy sampling locations, legal-size CPUE ranged from 1.9 ± 0.2 legal-size.potlift^{-1} in 2012 to 10.5 legal-size.potlift^{-1} in 2016. By weight, legal-size CPUE ranged from 0.5 ± 0.1 kg.potlift^{-1} in 2012 to 2.9 ± 0.1 kg.potlift^{-1} in 2016.

The mean CPUE of pre-recruits recorded by the FIS has followed a similar trend to legal-size crabs in this region. The survey CPUE of pre-recruit crabs was relatively low by abundance (<2 pre-recruits.potlift^{-1}) and by weight (<0.3 kg.potlift^{-1}) at standard locations in 2004, 2012 and 2013 (Figure 3.10c and d). A minimum of 0.4 ± 0.1 pre-recruits.potlift^{-1}, equivalent to 0.1 ± 0.0 kg.potlift^{-1}, was observed in 2004. Similarly low values were observed at standard locations in 2012 by abundance (0.8 ± 0.1 pre-recruits.potlift^{-1}) and by weight (0.1 ± 0.0 kg.potlift^{-1}) . Relatively high survey CPUE by abundance (>5 pre-recruits.potlift^{-1}) and by weight (>0.7 kg.potlift^{-1}) were observed in 2005, 2006, 2007, 2010 and 2015 at standard locations. In 2006, the survey CPUE of pre-recruits at standard locations reached a historical high by abundance (10.7 ± 0.9 pre-recruits.potlift^{-1}) and by weight (1.5 ± 0.1 kg.potlift^{-1}). Locations sampled under the draft interim harvest strategy ranged from 1.1 ± 0.2 pre-recruits.potlift^{-1} in 2012 to 7.6 pre-recruits.potlift^{-1} in 2015. By weight, locations sampled under the draft interim harvest strategy ranged from 0.2 ± 0.0 kg.potlift^{-1} in 2012 to 1.2 ± 0.1 kg.potlift^{-1} in 2015. In 2016, locations sampled under the draft interim harvest strategy indicate that pre-recruit CPUE was the third lowest on record at 2.7 ± 0.2 pre-recruits.potlift^{-1}. By weight, pre-recruit CPUE was 0.5 ± 0.0 kg.potlift^{-1}and the fourth highest on record.

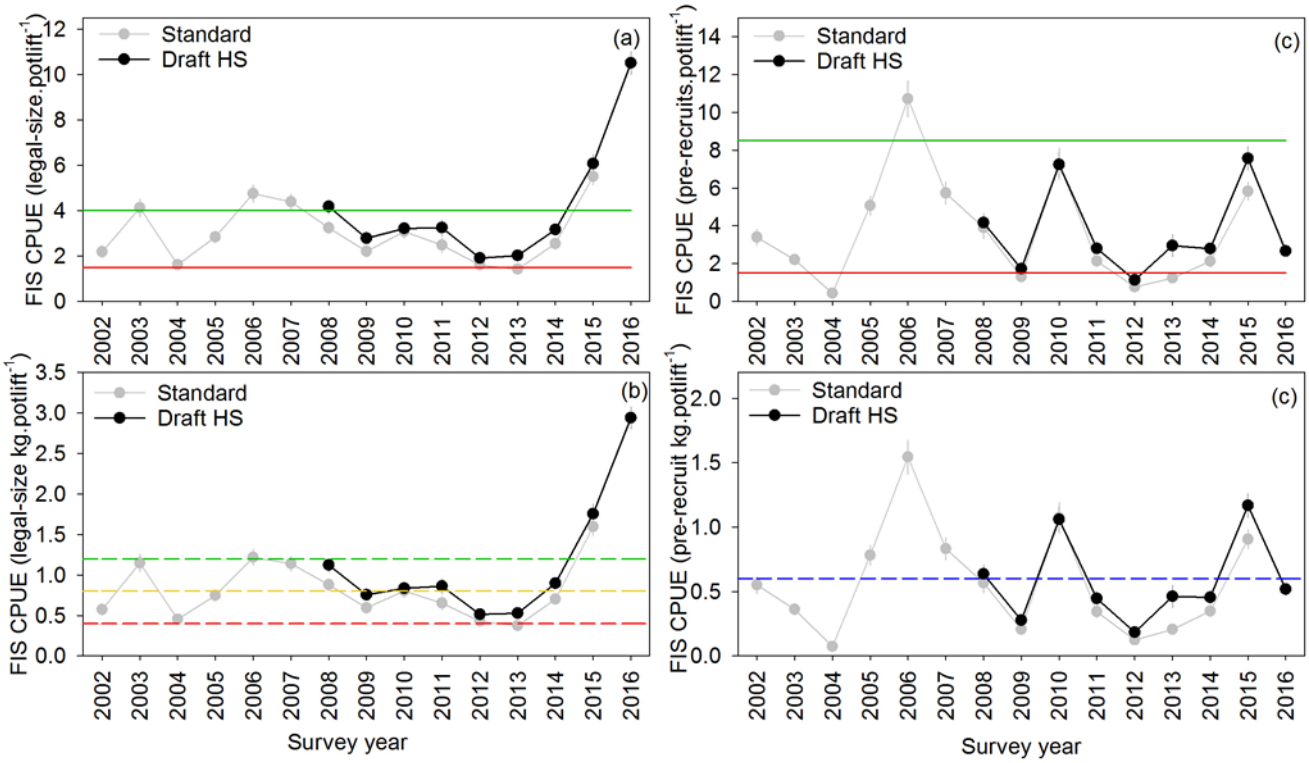

Figure 3.10 Key fishery-independent outputs used to assess the status of the Gulf St Vincent (GSV) zone of the Blue Crab Fishery (BCF). Fishery-independent (FIS) catch per unit effort (CPUE) by (a) abundance legal-size crabs (legal-size.potlift^{-1}), (b) weight of legal-size crabs (kg.potlift^{-1}), (c) abundance of pre-recruit crabs (pre-recruits.potlift^{-1}), and (d) weight of pre-recruit crabs (kg.potlift^{-1}). Standard sites refer to sites which have not changed since 2002 (excludes new sites) and draft HS sites refer to the subset of 60 sites sampled since 2008. Solid green, and red lines represent the upper and lower limit reference points identified in the Management Plan (PIRSA 2012), see Table 1.1. Dashed green, red and yellow lines represent the draft target, limit and trigger reference points and blue line represents the pre-recruit threshold identified in the draft interim harvest strategy, see Table 1.2. Error bars, standard error.

Spatial mapping of density data obtained from the FIS in 2008–2016 indicates that legal-size and pre-recruit crabs were distributed patchily throughout GSV (Figure 3.11 and 3.12). In most years, the highest legal-size densities were observed adjacent to Port Adelaide. In the northern part of the gulf, the highest densities of legal-size crabs were observed near Port Wakefield from 2008–10, adjacent to Black Point in 2008 and 2010 and at Ardrossan in 2008 and 2013. In 2016, high legal-size densities were observed throughout the northern part of the gulf, particularly near Black Point and Ardrossan. Lower densities of legal-size crabs were generally recorded in the southern gulf, however, near Port Adelaide legal-size densities were relatively high from 2010–2012 and near Glenelg in 2016.

Pre-recruit density was highly variable in GSV from 2008-2016. In 2008, 2010 and 2013, high densities of pre-recruits were observed near Ardrossan. In 2008, 2010 and 2015, high pre-recruit densities were also observed adjacent to Black Point. In 2016, pre-recruit density was relatively low, with the highest abundances observed in the centre of the gulf and the middle

of the northern gulf adjacent to Black Point. In 2010 and 201,1 high pre-recruit densities were observed in the central part of GSV adjacent to Port Adelaide.

Since 2008, the proportion of legal-size and pre-recruit crabs has fluctuated during the June/July FIS (Figure 3.13). Length frequency data indicates that high proportions of pre-recruit crabs were observed in 2010, 2013 and 2015 (56–69%), while high proportions of legal-size crabs were observed in all other years (53–79%). Male crabs were dominant in all years, with 51–60% of crabs identified as male from 2008–2014. In 2015 and 2016 the proportion of male crabs increased to 65% and 74%, respectively. The modal size of male crabs was below legal-size in 2010, 2013 and 2015 (100–104 mm CW) and 2014 (105–109 mm CW). Modal size increased above legal-size for male crabs in 2008, 2009 and 2011 (110–114 mm CW) and 2012 and 2016 (115–119 mm CW). The size distribution of females also varied substantially among years. Female crabs had a modal size below the legal-size limit in 2010 and 2015 (100-104 mm CW) and in 2008 (105–109 mm CW). The modal size of female crabs was above the legal-size limit in 2009, 2011 and 2016 (110–114 mm CW) and 2012 (115–119 mm CW).

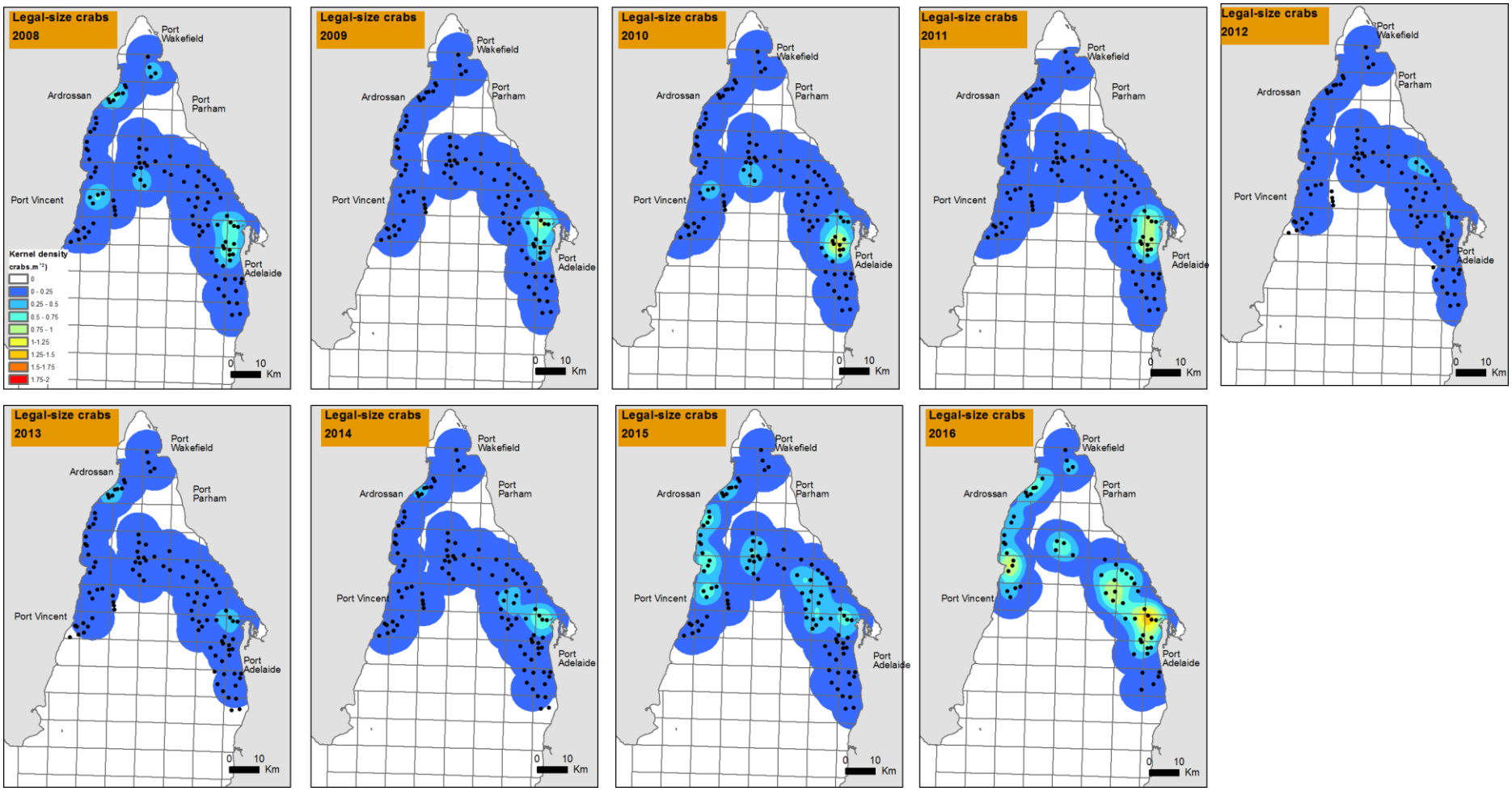

Figure 3.11 Kernel density maps showing the relative density (crabs per square metre) of legal-size crabs from June/July fishery-independent surveys (FIS) sampled at revised locations in Gulf St Vincent (GSV) sampled at 104 sites from 2008–15 and 60 sites in 2016. Sampling locations denoted by ●.

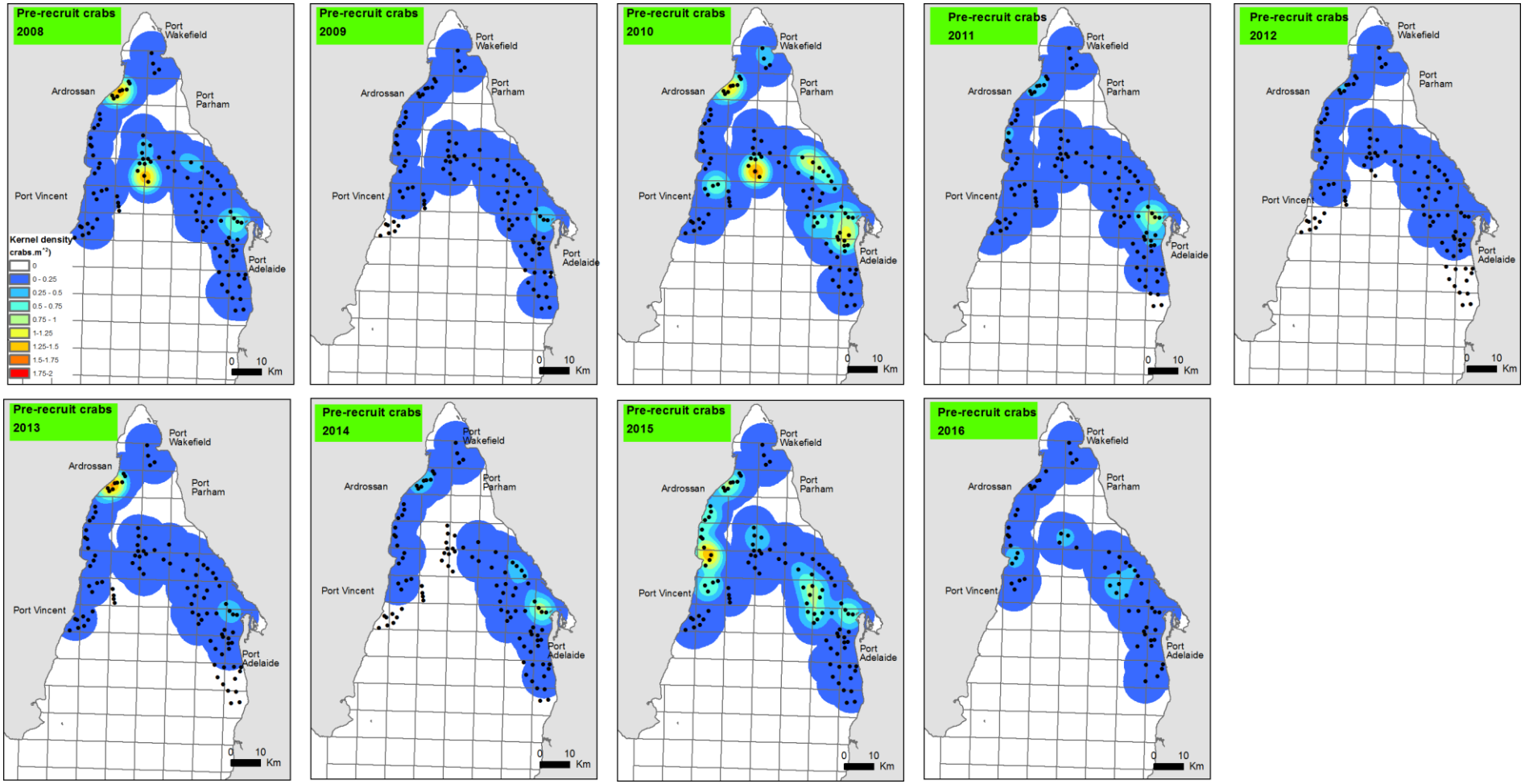

Figure 3.12 Kernel density maps showing the relative density (crabs per square metre) of pre-recruit crabs from June/July fishery-independent surveys (FIS) sampled in Gulf St Vincent (GSV) at 104 sites from 2008–15 and 60 sites in 2016. Sampling locations denoted by ●.

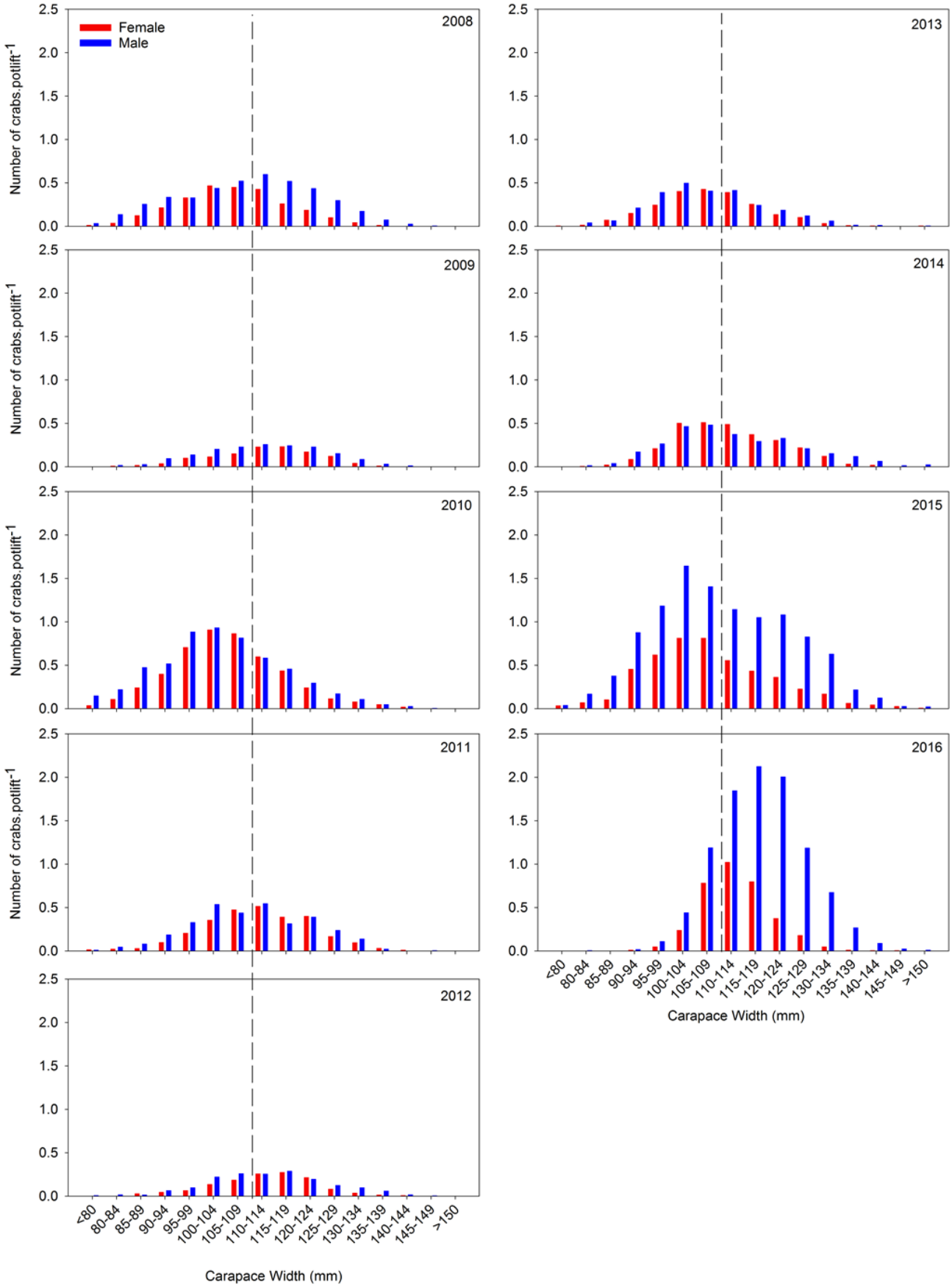

Figure 3.13 Length frequency distributions of male and female Blue Crabs from June/July fishery-independent surveys (FIS) in Gulf St Vincent (GSV) sampled at 60 sites selected under the draft interim harvest strategy from 2008–2016. Minimum size limit 110 mm carapace width, CW (---).

3.4. West Coast

The WC zone has historically produced the lower levels of catch than the SG and GSV Zones. From 1985/86–2006/07, annual catch from the WC remained below 30 t (Figure 3.14). From 2007/08–2014/15, catch ranged from 41–58 t. In 2015/16, 31 t was harvested, representing a 25% decrease from 2014/15 (41 t) and the lowest catch since 2006/07 (21 t). Trends in effort generally followed trends in catch. Effort peaked at 892 boat days in 2013/14 before declining to 608 boat days in 2014/15 and 497 boat days in 2015/16. CPUE declined from 1983/84 to a low of 15 kg.boat day^{-1} in 1987/88. A large increase in CPUE was observed in 1989/90 where a maximum of 162 kg.boat day^{-1} was observed. Since then, CPUE has remained below 100 kg.boat day^{-1}. Annual CPUE decreased 8% from 68 kg.boat day^{-1} in 2014/15 to 62 kg.boat day^{-1} in 2015/16, this was the lowest CPUE observed since 2006/07 (53 kg.boat day^{-1}).

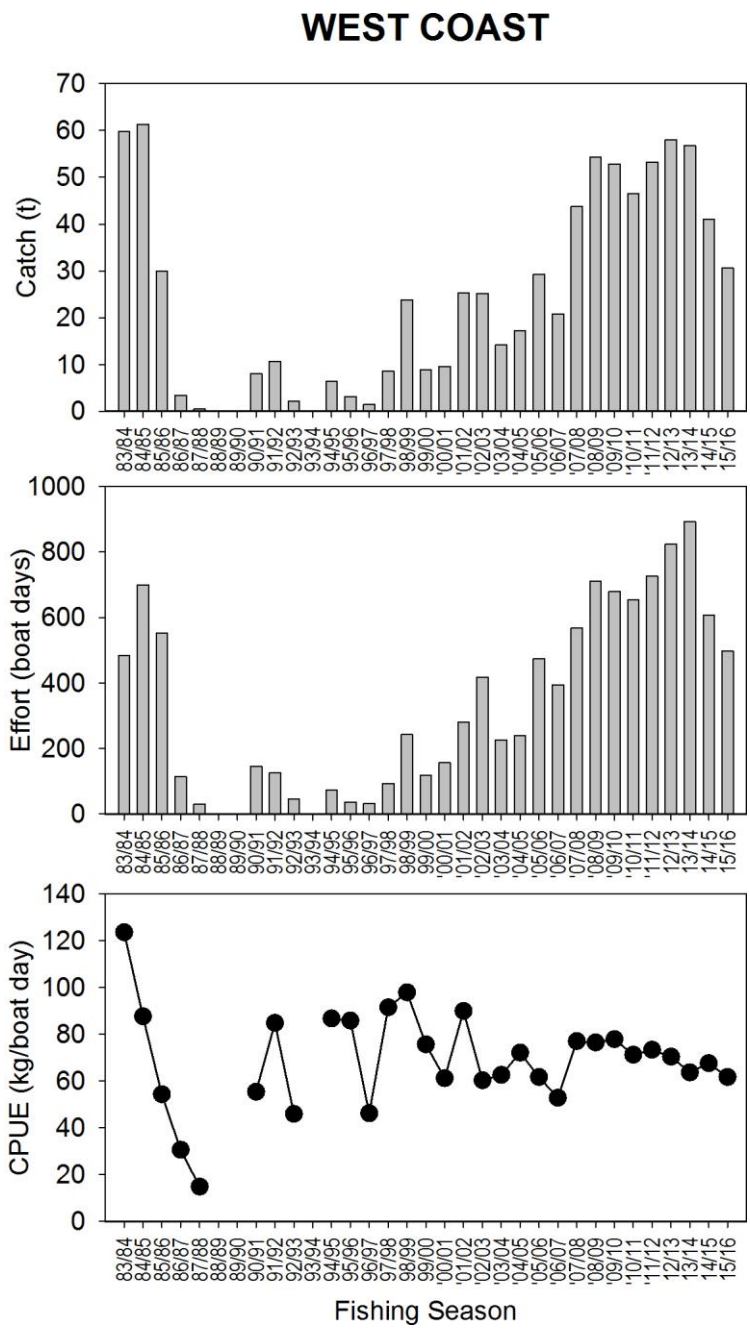

Figure 3.14 Key outputs used to assess the status of the West Coast (WC) Blue Crab stock. From top. Trends in catch (t), effort (boat days) and catch per unit effort (CPUE, kg.boat day^{-1}).

3.5. Fishery performance

Data were available for one of the three PIs specified in the Management Plan for the SG and GSV pot fishing zones in 2015/16 (Table 3.1). The RPs for survey CPUE were developed based on standard potlift locations (106 sites in SG and 104 sites in GSV) sampled since 2002. As a subset of these (60 sites) were sampled in each gulf during the 2016 FIS, there were inadequate data for assessment of the legal-size and pre-recruit CPUE PIs against the Management Plan RPs. Consequently, commercial CPUE of legal-size crabs was the only PI which could be assessed and this remained between the upper and lower limit RPs in SG and GSV during 2015/16.

In 2015/16, data were available for all PIs in GSV and SG under the draft interim harvest strategy. Under this strategy, reference points were developed based on the 60 sites sampled during June/July surveys in each gulf from 2008–2015. In SG, the PI for survey CPUE of legal-size crabs was between the target and the trigger RPs in 2016 and the pre-recruit CPUE was above the threshold RP (Table 3.2). In GSV, the PI for survey CPUE of legal-size crabs was above the target RP, while pre-recruit CPUE was below the threshold RP.

PIs have not been developed to facilitate stock assessment of the West Coast (WC) region.

Table 3.1 Summary of the performance of the Spencer Gulf (SG) and Gulf St Vincent (GSV) pot fishing zone for 2015/16 against the key biological performance indicators (PIs). The values highlighted in green indicate that the value was above the upper limit reference point (RP) for that PI. *Reduced surveys were undertaken in 2016 in SG and GSV.

Zone	Data source	Performance indicator	Limit RP		2015/16
			Lower	Upper	
SG	FIS	CPUE of legal-size crabs (legal-size crabs/potlift)	5.0	8.0	NA
	FIS	CPUE of pre-recruits (pre-recruits/potlift)	2.0	9.0	NA
	Catch & effort	CPUE of legal-size crabs (kg/potlift)	2.0	4.0	3.5
GSV	FIS	CPUE of legal-size crabs (legal-size crabs/potlift)	1.5	4.0	NA
	FIS	CPUE of pre-recruits (pre-recruits/potlift)	1.5	8.5	NA
	Catch & effort	CPUE of legal-size crabs (kg/potlift)	2.0	4.0	3.5

Table 3.2 Summary of the performance of the Spencer Gulf (SG) and Gulf St Vincent (GSV) pot fishing zone for 2015/16 against the key biological performance indicators (PIs) under the draft interim harvest strategy. The values highlighted in green indicate that the value was above the trigger limit reference point (RP) for that PI.

Zone	Data source	Performance indicator	RP				2015/16
			Limit	Trigger	Target	Threshold	
SG	FIS	CPUE of legal-size crabs (legal-size kg/potlift)	0.7	1.7	2.7	-	2.1
	FIS	CPUE of pre-recruits (pre-recruits kg/potlift)	-	-	-	1	1.9
GSV	FIS	CPUE of legal-size crabs (legal-size crabs kg/potlift)	0.4	0.8	1.2	-	2.9
	FIS	CPUE of pre-recruits (pre-recruits kg/potlift)	-	-	-	0.6	0.5

4. DISCUSSION

4.1. Stock status

This stock assessment determined the current status of South Australia's Blue Swimmer Crab resource through analysis of data collected by several long-term monitoring programs. The current harvest strategy for the BCF does not define when the stock is considered 'recruitment-overfished' and PIs are not explicitly linked to a definition of stock status. During 2015/16 reduced FIS were undertaken in both gulfs during June/July. As a result, the PIs based on survey CPUE could not be assessed against the existing reference points (RPs) under the current harvest strategy. A draft interim harvest strategy has been developed and PIs have been assessed against RPs based on the reduced survey design undertaken in June/July. As the Management Plan and revised harvest strategy have not yet been finalised, this assessment uses a 'weight of evidence' method to determine stock status.

Three primary datasets were available to assess the status of the BCF in 2015/16: 1) FIS data; 2) fishery-dependent commercial logbooks; and 3) fishery-dependent voluntary pot-sampling data. The FIS data are considered to provide the most reliable indices of relative abundance. This is because: 1) FIS include a standardised sampling design (with respect to locations, months and gear), from 2008–2016, and a longer term standardised sampling design which was utilised from 2002–2015;
2) the difficulty in quantifying the effects of fisher experience, temporal and spatial shifts in catch and effort, and improvements in catching efficiency (e.g. gear modification, vessel technology, selectivity of commercial pots) on commercial CPUE; and 3) the limited data (spatially and temporally) available from the voluntary pot-sampling program.

4.1.1. Spencer Gulf

In 2015/16, commercial CPUE was the sixth highest value recorded since 1996/97 and was above the lower limit RP specified in the Management Plan. This was coupled with almost the entire SG component of the TACC being caught for the twelfth consecutive fishing season. In 2016, legal-size survey CPUE decreased by 34% compared to 2014 and was the lowest value recorded for the past 6 surveys. Despite this, legal-size CPUE was between the target and trigger RPs specified in the draft interim harvest strategy. Pre-recruit CPUE was the highest value recorded for the past 6 surveys and was above the threshold RP specified in the draft interim harvest strategy. Pre-recruit CPUE from the voluntary pot sampling program was the second highest on record. On the basis of this information, the biological stock is unlikely to be recruitment overfished and the current level of fishing mortality is unlikely to cause the biological stock to become recruitment overfished. Consequently, using the national framework for stock status reporting (Flood *et al.* 2014), the SG zone of the BCF is classified as **'sustainable'.**

4.1.2. Gulf St Vincent

In 2015/16, commercial CPUE was the second highest value recorded since 1996/97 and was between the upper and lower limit RPs specified in the Management Plan. The baseline TACC was increased to 245.1 t in 2016, and almost the entire GSV component of the TACC was caught for the third consecutive fishing season. Legal-size survey CPUE increased by 68% from 2015 to 2016, equivalent to the highest value on record and above the target RP in the draft interim harvest strategy. Pre-recruit survey CPUE declined by 56% from 2015 to 2016 and was below the threshold RP in the draft interim harvest strategy. Despite this, pre-recruit survey CPUE was the fourth highest value recorded since 2008 and pot sampling data indicated high pre-recruit abundance from July–October 2016. On the basis of this information, the GSV zone of the BCF is not considered to be recruitment overfished, and the current level of fishing pressure is unlikely to cause the fishery to become overfished. Therefore, using the national framework for stock status reporting (Flood *et al.* 2014), the GSV zone of the BCF is classified as **'sustainable'.**

4.1.3. West Coast

A negligible amount of Blue Crabs is landed by the commercial sector on the WC and no FIS data are available for this region. Consequently, there is insufficient information available to confidently classify the status of this stock. Therefore, using the national framework for stock status reporting (Flood *et al.* 2014), the WC zone of the BCF is classified as '**undefined'**.

4.2. Performance indicators and harvest strategy

The harvest strategy contained within the Management Plan (PIRSA 2012) includes biological performance indicators which provide measures of the status of the fishery. The three performance indicators are: (1) relative abundance of pre-recruit crabs from FIS (pre-recruits.potlift^{-1}), (2) relative abundance of legal-sized crabs from FIS (legal-size.potlift^{-1}), and (3) commercial CPUE (kg.potlift^{-1}) of legal-sized crabs. Upper and lower limit RPs are established for each PI to provide guidance on the TACC setting process. Historically, commercial CPUE has been relatively stable despite fluctuating FIS CPUE and therefore legal-size and pre-recruit survey CPUE have been the primary drivers when determining stock status and setting the TACC. The RPs for survey CPUE were determined based on a seven-year reference period (2002–2009) where standard sites were sampled in each gulf in June/July using small-mesh research pots. The lower limit RP is considered the benchmark for undesirable fishery performance that the fishery aims to avoid. Where the lower limit RP is breached for any of the indicators, decision rules are applied and a TACC reduction may be considered. The upper limit RP is considered to be a benchmark for exceptionally positive fishery performance. The provision for TACC increases above the baseline of 626.8 t is not included in the current Management Plan and only the lower limit RPs are used for the purpose of TACC setting. The Management Plan

does, however, state that decision rules for TACC increases will be discussed under the harvest strategy review.

There are several key limitations under the current Management Plan. Firstly, the FIS data used to set the TACC are 9–11 months old. Secondly, the PIs and harvest strategy are not explicitly linked to a definition of stock status. A new draft interim harvest strategy has been developed by the Blue Crab Fishery Harvest Strategy Review Committee as part of the Management Plan review. As part of this review, a decision was made to transition from June/July surveys to March/April surveys to reduce the time lag between surveys and TACC setting. In March 2015, 50 sites were sampled in GSV and from March/April 2016, 60 sites were sampled in both gulfs. In 2016, the number of sites sampled during June/July was reduced from 106 sites in SG and 104 sites in GSV to 60 sites in each gulf. The time lag between surveys and TACC setting will remain as a limitation until at least three paired surveys in June/July and March/April have been completed and PIs are developed based on the March/April time series. As a result, the draft interim harvest strategy provides RPs based on the 60 sites sampled during June/July from 2008–2015. Data from 2002–2007 was not used to develop RPs as new sites were added from 2008.

Under the draft interim harvest strategy, legal-size relative biomass (kg.potlift^{-1}) is the primary PI and decision rules have been designed to provide clear guidance to determine the TACC. Consistent with the *South Australian Fisheries Harvest Strategy Policy* (PIRSA 2015), the TACC allocations align with the management aims of the national framework for stock status reporting (Flood *et al.* 2014). The draft interim harvest strategy includes a modified traffic light system with colours reflective of stock status classifications. Where values are above the trigger RP, the fishery is considered to be operating at a sustainable level (green). At this level, limited management intervention is required, other than setting TACC values that are biologically sustainable and maximising economic returns. Where the stock is below the trigger reference point, legal-size biomass is decreasing and fishing pressure is too high, and the stock would be classified as transitional-depleting. Where values are below the trigger RP (yellow), TACC reductions are significant and aim to recover the stocks from either a recruitment overfished state or prevent the stock from moving into a recruitment overfished category. Where values are below the limit RP (red), the fishery would be considered ‘recruitment overfished’ (i.e. spawning stock biomass has been reduced by fishing so that average recruitment levels are significantly reduced). When fishing pressure is reduced and the legal-size biomass increases, the stock would move into a transitional-recovering status. By definition, a transitional-recovering stock is “a recovering stock– biomass is recruitment overfished, but management measures are in place to promote stock recovery, and recovery is occurring.” A transitional-recovering stock is actually an overfished stock, therefore, the legal-size biomass will be at a lower level than if the stock was classified as transitional depleting. The draft interim harvest strategy doesn’t currently include decision rules for where the stock is considered to be environmentally limited.

4.3. Future directions

The PIs and associated RPs under the draft interim harvest strategy will need to be reviewed when three years of paired June/July and March/April survey data become available (Beckmann *et al.* 2016). In particular, and if an index of pre-recruits is used as a secondary indicator, the March/April pre-recruit index will need to be reviewed as the timing of peak pre-recruit abundance appears to occur later in the year (from June onwards). As there are existing data, the two most tractable options for measuring pre-recruits would be to continue a reduced June/July survey and/or modify the pot sampling program to expand temporal coverage to increase the likelihood of capturing the variable timing of peak recruitment.

The Management Plan and draft interim harvest strategy require utilisation of data from small-mesh research pots to determine relative abundance or biomass based on FIS catch rates. The major advantage of using research pots is that pot design has not changed since 2002 thus allowing for comparison over a 14-year time series, and research pots have smaller mesh and retain more pre-recruit crabs than commercial pots. Commercial gear has been sampled alongside research pots in most years since 2002, however, there have been variations in mesh size, pot diameter and escape gaps. This is evident in research and commercial pot catch rates as in some years legal-size CPUE is higher for research pots and in some years legal-size CPUE is higher in commercial pots (see Appendix C). For example, in SG the legal-size CPUE decreased from 2014 to 2016 when examining research potlifts, while CPUE increased when examining commercial potlifts. This may be due to an increase in the efficiency of commercial pots and not reflective of an increase in biomass. Thus, as research pots have not changed though time, they are the most reliable source when examining changes in relative biomass.

There are several other avenues of research that would reduce uncertainty in the assessment of Blue Crab stocks. Firstly, increasing the frequency of data on the catch from the recreational sector would enhance understanding of the temporal variation in recreational catch and allow the monitoring of relationships between catches and sector allocations. This is important for a short-lived species such as Blue Crabs because substantial changes in abundance, catch and effort can occur in a relatively short time period. Secondly, increasing knowledge of ecosystem changes on Blue Crab stocks would enhance understanding of predator-prey interactions and trophic level changes. This is being addressed as part of an FRDC project (2013-031). Finally, physical-oceanographic processes and patterns of larval settlement need further investigation to enhance harvest strategies and maximise production opportunities. Preliminary work has been undertaken for the SG zone as part of an FRDC project (2008-011; McLeay *et al.* 2015). However, more stratified sampling is required to estimate egg production and crab biomass and determine the areas which contribute the most to larval settlement.

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APPENDIX A: POT SAMPLING DATA COLLECTION

Table 2.1 Summary of the pot-sampling data collected in the Spencer Gulf (SG) pot fishing zone from 2008–2015 (calendar year). Catch & effort data current available until August 2016, September-December data not included.

Statistic	2008	2009	2010	2011	2012	2013	2014	2015	2016*
Active licences	5	5	4	4	4	4	4	4	4
Licences providing data	4	4	4	3	4	4	4	2	1
Boat days during sampling period	971	696	734	526	664	732	700	628	711
Boat days sampled	434	523	493	128	532	665	582	80	130
% of total boat days sampled	45%	75%	67%	24%	80%	91%	83%	13%	NA
Blocks fished during sampling period	39	29	36	23	33	42	33	22	29
Blocks sampled	28	27	28	8	32	29	20	7	8
Pots sampled	435	527	516	129	539	688	584	81	130
Crabs measured	8,526	8,750	10,206	2,585	12,700	16,308	12,218	2,291	3,377

Table 2.2 Summary of the pot-sampling data collected in the Gulf St Vincent (GSV) pot fishing zone from 2008–2014 (calendar year). Catch & effort data current available until August 2016. September-December data not included.

Statistic	2008	2009	2010	2011	2012	2013	2014	2015	2016
Active licences	4	3	3	3	3	3	3	3	3
Licences providing data	3	3	3	3	3	3	3	3	3
Boat days during sampling period	443	492	425	512	407	203	590	638	568
Boat days sampled	169	328	352	365	328	189	466	546	407
% of total boat days sampled	38%	67%	83%	71%	81%	93%	79%	86%	NA
Blocks fished during sampling period	15	22	27	24	29	20	21	31	23
Blocks sampled	10	13	19	15	21	14	18	24	19
Pots sampled	170	331	374	371	386	268	538	732	441
Crabs measured	3,485	5,474	7,308	6,845	6,423	4,961	13,596	20,829	15,245

APPENDIX B: MARCH/APRIL SURVEY RESULTS

B1 Spencer Gulf

Table B.1 Summary of the fishery-independent survey (FIS) data collected in Spencer Gulf (SG) during April 2016. CPUE, catch per unit effort.

Statistic	**2016**
Potlifts	300
Crabs measured	7,471
Legal-size CPUE (kg.potlift^{-1})	3.0 ± 0.1
Legal-size CPUE (legal-size.potlift^{-1})	11.2 ± 0.4
Pre-recruit CPUE (kg.potlift^{-1})	2.2 ± 0.1
Pre-recruit CPUE (pre-recruits.potlift^{-1})	13.7 ± 0.5

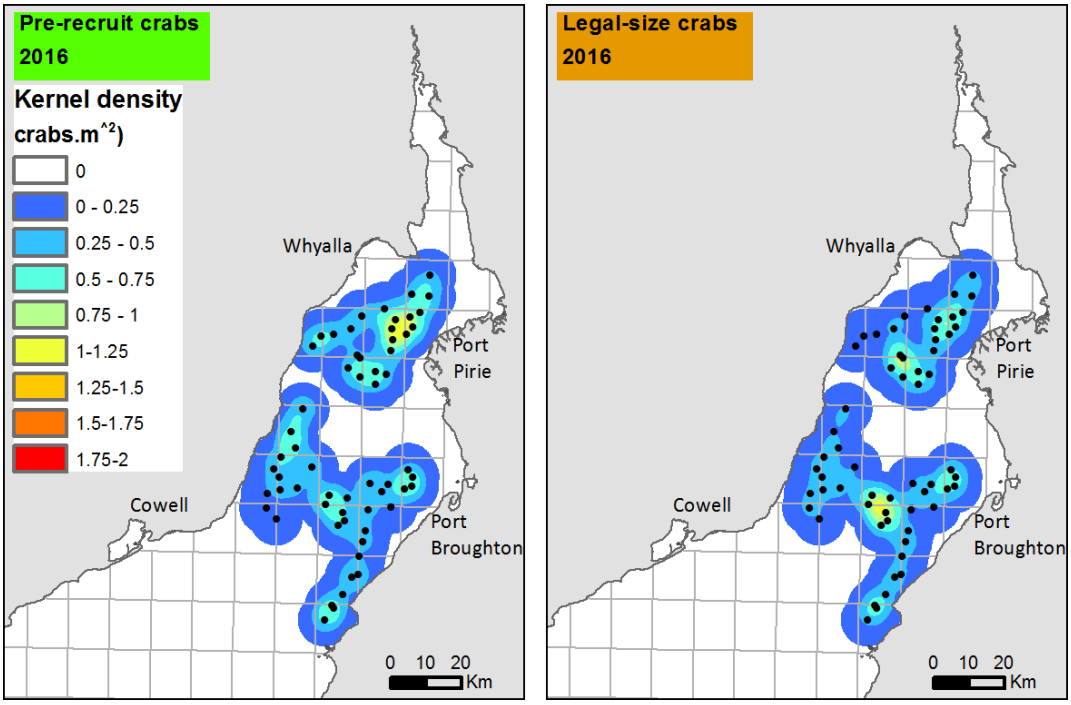

Figure B.1 Kernel density maps showing the relative density (crabs.m^2) of pre-recruit and legal-size crabs from the 2016 April fishery-independent survey (FIS) in Gulf St Vincent (GSV). Sampling locations denoted by •.

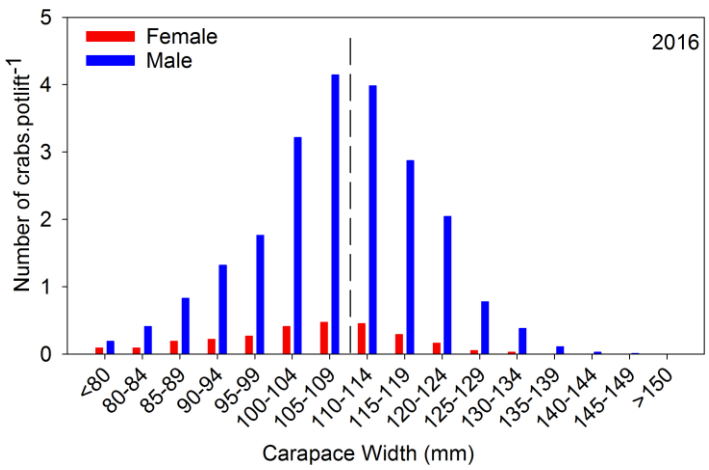

Figure B.2 Length frequency distributions of male and female Blue Crabs from the April 2016 fishery-independent survey (FIS) in Spencer Gulf (SG). Minimum size limit 110 mm carapace width, CW (---).

B2 Gulf St Vincent

Table B.2 Summary of the fishery-independent survey (FIS) data collected in Gulf St Vincent (GSV) during March 2015 and 2016. CPUE, catch per unit effort.

Statistic	**2015**	**2016**
Potlifts	247	299
Crabs measured	3348	3265
Legal-size CPUE (kg.potlift^{-1})	2.6 ± 0.1	3.2 ± 1.8
Legal-size CPUE (legal-size.potlift^{-1})	8.4 ± 0.5	10.4 ± 0.3
Pre-recruit CPUE (kg.potlift^{-1})	0.9 ± 0.1	0.1 ± 0.2
Pre-recruit CPUE (pre-recruits.potlift^{-1})	5.2 ±0.3	0.6 ± 0.1

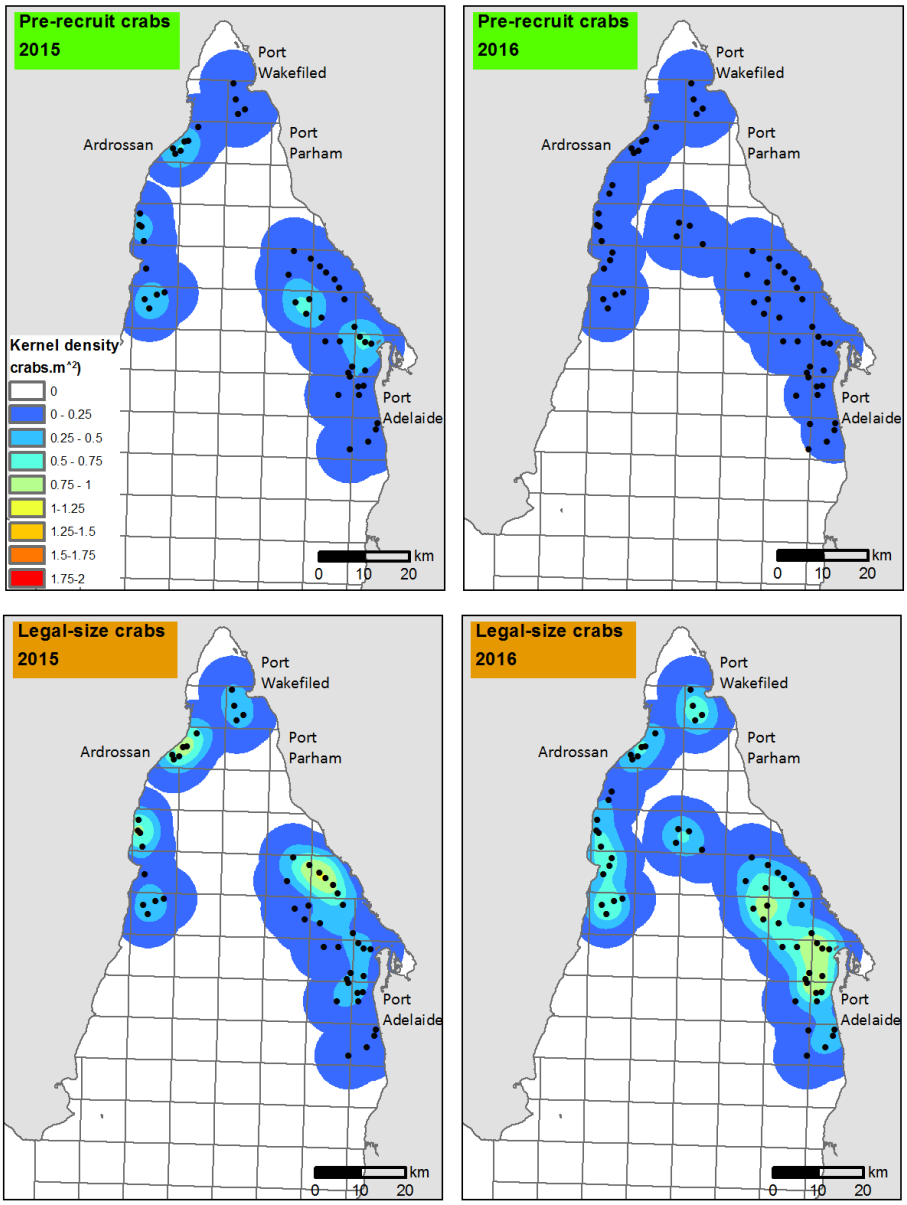

Figure B.3 Kernel density maps showing the relative density (crabs.m^2) of pre-recruit and legal-size crabs from the 2015 and 2016 March fishery-independent surveys (FIS) in Gulf St Vincent (GSV). Sampling locations denoted by •.

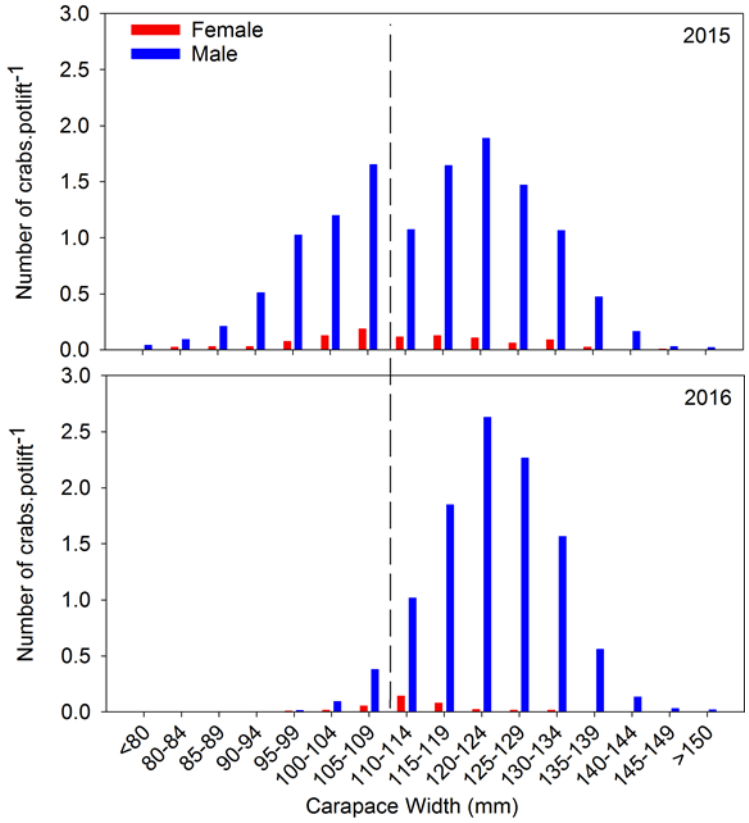

Figure B.4 Length frequency distributions of male and female Blue Crabs from the March 2015 and 2016 fishery-independent surveys (FIS) in Gulf St Vincent (GSV). Minimum size limit 110 mm carapace width, CW (---).

APPENDIX C: GEAR SELECTIVITY

C.1 Spencer Gulf

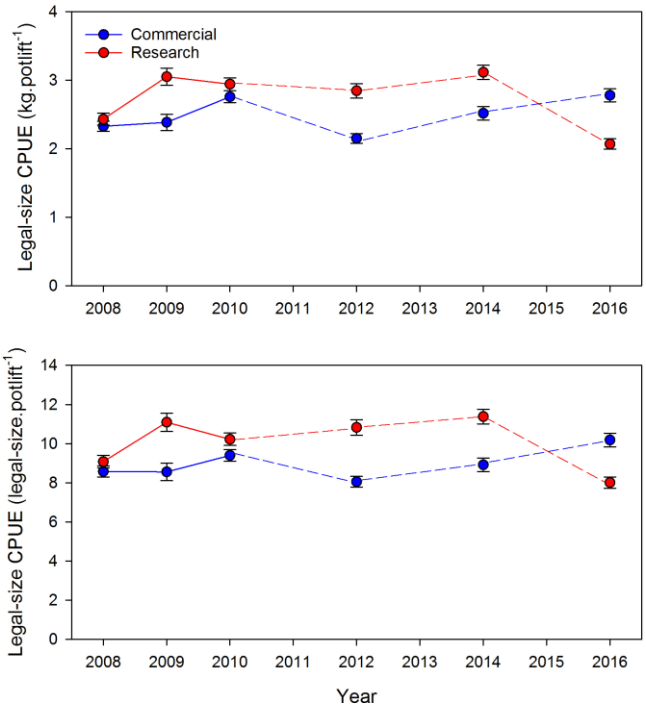

Figure C.1 Mean catch per unit effort (CPUE) of legal-size crabs from research and commercial pots from 60 sites sampled from June/July 2008–2016 in Spencer Gulf (SG). Error bars, standard error. Note, surveys were not conducted in 2011, 2013 or 2015.

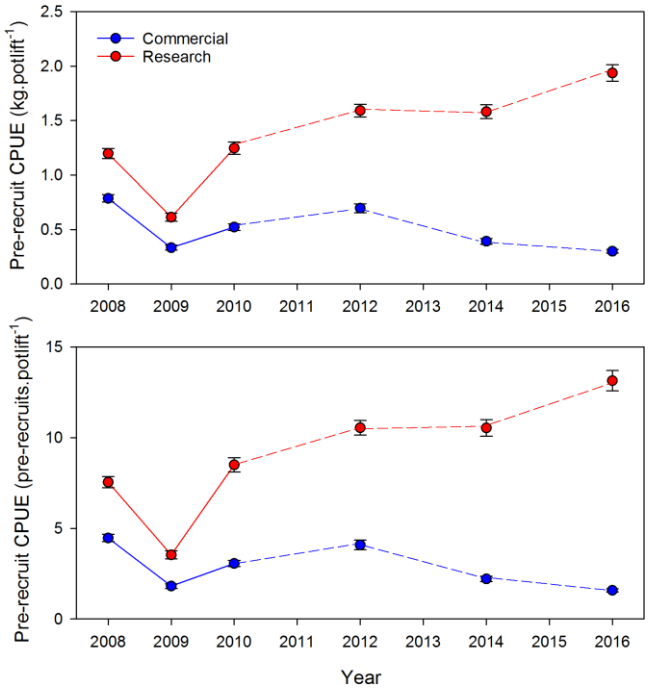

Figure C.2 Mean catch per unit effort (CPUE) of pre-recruit crabs from research and commercial pots from 60 sites sampled from June/July 2008–2016 in Spencer Gulf (SG). Error bars, standard error. Note, surveys were not conducted in 2011, 2013 or 2015.

C.2 Gulf St Vincent

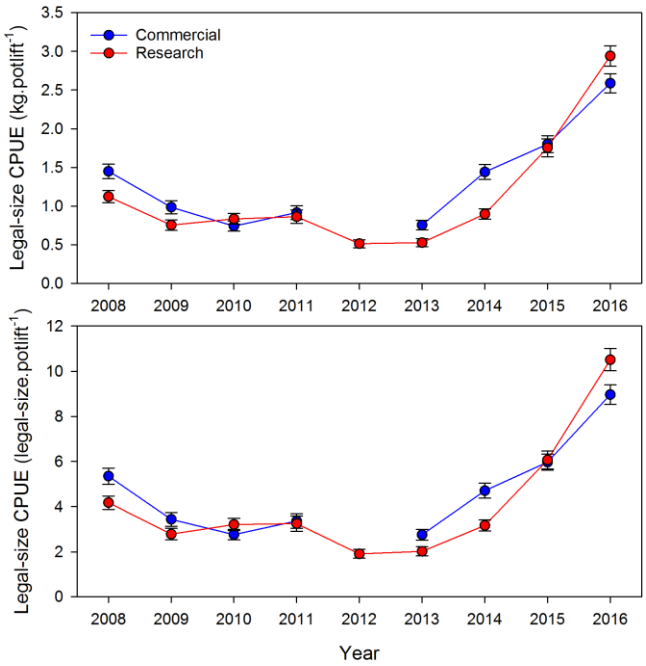

Figure C.3 Mean catch per unit effort (CPUE) of legal-size crabs from research and commercial pots from 60 sites sampled from June/July 2008–2016 in Gulf St Vincent (GSV) during June and July from 2002 to 2015. Error bars, standard error. Note, research pots were not sampled in 2012.

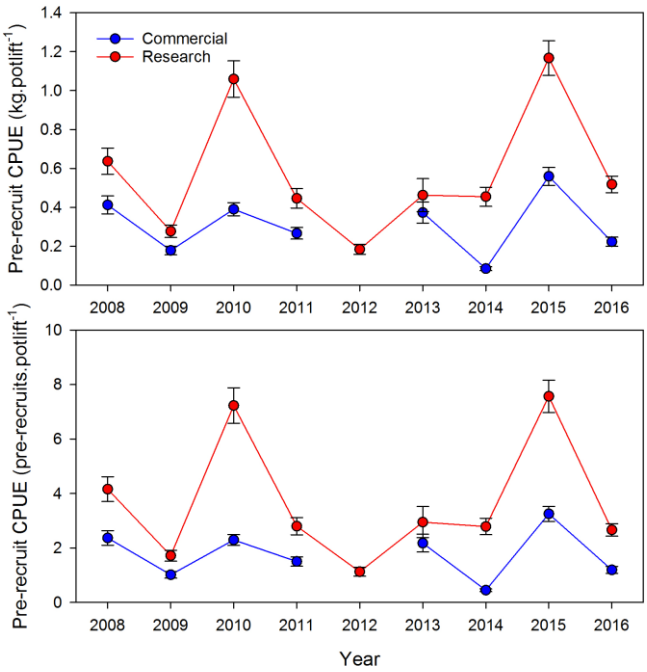

Figure C.4 Mean catch per unit effort (CPUE) of pre-recruit crabs from research and commercial pots from 60 sites sampled from June/July 2008–2016 in Gulf St Vincent (GSV) during June and July from 2002 to 2015. Error bars, standard error. Note, research pots were not sampled in 2012.