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Gulf St Vincent Prawn *Penaeus (Melicertus) latisulcatus* Fishery 2015/16

C. L. Beckmann and G. E. Hooper

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September 2016

Fishery Assessment Report to PIRSA Fisheries and Aquaculture

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EXECUTIVE SUMMARY

This stock assessment determined the current status of the Gulf St Vincent Prawn Fishery (GSVPF) through analysis of data collected by several long-term monitoring programs. The current Management Plan, which includes a harvest strategy for the fishery, is being reviewed and due for completion in 2016. The fishery is currently operating under interim harvest strategy arrangements and there are no performance indicators linked to a definition of stock status. Consequently, this assessment uses a 'weight of evidence' approach to determine stock status.

Fishing was conducted over 296 vessel nights in 2015/16 and the total harvest was 222 t, including 4 t from the fishery-independent survey (FIS). This was 12% lower than 2014/15 (252 t including 3 t FIS catch). During the early spawning period (November-December) of 2015/16, 20 t was harvested. This was a 65% decrease compared to 2014/15 (57 t), following a 40% reduction in the number of nights fished during this period. In 2015/16, standardised commercial catch per unit effort (CPUE) was 929 $kg.vessel.night^{-1}$, 95% Confidence Interval (CI) [900, 958]. This was a 4% increase compared to 2014/15 where CPUE was 894 $kg.block.vessel.night^{-1}$, 95% CI [867, 921].

The standardised survey CPUE was 46.4 $kg.trawl\text{-}shot^{-1}$, 95% CI [40.1, 53.4] in May 2016. This was a 50% increase compared to May 2015 and the second highest value recorded in May. The recruitment index recorded in May 2016 was 880.9±120.6 $recruits.h^{-1}$. This was a 169% increase compared to May 2015 (327.6±62.2 $recruits.h^{-1}$) and the second highest on record.

On the weight of evidence, these data indicate that the GSVPF biomass is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (that is, the stock is not recruitment overfished) and that fishing pressure is adequately controlled to avoid the stock becoming recruitment overfished. Therefore, using the national framework for stock status reporting (Flood *et al.* 2014), the GSVPF stock is classified as '**sustainable**'.

Table 1. Key Gulf St Vincent Prawn Fishery statistics for the 2015/16 season.

Statistic	**2015/16**
Total allowable commercial effort (TACE)	300 nights (30 pre-Christmas)
Total commercial catch	222 t (including 4 t from survey)
Total effort	2,799 hours, 296 vessel nights
Standardised commercial CPUE	929 $kg.vessel.night^{-1}$, 95% CI [900, 958]
Standardised survey CPUE	46.4 $kg.trawl\text{-}shot^{-1}$, 95% CI [40.1, 53.4]
Fishery recruitment index	880.9±120.6 $recruits.h^{-1}$
Status	**Sustainable**

1. INTRODUCTION

1.1. Overview

Stock assessments for the Gulf St Vincent Prawn Fishery (GSVPF) targeting the western king prawn *Penaeus (Melicertus) latisulcatus* (Kishinouye 1996) are part of the South Australian Research and Development Institute (SARDI) Aquatic Sciences' ongoing assessment program. This fishery stock assessment report assesses the current status of the Gulf St Vincent Prawn Fishery (GSVPF), including new data from the 2015/16 (1 November 2015 to 31 July 2016) fishing season.

This report has three aims: 1) to present information relating to the fishery and biology of the species; 2) to assess the current status of the western king prawn resource in Gulf St Vincent and consider the uncertainty associated with the assessment; and 3) to identify future directions for the research program.

1.2. Description of the fishery

1.2.1. *Access*

Three commercial prawn fisheries occur within South Australia – the Spencer Gulf Prawn Fishery (SGPF), the GSVPF (Figure 1.1) and the West Coast Prawn Fishery (WCPF). The SGPF is the largest prawn fishery in South Australia in both total catch and numbers of licences (39). The WCPF is the smallest of the three prawn fisheries with three licences. There are currently ten commercial fishery licences issued for the GSVPF.

The GSVPF is a single species fishery that targets the western king prawn, *Penaeus (Melicertus) latisulcatus*. In addition to prawns, commercial licence holders are permitted to retain and sell two species of by-product harvested incidentally during prawn trawling: Balmain Bug (*Ibacus* spp) and Southern Calamari (*Sepioteuthis australis*). A smaller penaeid, *Metapenaeopsis crassima*, is also permitted to be retained in South Australian waters but is of no commercial value.

Fishing is permitted in all waters greater than 10 m in depth north of the geodesic joining GSV, Investigator Strait and Backstairs Passage. GSVPF is divided into 121 prawn fishing blocks for research purposes (Figure 1.1). The major home ports for the GSVPF are Port Adelaide and North Haven.

The fishing season occurs from 1 November to 31 July of the following year with a closure in January and February. Trawling is undertaken at night between sunset and sunrise, and generally between the last quarter and first quarter of the moon.

Commercial fishing is undertaken using demersal otter trawls (Figure 1.2) that tow a funnel-shaped net that leads into a bag (most commonly referred to as a cod end) over the sea floor (Figure 1.3).

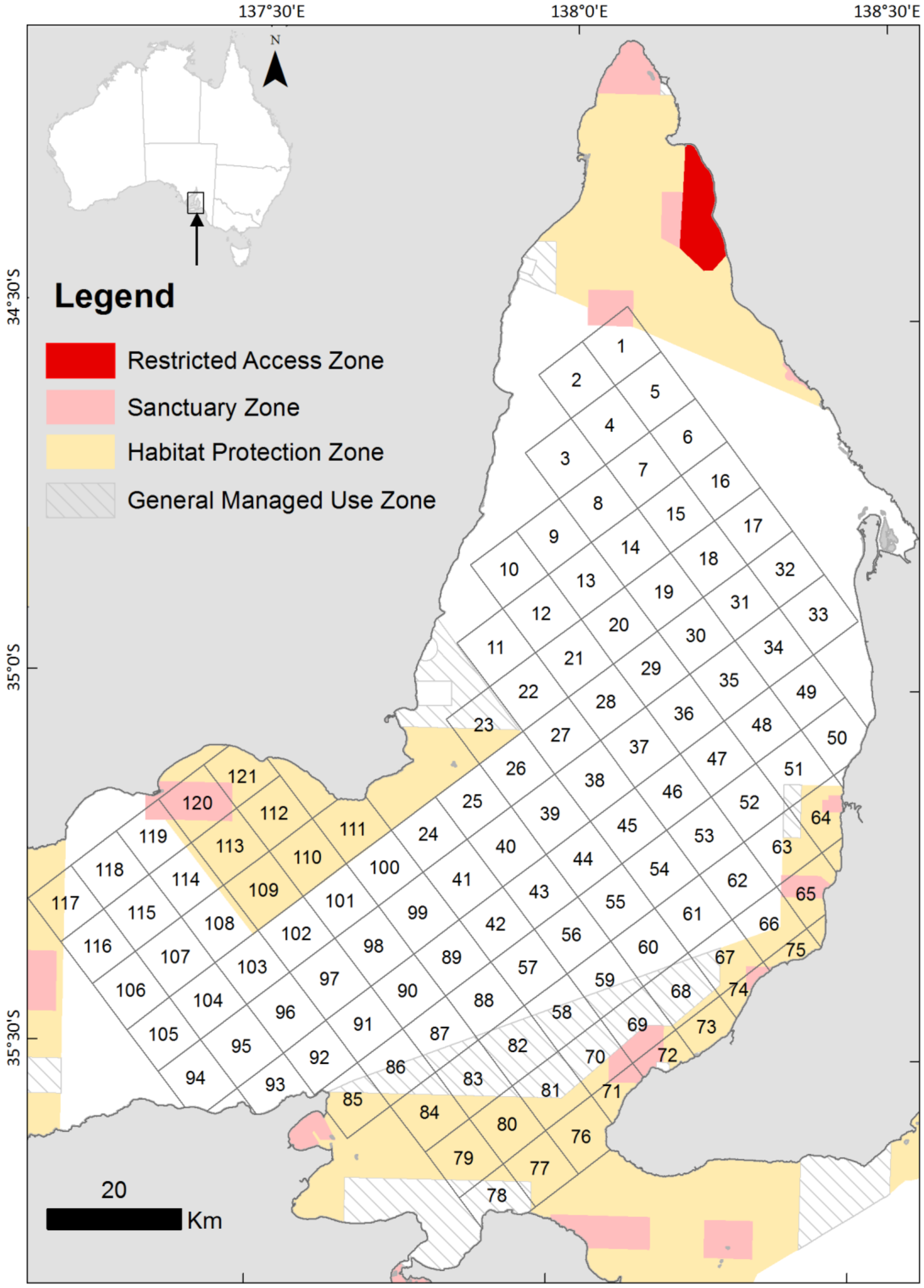

Figure 1.1 The research management blocks for the Gulf St Vincent Prawn Fishery.

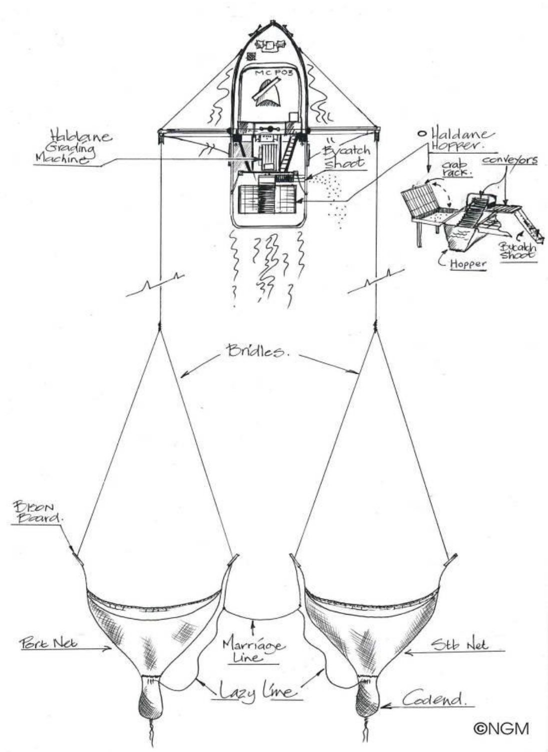

Figure 1.2 Double rig trawl gear and location of hopper sorting and prawn grading systems used in the Gulf St Vincent Prawn Fishery. Figure from Carrick (2003).

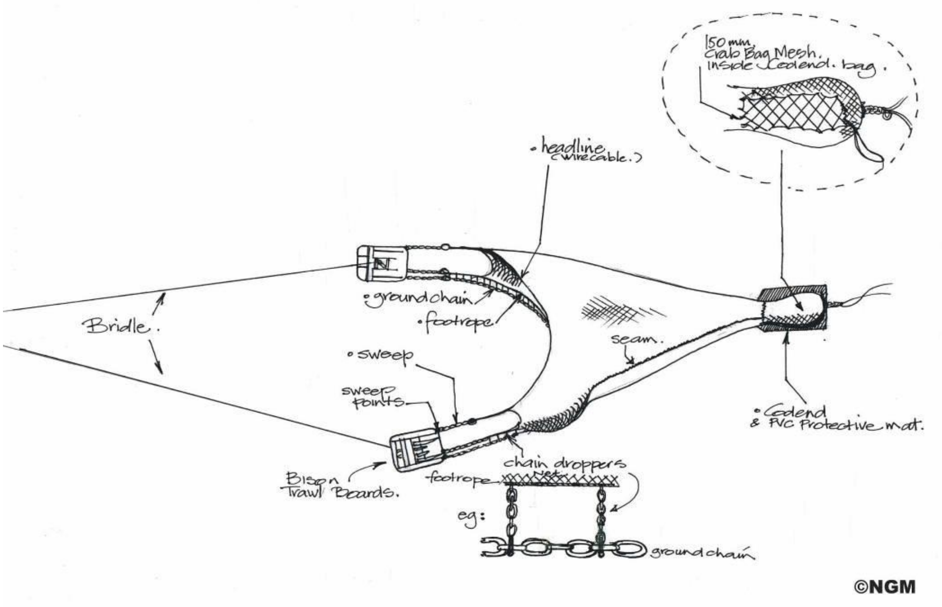

Figure 1.3 Trawl net configuration showing trawl boards, head rope, ground chain and cod end with crab bag as used in the Gulf St Vincent Prawn Fishery. Figure from Carrick (2003).

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 western king prawn resource. General regulations for South Australia's prawn fisheries are described in the *Fisheries Management (General)* Regulations 2007, with specific regulations located in the *Fisheries Management (Prawn Fisheries) Regulations 2006*. These three documents provide the statutory framework for management of the GSVPF. This is captured within the GSVPF Management Plan (Dixon and Sloan 2007) that provides the over-arching policy framework for daily management of the fishery. The key management milestones are presented in Table 1.1.

The GSVPF is a limited-entry, input-controlled fishery with 10 licensed operators. The fishery is managed through spatial and temporal restrictions on effort, as well as vessel size and power, type and number of trawl nets towed, maximum headline length and minimum mesh sizes. Fishing takes place between sunset and sunrise. No trawling is permitted in waters shallower than 10 m. Current management arrangements are summarised in Table 1.2.

The GSVPF has undergone considerable management changes over the past 40 years. Zacharin (1997) developed the first Gulf St Vincent Prawn Fishery Management Plan that documented the management history, policy framework and Performance Indicators for the fishery. A review and update of the Management Plan (hereafter termed the Plan) was undertaken in 2007 (Dixon and Sloan 2007).

Table 1.1 Major management milestones for the Gulf St Vincent Prawn Fishery.

Date	Management Change
1967	Commercial prawn fishing commences in GSV
1968	All SA waters closed to trawling except for specific managed zones for which permits are offered and all waters less than ten metres are closed to trawling
1969	The *Preservation of Prawn Resources Regulations 1969* is introduced and vessels licensed to fish for prawns
1975	The fishery is split into two zones when five permits are issued to specifically fish in Investigator Strait
1982	Number of Investigator Strait zone fishers reduced to two
1982	Triple rig trawl nets introduced
1986	A review of management was completed by Prof Parzival Copes
1986	A licence rationalisation strategy was implemented as an outcome of the review
1987	The *Fisheries (Gulf St Vincent Prawn Fishery Rationalisation) Act 1987* is introduced
1987	The two Investigator Strait entitlements removed and four GSVPF licences removed over the following four years and the two zones are once again amalgamated

Date	Management Change
1990	Prof Parzival Copes was requested to complete his second review of the fishery
1990	Licences reduced to 10 in GSVPF
1991	Fishery closed in June
1991	A Select Committee of the House of Assembly of South Australia reviewed the fishery's management options
1994	The fishery re-opened in February
1995	A review of the fishery was conducted by Dr Gary Morgan
1998	First management plan for the fishery was introduced (Zacharin 1998)
2000	*Fisheries (General) Regulations 2000* enabled "large" vessels to enter the fleet
2007	The second management plan was implemented (Dixon and Sloan 2007)
2011	A review of the fishery was undertaken by (Knuckey *et al*. 2011).
2012	The fishery was closed in November by unanimous agreement of industry. Introduction of T90 mesh cod end
2013	Morgan and Cartwright (2013) completed a review of the fishery management framework
2014	Dichmont (2014) review of the stock assessment methods, processes and outputs.
2014	Fishery reopened to fishing in November 2014. Individual transferable units introduced. *Revised framework for longer-term management of the Gulf St Vincent Prawn Fishery* developed

Table 1.2 Current management arrangements for the Gulf St Vincent Prawn Fishery

Management tool	Current restriction
Permitted species	*Penaeus (Melicertus) latisulcatus*, *Ibacus* spp., *Sepioteuthis australis*
Limited entry	10 licences
Licence transferability	Permitted
Corporate ownership	Permitted
Spatial and temporal closures	Yes
Method of capture	Demersal otter trawl
Trawl rig	Single, double or triple rig
Trawling times	Not during daylight hours
Maximum combined headline length	27.43 or 29.26 m (non-amalgamated gear), 43.89 m (amalgamated gear)
Minimum cod end mesh size	58 mm
Maximum vessel length	22 m
Maximum vessel power	336 kW
Catch and effort data	Daily logbook and Catch Disposal logbook submitted after each trip
Landing locations	Landings permitted anywhere in the State
Landing times	Landings permitted at any time during the season

Following recommendations made in an independent review of the GSVPF in 2011, two significant changes were implemented in the fishery during the 2011/12 season: 1) the number of surveys conducted during the fishing season was reduced to two (i.e. April and May); and 2) in March 2012, all trawl nets used for commercial fishing were modified to T90-mesh cod-ends and modified Nordmore grids to facilitate the escapement of small prawns and reduce the level of bycatch (Dixon *et al.* 2013). From 2012, surveys were conducted using T90-mesh cod-ends and grids in one net and with traditional diamond mesh in the alternate net. Data relating to the catch of each net were recorded separately.

Following the fishery's closure in 2012/13–2013/14, an interim management framework was developed with stakeholder input and implemented in November 2014. The management framework includes an individual transferrable effort (ITE) system, which adopts transferrable nights as the effort unit. Under the new management framework, a number of control rules have been removed from the fishery. Specifically, fishing activity during each fishing period was previously guided by harvest strategy decision rules, based on mean prawn size data from fishery-independent surveys, to spatially restrict fishing operations using closure lines. At sea decision rules relating to maximum total catch and minimum average catch were also in used to adjust closure lines or close areas to fishing.

From 2014/15, control rules for spatial management, mean prawn size and mean nightly catches per vessel were removed and the St Vincent Gulf Prawn Boat Owner's Association developed an industry code of practice. The code of practice is a non-legislated document which describes expected activities for the GSVPF that are not included in regulation or licence conditions. The industry code of practice specifies that the target-size prawns should be larger than 28 prawns per kg. If prawns in any shot are smaller than 32 prawns per kg skippers must implement a "move-on" provision (i.e. skippers move the vessel away from the path of the previous shot by a buffer of one nautical mile). A minimum catch "move-on" provision was also trialled for the 2014/15 and 2015/16 seasons. This required skippers to "move-on" where catches were less than 350 kg per vessel per night, over two consecutive nights. The code of practice also includes two distinct regions managed throughout the fishing season. Zone 1 (North of 35°09' South) open for pre-Christmas fishing and from 1 March to 15 April, and Zone 2 (South of 34°55' South) open from 16 April to 31 July. These zones are intended to represent historical areas of operation for the fishery on a season basis and skippers are encouraged to contain fishing within these zones.

From 2014/15, the allocated nights could be used anytime during the season, however, the number of allocated fishing nights that could be fished pre-Christmas (November and December) was restricted. A revised daily logbook and nightly fishing reports were also implemented from 2014/15. The daily reports require licence holders to provide more detailed spatial information (start and end coordinates of each trawl-shot) and the nightly fishing reports require a summary of total catch unloaded per grade which is reported within 48 hours of unloading. Also, in November 2015, restrictions on the construction of the T90 cod-end were modified so that no more than 33 meshes were made up of standard mesh (previously between March 2012 and November 2015 no more than 10 meshes were allowed).

1.3. Biology of the western king prawn

1.3.1. *Distribution*

The western king prawn, *P. latisulcatus,* is distributed throughout the Indo-west Pacific (Grey *et al.* 1983). Its distribution in South Australia is unique, as it is at the lowest end of its temperature tolerance range, primarily restricted to waters of Spencer Gulf and GSV and along the West Coast of South Australia (Ceduna, Venus Bay and Coffin Bay).

P. latisulcatus is a benthic species that prefers sandy areas to seagrass or vegetated habitats (Tanner and Deakin 2001). Both juvenile and adult prawns exhibit strong diel behaviour of daytime burial and nocturnal activity (Rasheed and Bull 1992; Primavera and Lebata 2000). Strong lunar and seasonal (attributed to temperature) differences in activity are also exhibited, where prawn activity and therefore catchability are greater during the dark phase of the lunar cycle and during warmer months (Penn 1976; Penn *et al.* 1988).

The distribution and abundance of *P. latisulcatus* within gulfs and estuaries are affected by salinity and the presence of sandy substrate (Potter *et al.* 1991). Higher abundances are associated with salinities above 30‰ (Potter *et al.* 1991). Tagging experiments have shown that tagged-prawn movements in GSV were predominately north to south (Kangas and Jackson 1997). Tag-recaptures from releases in eastern Investigator Strait showed a general west and north-west displacement, however, this was based on a small number of tag returns (Kangas and Jackson 1997).

1.3.2. *Reproductive biology*

Adult prawns aggregate, mature, mate and spawn in deep water (>10 metres) between October and March (King 1977). Ovary development followed by spawning of fertile eggs occurs during a single intermoult period (30-40 days) (Penn 1980) where fertilisation presumably occurs immediately prior to, or on release of, the eggs by the female. Multiple spawning events may also occur as spawning frequency is related to moulting frequency (Penn 1980; Courtney and Dredge 1988). During the peak spawning period, the sex ratio of harvested *P. latisulcatus* is typically female-biased, likely due to greater foraging activity of females (Penn 1976; Penn 1980; Svane and Roberts 2005). The ideal temperature range for spawning is between 17°C (Penn 1980) and 25°C (Courtney and Dredge 1988), which generally coincides with spring and summer in South Australia (~October to March). In both gulf fisheries in South Australia, the majority of spawning occurs in November and December, and likely relates to the ability of prawns to optimise reproductive success via shorter larval durations and higher larval survival that result from the relatively higher gulf temperatures during that time of year (Roberts *et al.* 2012).

In all three South Australian fisheries, fecundity increases exponentially with carapace length (CL), however the increase is more pronounced in the cooler waters of GSV (Carrick 2003). Thus, larger prawns make a greater contribution to total egg production due to greater insemination rates and higher fecundity (Penn 1980; Courtney and Dredge 1988; Carrick 1996). However, ovarian senescence in large females may occur (Courtney *et al.* 1995).

1.3.3. *Early life history*

P. latisulcatus has an offshore adult life history phase and an inshore juvenile phase. Prawn larvae undergo metamorphosis through four main stages: nauplii, zoea, mysis and post-larvae. Key parameters that affect larval development and survival are generally considered to be: temperature, salinity and food availability (Preston 1985; Jackson and Burford 2003; Bryars and Havenhand 2006; Lober and Zeng 2009). The effect of water temperature is an important factor, with faster development and higher survival in warmer water (Hudinaga 1942; Roberts *et al*. 2012).

Prawn larvae are dispersed by wind-driven and tidal currents. Kangas (1999) modelled larval dispersion in GSV and demonstrated that spawning events in northern GSV were more likely to result in settlement in northern nursery areas than spawning in southern GSV. In GSV, Kangas (1999) showed that post-larvae settled in inshore nursery areas at 1 mm CL, with juveniles 2–7 mm CL comprising 90% of the surveyed population. The post-larvae produced from early spawning events settled in nursery areas during December or January, when growth was high, and then emigrated to deeper water in May or June (at ~20 mm CL). Alternatively, post-larvae produced from late spawning settled in nurseries from March and due to slow growth they “over-wintered” in the nursery areas, recruiting to the trawl grounds in the following summer (Kangas 1999).

1.3.4. *Stock structure*

Analyses using r-DNA have shown significant genetic differences in haplotype distribution of *P. latisulcatus* between South Australia and Western Australia (Carrick 2003). However, an analysis of the genetic structure of *P. latisulcatus* using electrophoresis suggests a homogenous stock in South Australia (Carrick 2003).

1.3.5. *Growth*

As with other crustaceans, prawns undergo a series of moults to increase their size incrementally. The inability to directly age prawns has increased the reliance on tag-recapture and cohort analysis to determine their growth rate. Tag-recapture studies of prawns in GSV were undertaken by King (1977) and Carrick (1982). Growth parameters were determined from 464 recaptures using a modified von Bertalanffy growth model by Kangas and Jackson (1997). Differences in growth were apparent between genders and within years. Maximum growth occurred in April for males and early March for females. Between October and December, growth did not increase with increasing water temperature, which may have been due to the allocation of energy to reproduction rather than growth. Morgan (1995) also provided growth estimates for GSV from several sources including commercial length-frequency, fishery-independent length-frequency and tagging data.

Length-weight relationships have not been determined for adult prawns in GSV. The relationship between prawn carapace length (CL, mm) and weight (g) from Spencer Gulf was determined from a sample of over 2000 prawns (Carrick 2003). The power relationship described by the equation “Weight = $a \times$ carapace length^{b}” varies between males (a= 0.00124, b=2.76) and females (a= 0.00175, b=2.66). Kangas (1999) determined the length-weight relationship for juvenile prawns in GSV (a= 0.00066, b=2.91, N=325) (Figure 1.11). The size range of individuals in the study of Kangas was 2.4–20.4 mm CL and sex could not be distinguished at such small sizes.

1.3.6. *Natural mortality*

The instantaneous rate of natural mortality for both sexes combined was estimated by Kangas and Jackson (1997) as 0.003 per day for GSV prawns. Morgan (1995) provided similar estimates of natural mortality from a range of empirical methods and models. These values are within the range of those estimated for *P. latisulcatus* in Spencer Gulf (0.003 to 0.005; King 1977), the West Coast Prawn Fishery (0.001 to 0.014; Wallner 1985) and Western Australia (0.002 to 0.005; Penn 1976). Sex-specific estimates of natural mortality from Xiao and McShane (2000) provided an opposing result, with 0.0031 per day for females and 0.0034 per day for males.

1.3.7. *Biosecurity and prawn health*

The health of South Australian populations of *P. latisulcatus* and the potential effects of coastal pollutants, parasites and disease on growth, survival and reproduction is poorly understood. Roberts *et al.* (2010) assessed the disease status of prawns (focussing on viruses) collected from key nursery sites in both Spencer Gulf and Gulf St Vincent. A naturally occurring (endemic), and likely harmless, MBV-like virus was observed in ~60% of prawns, which is a common virus known to occur throughout Australia.

1.4. Research program

There have been numerous projects to address key knowledge gaps for western king prawns in Gulf St Vincent. They relate to aspects of western king prawn population dynamics and biology (King 1977; Kangas 1999; Xiao and McShane, 2000; Tanner and Deakin 2001; Roberts *et al.* 2012), stock structure (Carrick 2003), biosecurity and disease (Roberts *et* al; 2009), gear technology (McShane, 1996; Broadhurst *et al.* 1999; Dixon *et al.* 2013; Gorman and Dixon, 2015), trawling impacts (Tanner 2003) and fisheries modelling (Xiao, 2004). Previous stock assessment and stock status reports also provide detailed biological information and catch history that has been used to assess the status of the fishery (Kangas and Jackson 1997; Xiao and McShane 1998; Boxshall *et al.* 1999; Boxshall and Williams 2000; Boxshall and Johnson 2001; Svane 2003; Svane and Johnson 2003; Roberts *et al.* 2005;2007a, 2007b; 2008; 2009; Hooper *et al.* 2009; Dixon *et al.* 2011; 2012; Beckmann *et al*. 2015).

From 2011 to 2014, three separate independent reviews of the stock assessment and harvest strategy for the GSVPF were conducted (Knuckey *et al.* 2011; Morgan and Cartwright 2013; Dichmont 2014). As a result of these reviews, there has been a substantial rationalisation of the research program. The principal change is a reduction from four to one fishery-independent surveys (FIS) per year (conducted in May). The 2015/16 research program included the collection of basic fisheries statistics, biological and FIS information and the production of this stock status report that assesses the status of the GSVPF.

1.5. Information sources used for assessment

1.5.1. *Fishery-independent survey data*

Fishery-independent data have been collected for the GSVPF since 1984 through FIS and on-board observing. Surveys were conducted in consecutive fishing periods (December, March, April and May) between 2004/05 and 2010/11. Beginning 2011/12, the number of stock assessment surveys was reduced from four to two, with surveys conducted in April and May on the dark of the moon. Surveys were not conducted in 2012/13 and from 2013/14 a single stock assessment survey has been conducted in May.

1.5.2. *Commercial catch and effort data*

SARDI maintains a comprehensive catch and effort database for the GSVPF using data collected from the compulsory fishing logbook system (see Dixon *et al*. 2012). Fishery-dependent (catch and nominal effort) data for the GSVPF are available from 1968. Annual data (1968–1972) and monthly data (January 1973 to June 1987) were obtained from South Australian Fishing Industry Council (SAFIC) annual reports. Data from July 1987 were obtained from daily commercial logbooks provided to SARDI. Commercial logbooks from July 1987 to June 1991 provided data on estimated prawn catch, trawl time and fishing block. No fishing was conducted from July 1991 to February 1994. Logbooks from March 1994 onward provided data for each trawl-shot including start/finish times, estimated prawn catch and fishing block. Estimated prawn catch for each shot was adjusted using validated post-harvest catches reported in monthly logbooks. Catch and effort data includes fishery-dependent “searching” and spot survey catches, as well as fishery-independent survey catches that are retained for sale by the St Vincent Gulf Boat Owners Association.

1.6. Stock status classification

A National Fishery Status Reporting Framework (NFSRF) for stock status classification was recently developed for the consistent assessment 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 reference points. Each stock is then classified as ‘sustainable’, ‘transitional-recovering’, ‘transitional-depleting’, ‘overfished’, ‘environmentally limited’, or ‘undefined’ (Table1.3). PIRSA has adopted this classification system to determine the status of all South Australian fish 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. Fishery-independent surveys

Surveys using commercial vessels with fishery-independent observers on-board, were conducted in Gulf St Vincent prior to the December, March, April and May harvest periods from 2004/05 to 2010/11, in March and May in 2012/13, and in May only from 2013/14. To enable temporal comparison of the FIS data used to assess the performance of the fishery (standardised survey CPUE and the fishery recruitment index), this report uses data collected from May surveys only.

From 2012, surveys were conducted using T90-mesh cod-ends and grids in one net and with traditional diamond mesh in the alternate net, and the catch was sorted separately for each net.

Surveys were typically done using between three and six vessels over two to three consecutive nights commencing on the second and third nights following the last quarter of the moon. There were two exceptions; 1) 2005 to 2008, when surveys were conducted during one night on the dark of the moon with approximately ten vessels and, 2) the 2014 survey, which was extended over the dark phase of the moon with only one vessel participating. From 2004/05 to 2015/16, the number of sites sampled has ranged from 101–112, except for 2014 where a 'reduced' survey of 48 sites was completed. This report includes data from up to 109 survey locations as specified in the draft Management Plan.

Survey shots were done at semi-fixed sites in the 10 regions of the GSVPF (Figure 2.1). Each shot began close to a known location (recorded by Global Positioning System, GPS) and then continued in a set direction for a specified period of time (usually 30 minutes). The total distance covered was dependent on trawl speed, which was influenced by vessel power, tide and weather conditions. Data collected for each shot location include the total catch, catch of each prawn size grade, number of nets used, trawl duration, tide direction, and the number of prawns in a 7 kg bucket (bucket count) as a rapid measure of prawn size. Catch per unit effort (CPUE) was expressed in kg.trawl-shot^{-1}± standard error (SE). Where T90 and diamond mesh were sampled side by side, catch from one net was multiplied by two.

Estimates of mean prawn size (prawns per kg, PPKG) are calculated from the 7 kg subsample, with higher counts representing smaller prawns and lower counts representing larger prawns. To present the spatial distribution of catch rate and prawn size, prawns were defined as small (>33 PPKG), medium (28–33 PPKG), large (26–28 PPKG) and extra-large (<26 PPKG), and CPUE was defined as very low (<50 kg/trawl-shot), low (50-100 kg/trawl-shot), moderate (100–150 kg/trawl-shot) and high (>150 kg/trawl-shot). The GPS locations of each trawl station were used to specify the prawn size (colour coded) and CPUE (bubble size increases with increased CPUE).

A random sample of 100 prawns is also taken from each shot to obtain information on sex ratio and length-frequency. The catch rate of recruits per trawl-hour was determined for each survey. 'Recruits' are defined for this purpose as prawns ≤32 mm CL for males and ≤34 mm CL for females.

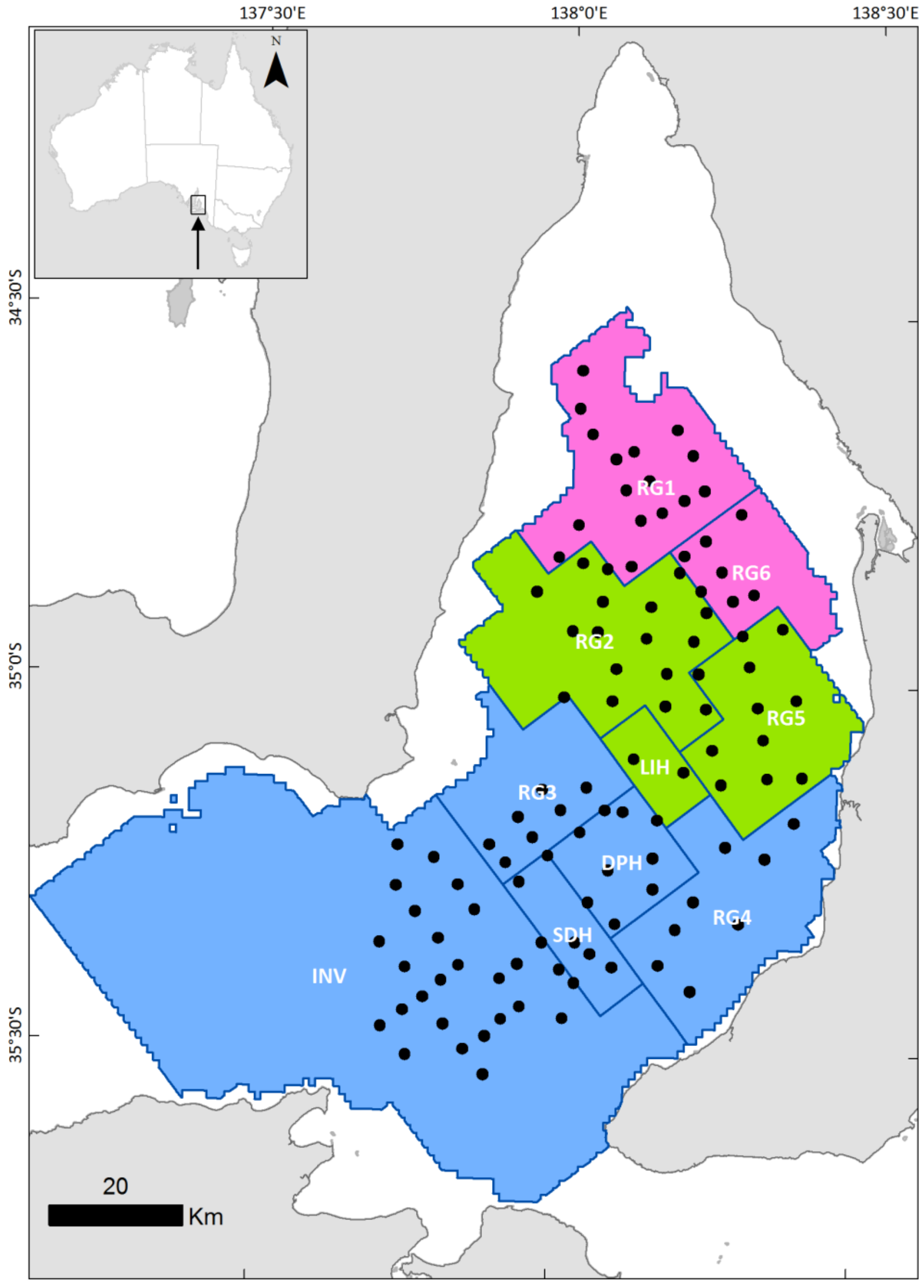

Figure 2.1 The 109 survey stations specified in the draft Management plan and regions of the Gulf St Vincent Prawn Fishery. The northern gulf (pink) includes region (RG) 1 and RG6, the central gulf (green) includes RG2, RG5 and little hole (LIH), and the southern gulf (blue) includes deep hole (DPH), southern deep hole (SDH) and Investigator Strait (INV).

2.2. Fishery statistics

2.2.1. *Catch and effort*

In this report, a “fishing year” is defined as the period from 1 November to 31 July the following year. Catch data includes all commercial and survey catch (t) and effort is presented as either vessel nights or kg.hour^{-1}. As the main spawning period for *P. latisulcatus* in GSV extends from November to March, catch data are also presented for early (Nov. – Dec.), late (Jan. – Mar.) and non-spawning (Apr. – Oct.) periods. The spatial distribution of the annual harvest per fishing block is presented from 2007/08–2015/16, however, confidential data (<5 licence holders) are not shown.

2.2.2. *Prawn size*

Mandatory reporting of commercial prawn-grade data in daily logbooks was introduced in 2005/06. Data were available from five large vessels from March 2006, six large vessels from March 2007, seven large vessels from December 2009 and on occasions by one small vessel from April 2007. Consequently, total graded catch does not always sum to the total reported catch. Data analysed for this section were from commercial fishing nights only. The grade is determined from the number of prawns to the pound (e.g. U10 = under 10 prawns per pound). In this section, data were reported as the proportion of the commercial catch occurring in each of the size classes and the number of prawns per kilogram calculated from grade data (see Dixon *et al.* 2012). To facilitate interpretation of the prawn-grade data, grades were converted to four categories (Table 2.1). For analysis of trends within years, a fifth category, soft and broken (S&B), was established for prawns that were not graded. The number of prawns per kilogram was estimated for each of the prawn grades as per (Dixon *et al.* 2012). Uncertainty associated with the calculation of prawn size arises from: 1) data not being available from the entire fleet; 2) assumptions regarding the calculation of mean prawn size (converting reported grades to prawns per kilogram); and 3) uncertainty associated with the un-validated grade data provided in logbooks (Dixon *et al.* 2012).

Table 2.1 Categories assigned to reported prawn grades from commercial logbook data for the Gulf St Vincent Prawn Fishery.

Prawn grade	Categories in logbook	PPKG
U8 (XL)	U6	13.2
	U8, XL	15.4
	U10, L	19.8
10/15 (Large)	9/12	23.1
	U12	24.2
	LM	27.5
	10/15	27.5
	13/15	30.8
	10/20 (50%), 12/18 (50%)	33.0
16/20 (Medium)	10/20 (50%), 12/18 (50%)	33.0
	16/20, M	39.6
21+ (Small)	SM, 19/25	48.4
	21/25	50.6
	S, 20+, 21/30	56.1
	26+	61.6
	30+, 31/40,	78.1
SB (Soft & Broken)	S/B, B&D, MIX, REJ, SMS, blank, ERR	

2.3. Catch rate standardisation

CPUE is assumed to be proportional to prawn abundance. However, to improve relationships between CPUE rates and relative biomass, it is often important to standardise CPUE to remove the influence of variables that are not related to abundance.

CPUE standardisation was undertaken using survey data (standard diamond cod-end only) collected from 109 shot locations from 2004/05–2014/15 as outlined in the draft Management Plan and daily logbook data from 1990/91–2014/15. Data was aggregated to catch (survey: kg trawl-shot^{-1}; commercial: kg block-vessel-night^{-1}) and 95% confidence intervals (CI) are shown. Survey catches (per 30-min trawl-shot) was adjusted to the standard measure of two nets where necessary. Generalised linear modelling (GLM) was used to standardise CPUE as per the methods in Noell *et al.* (2015). The commercial logbook database prior to 1991 was incomplete, particularly by block and vessel, and therefore not included in the standardisation. Variables found to be non-significant in the bio-economic model (Noell *et al.* 2015) were not included in the model.

3. RESULTS

3.1. Fishery-independent surveys

3.1.1. *Nominal indices*

Nominal survey CPUE (diamond mesh) increased from 2004/05 to 2007/08 and declined thereafter (Figure 3.1a). Prior to the closure of the fishery in 2012/13, survey CPUE had declined to a historical low of 22.6±2.2 kg.trawl-shot^{1} in May 2012. CPUE from the 'reduced' May 2014 survey was 54.0±4.8 kg.trawl-shot^{-1}, but declined to 30.9±2.1 kg.trawl-shot^{-1} in May 2015. In May 2016, survey CPUE rate increased 43% to 44.2±2.9 kg.trawl-shot^{-1}. This was the second highest CPUE on record after May 2014. CPUE from the T90 mesh sampled since 2011 has followed a similar trend increasing 67% from 21.9±1.8 kg.trawl-shot^{-1} in 2015 to 36.6±2.6 kg.trawl-shot^{-1} in 2016.

Trends in 'adult' CPUE (>20+ grade from the entire graded catch) generally reflect those of total CPUE (Figure 3.1b). In May 2016, adult CPUE was 35.7±2.6 kg.trawl-shot^{-1}, a 24% increase compared to May 2015 (28.8±1.9 kg-trawl.shot^{-1}) and the fourth highest on record. CPUE from the T90 mesh sampled since 2011 has followed a similar trend to that estimated from diamond mesh, increasing 44% from 20.7±1.6 kg.trawl-shot^{-1} in 2015 to 29.8±2.3 kg.h^{-1} in 2016.

The survey CPUE of 'new recruits' (20+ grade from the entire graded catch), has fluctuated through time (Figure 3.1c). Prior to the fishery closure in 2012/13, the CPUE of 'new recruits' more than doubled between consecutive May surveys in 2011 and 2012. Following the fishery closure, the 'new recruit' CPUE from the 'reduced' May 2014 survey was 12.9±1.6 kg.trawl-shot^{-1}, the highest on record. In May 2016, the 'new recruit' CPUE was 9.2±1.2 kg.trawl-shot^{-1}, three times higher than the 2015 CPUE (3.2±0.5 kg.trawl-shot^{-1}) and the second highest on record. CPUE of new recruits estimated from the T90 mesh since 2011 has displayed a similar trend to that estimated from diamond mesh, with more than a three-fold increase observed from 2015 (2.1±0.3 kg.trawl-shot^{-1}) to 2016 (7.5±0.9 kg.trawl-shot^{-1}).

The recruitment index, calculated from a seven kg subsample per shot, reached a historical high of 1,069±158 recruits.h^{-1} during the 'reduced' survey in May 2014 (Figure 3.1d). Following re-opening of the fishery in November 2014, the May 2015 recruitment index was (327.6±62.2 recruits.h^{-1}) the lowest since 2004/05 (239.2±31.5 recruits.h^{-1}). In May 2016 the recruitment index was 880.9±120.6 recruits.h^{-1}, which was more than double the value observed in 2015 (327.6±62.2 recruits.h^{-1}) and the second highest value on record. The recruitment index from the T90 mesh sampled since 2011 displayed a similar temporal trends to that estimated using the diamond mesh, with more than a three-fold increase observed from 2015 (175.1±37.0 recruits.h^{-1}) to 2016 (660.9±89.0 recruits.h^{-1}).

Mean prawn size, calculated from a 7 kg subsample per shot, has fluctuated since 2007/08 (Figure 3.1e). Prior to the fishery closure, mean prawn size was the smallest on record at 37.1±1.2 prawns.kg^{-1} in May 2012. Following the fishery closure, mean prawn size increased 13% in May 2014 (32.8±1.1 prawns.kg^{-1}) and in 2015, mean prawn size was the largest on record at 29.1±0.8 prawns.kg^{-1}. In 2016, mean prawn size decreased 18% to 34.4±1.1 prawns.kg^{-1}. Temporal trends in mean prawn size estimated from the T90 mesh since 2011 are similar to those estimated from diamond mesh, with a 19% decrease observed from 2015 (28.7±0.7 prawns.kg^{-1}) to 2016 (34.1±1.0 prawns.kg^{-1}).

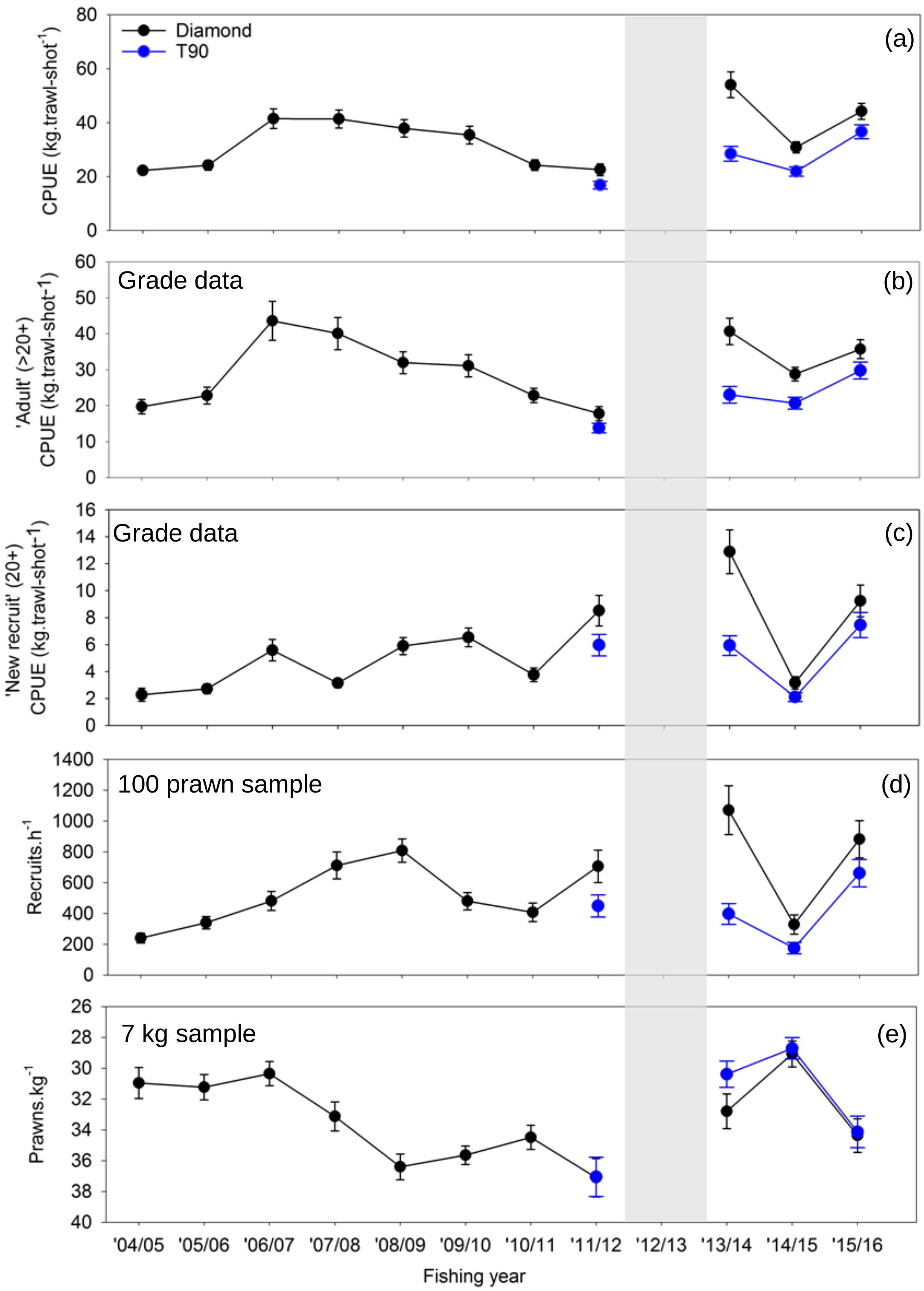

Figure 3.1 Key outputs from May fishery-independent surveys used to assess the status of the Gulf St Vincent Prawn Fishery; (a) total catch per unit effort (CPUE, $kg.h^{-1}$), (b) 'adult' (>20+) CPUE ($kg.h^{-1}$), (c) 'new recruit' (20+ grade) CPUE ($kg.h^{-1}$), (d) the recruitment index ($recruits.h^{-1}$) estimated from a 100 prawn subsample per shot, and (e) prawn size ($prawns.kg^{-1}$) estimated from a 7kg subsample per shot. Indices were calculated from shots in the draft management plan (MP). Note, T90 and diamond gear was sampled side by side from 2011/12 and a reduced survey was conducted in 2013/14. Error bars = standard error.

3.1.2. *Standardised survey catch rate*

The standardised survey CPUE data differed slightly from the nominal survey CPUE (raw) data in terms of absolute values, but trends were very similar (Figure 3.2). Region, year-survey and vessel were all highly significant (Table 3.1); however, a low overall model goodness-of-fit (adjusted R^2 value 0.14) indicates other unaccounted sources of variability. Only 15.3% of the deviance in survey catches was explained by the model (fishing year-survey being the most important at 8.7%), which indicates that 84.7% of the deviance was caused by unknown factors.

Standardised survey CPUE generally increased from December–May, with peak catch rates most often occurring in April or May (Figure 3.2). Survey CPUE remained relatively low between December 2004 and 2006 (range: 14.3–25.3 kg.trawl-shot^{-1}) but increased to a high of 37.4 kg.trawl-shot^{-1} 95% CI [32.1, 43.3] in May 2007. Relatively high survey CPUE persisted from March in 2008 to May in 2010 (range: 26.3–37.3 kg.trawl-shot^{-1}). This was followed by a period of low survey CPUE from December 2010–May 2012 (range: 18.6–29.4 kg.trawl-shot^{-1}).

The fishery was closed during 2012/13 and no surveys were undertaken. Standardised survey CPUE more than doubled from 20.6 kg.trawl-shot^{-1} in May 2012 to 50.5 kg.trawl-shot^{-1} in May 2014, 95% CIs [17.3, 24.4] and [40.9, 61.5], respectively (Figure 3.3). The fishery was re-opened in November 2014 and the subsequent May 2015 survey indicated a 39% decline in standardised survey CPUE to 30.9 kg.trawl-shot^{-1}, 95% CI [25.7, 36.8]. The May 2016, standardised survey CPUE was 46.4 kg.trawl-shot^{-1}, 95% CI [40.1, 53.4]. This represented a 50% increase compared to 2014/15 and was the second highest May value on record.

Table 3.1. Analysis of deviance (Type II test) for the GLM used to standardise survey CPUE for the Gulf St Vincent Prawn Fishery. Abbreviations: SS, sum of squares; df, degrees of freedom; *F*, *F*-statistic. $R^2_{\text{adj}} = 0.14$.

Effect	SS	df	*F*
fishing year-survey	278.2	32.0	10.8***
region	151.5	7.0	27.0***
vessel	61.5	13.0	5.9***
residuals	2717.5	3384.0	NA

Significance: *** $p < 0.001$.

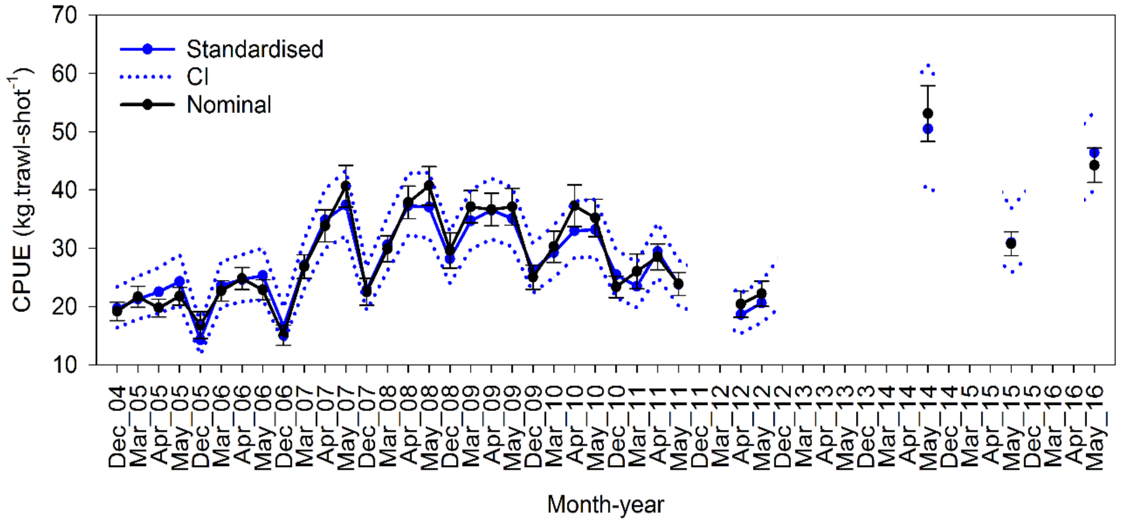

Figure 3.2 Comparison of model-predicted (standardised) mean survey catch per unit effort (CPUE, kg.trawl-shot^{-1}, 95% confidence intervals) in the Gulf St Vincent Prawn Fishery with raw (nominal) CPUE from December, March, April and May surveys from 2004–16. *No surveys were undertaken In December from 2011, in March from 2012 or in April and December from 2013.

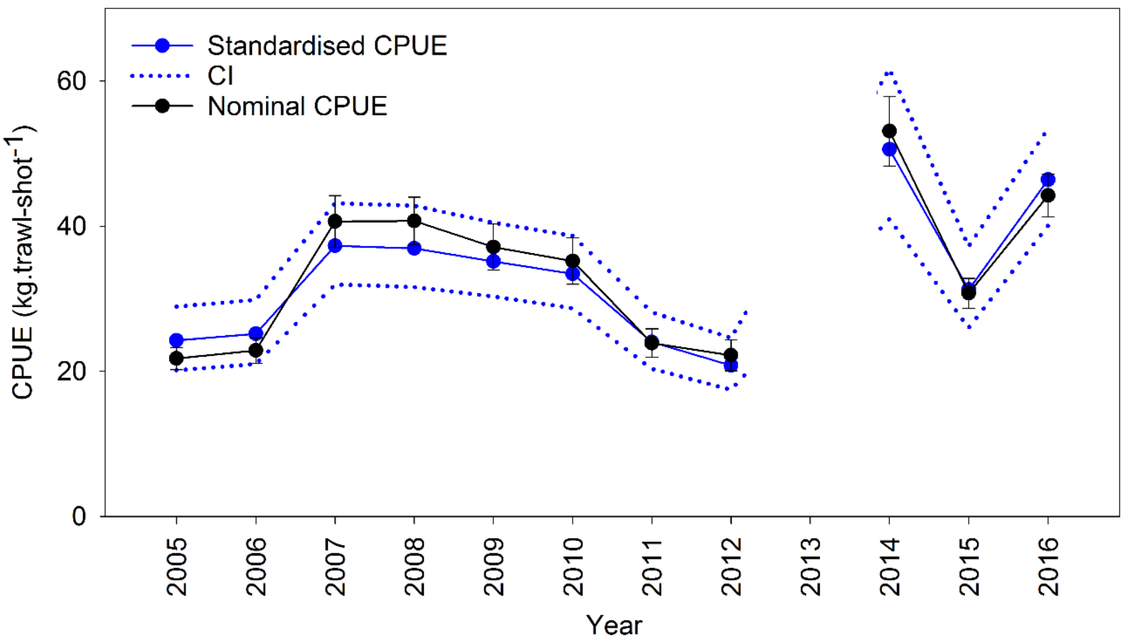

Figure 3.3 Comparison of model-predicted (standardised) mean survey catch per unit effort (CPUE, kg.trawl-shot^{-1}, 95% confidence intervals) in the Gulf St Vincent Prawn Fishery with mean raw (nominal) CPUE (±SE) during May fishery-independent surveys from 2004–2016. *No surveys were undertaken in 2013.

3.1.3. *Regional trends in size and abundance*

From 2007/08–20011/12, small (>33 prawns.kg^{-1}) and medium size prawns (30-33 prawns.kg^{-1}) were broadly distributed throughout the gulf, with high (>150 kg/trawl-shot) and moderate CPUE (100-150 kg/trawl-shot) observed in multiple blocks from 2007/08 to 2009/10 (Figure 3.4). The spatial distribution of large (28-30 prawns.kg^{-1}) and extra-large size prawns (<28 prawns.kg^{-1}) varied between years. High CPUE of extra-large prawns was observed in several blocks in the northern gulf in 2007/08–2009/10, however, in 2010/11 and 2011/12 CPUE was mostly low (50-100 kg/trawl-shot) or very low (<50 kg/trawl-shot) for all size classes throughout the gulf. In 2013/14, the spatially reduced survey indicated moderate CPUE of large and extra-large prawns in the middle and southern gulf, and moderate CPUE of small and medium sized prawns in the middle and southern gulf. The 2014/15 survey indicated that low–moderate catch rates of large and extra-large prawns occurred throughout the gulf, while the CPUE of small and medium prawns was reduced compared to 2013/14 and higher in the northern part of the gulf compared to the southern part of the gulf. The 2015/16 survey indicated that moderate CPUE of extra-large prawns occurred in the southern part of the gulf while moderate–high CPUE of small and medium prawns occurred in the northern part of the gulf.

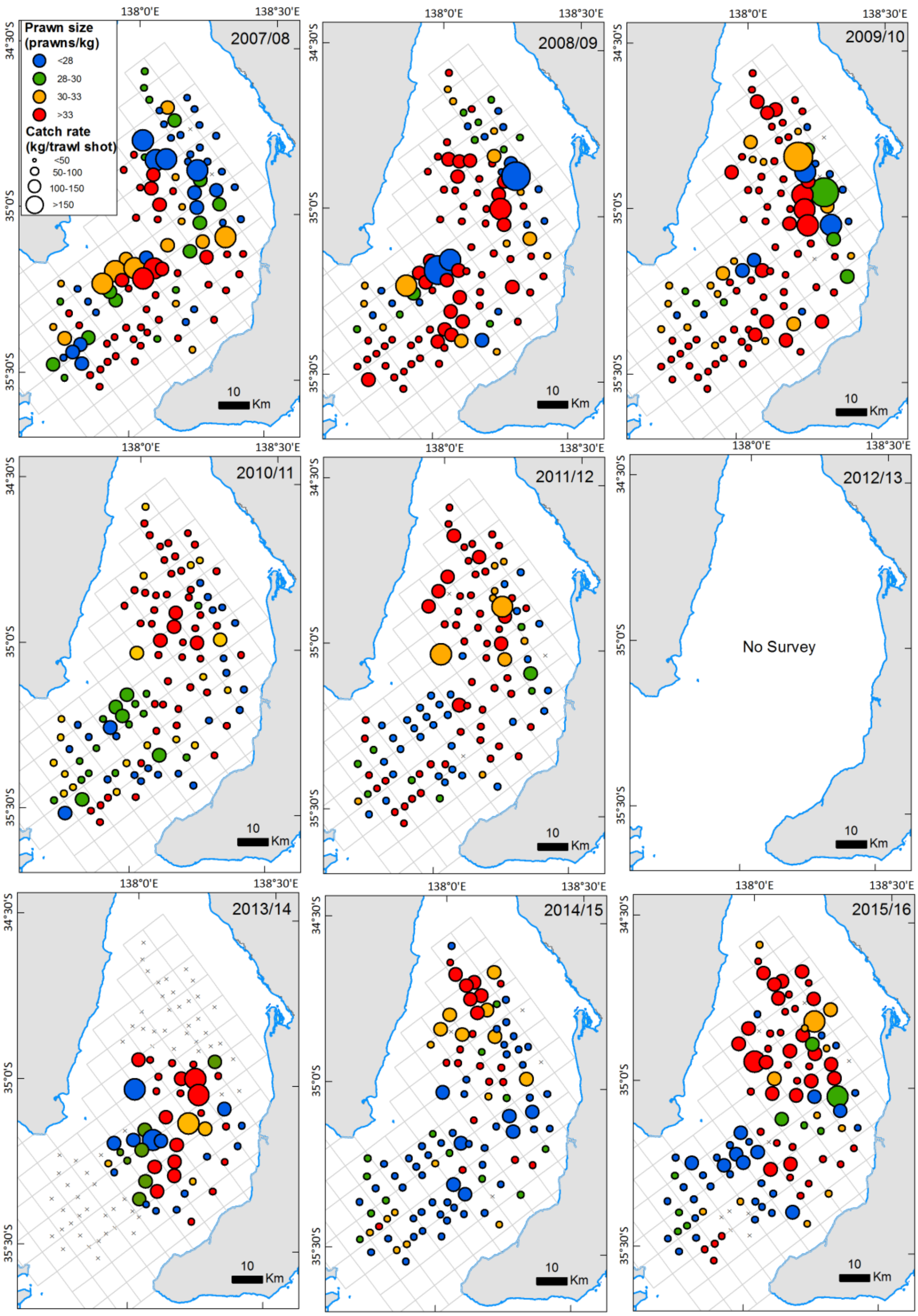

Figure 3.4 Catch rate and mean size from the diamond mesh cod end during the May 2015/16 stock assessment surveys of the Gulf St Vincent Prawn Fishery. (x) shot not completed.

3.2. Fishery statistics

3.2.1. *Catch and effort*

The total commercial harvest in 2015/16 was 221.9 t (including 4.1 t survey catch), which was 12.0% lower than 2014/15 (252.2 t, including 2.8 t survey catch; Figure 3.5a). Harvest during the early spawning period (November–December) was 20.1 t in 2015/16 and this represented 9.1% of the total annual catch. This was a 64.8% decrease compared to 2014/15 (57.1 t) and relatively low compared to historical levels. Similar to 2014/15, a high proportion of catch (24.5%) was also harvested during the late spawning period during March 2015 (54.4 t; Table 3.1). The highest proportion of catch (147.4 t, 66.4%) was harvested during the non-spawning season (April-July) in 2015/16. This was a 14.1% increase compared to 2014/15 (147.4 t) as a result of increased catch during July 2015/16 (42.7 t) compared to 2014/15 (22.0 t)

Commercial fishing was conducted over 296 vessel nights in 2015/16. This comprised 99% of the total allowable commercial effort (TACE) of 300 vessel nights (Figure 3.5b). Effort was similar to 2014/15 (294 vessel nights), but low compared to historical levels. During early spawning (November–December), 30 vessel nights were fished (100% of the allocation pre-Christmas). This was a 40% decrease compared to 2014/15 (50 vessel nights).

The total commercial effort in 2015/16 was 2,798 trawl hours, 4% lower than 2014/15 (2,904 hours, Figure 3.5c). This was the lowest effort since 2011/12 (2,428 trawl hours) and remains among the lowest levels of nominal effort observed for the fishery.

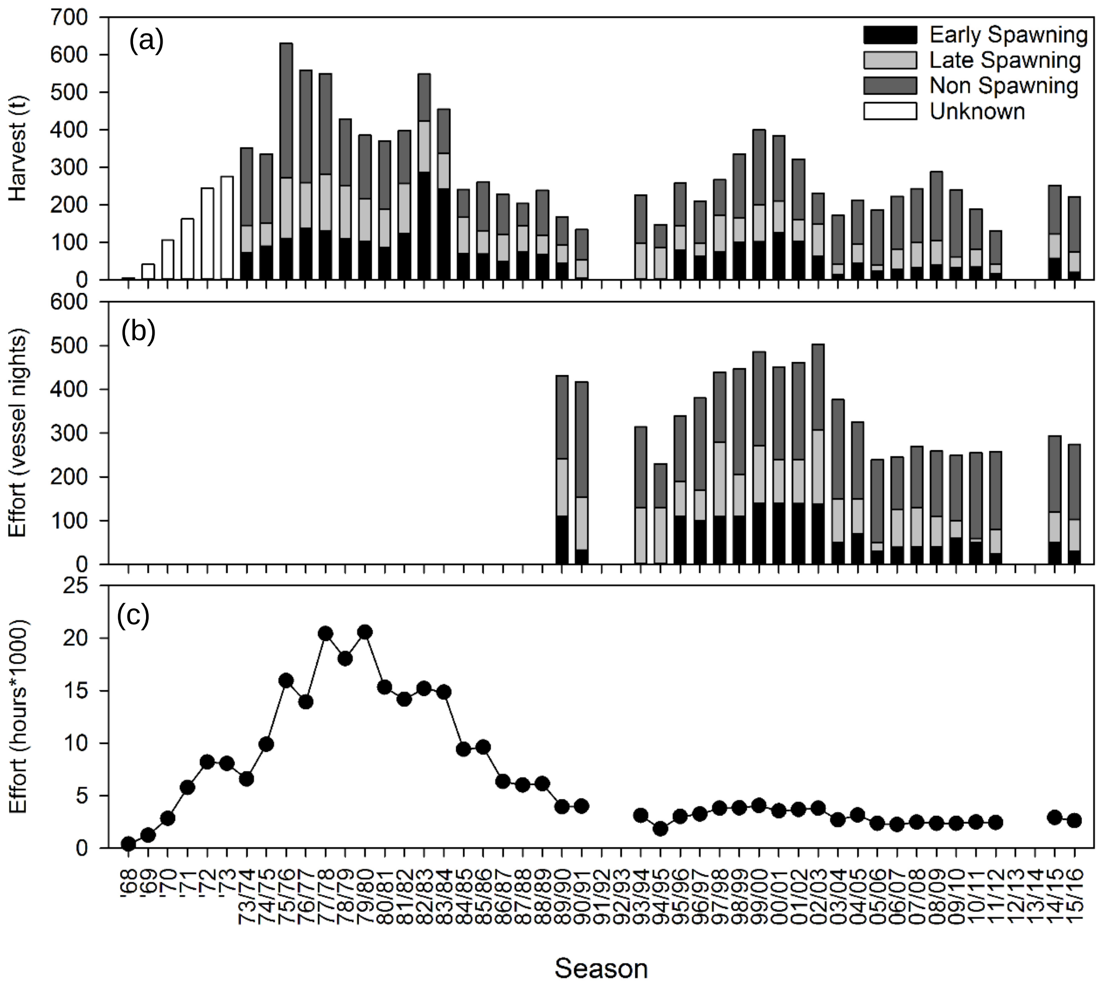

Figure 3.5 Fishery-dependent catch and effort data outputs for the Gulf St Vincent Prawn Fishery; (a) annual catch (t, including surveys) and (b) effort (vessel nights) separated by early spawning (November–December), late spawning (January-March) and non-spawning (April-October) and (c) annual commercial effort (hours * 1000).

Table 3.2. Monthly distribution of commercial (and survey) catch in the Gulf St Vincent Prawn Fishery from 1989/99–2015/16.

Season	Nov	Dec	Feb	Mar	Apr	May	Jun	Jul	Total
1989/99	35.8	9.4	-	47.8	33.6	42.3	-	-	168.8
1990/91	-	5.3	-	48.0	36.0	31.9	13.1	-	134.3
1991/92	-	-	-	-	-	-	-	-	-
1992/93	-	-	-	-	-	-	-	-	-
1993/94	-	-	-	97.9	69.3	41.2	17.0	-	225.4
1994/95	-	-	26.0	60.9	52.4	8.0	-	-	147.3
1995/96	30.7	48.3	-	65.5	46.4	67.1	-	-	258.0
1996/97	37.9	25.7	-	34.8	41.9	45.0	24.7	-	209.9
1997/98	43.8	31.7	15.8	81.3	53.7	40.5	-	-	266.9
1998/99	69.8	30.5	-	65.6	99.7	48.1	22.5	-	336.2
1999/00	19.3	82.6	27.3	71.0	76.3	91.7	32.0	-	400.2
2000/01	65.9	60.6	-	84.3	86.9	72.4	14.8	-	384.9
2001/02	8.8	94.0	-	58.5	80.6	62.1	18.1	-	322.1
2002/03	4.0	60.1	11.5	72.8	46.6	37.0	-	-	231.9
2003/04	-	13.9	-	28.9	69.5	57.7	2.5	-	172.5
2004/05	-	43.5 (2.0)	-	50.1 (2.4)	40.9 (2.0)	46.7 (2.4)	27.2	-	208.4 (8.8)
2005/06	-	21.2 (1.9)	-	13.6 (2.5)	64.1 (3.6)	40.4 (2.5)	35.5	-	174.9 (10.5)
2006/07	-	26.5 (1.6)	-	51.5 (2.9)	86.1 (3.7)	45.3 (4.5)	-	-	209.4 (12.7)
2007/08	-	30.2 (2.5)	-	63.5 (3.3)	69.6 (4.2)	65.8 (4.5)	-	-	229.0 (14.4)
2008/09	36.5	(3.2)	-	56.3 (4.0)	53.1 (4.1)	126.7 (4.1)	-	-	272.6 (15.4)
2009/10	-	31.4 (2.3)	-	24.7 (2.6)	109.2 (4.3)	58.3 (3.9)	-	-	223.6 (13.0)
2010/11	-	31.9 (2.5)	-	6.9 (2.9)	43.3 (3.0)	68.5 (2.6)	27.6	-	178.3 (11.0)
2011/12	16.0*		-	25.0	38.0 (2.0)	37.2 (2.1)	8.8*		125.0 (4.2)
2012/13	-	-	-	-	-	-	-	-	-
2013/14	-	-	-	-	-	(1.9)	-	-	(1.9)
2014/15	40.7	16.4	-	65.9	56.8	44.5 (2.8)	25.2*		249.4 (2.8)
2015/16	20.1*		-	54.4	49.8	32.4 (4.1)	42.7	18.4	217.8 (4.1)

*data amalgamated across more than one month due to confidentiality requirements (>5 licence holders), data from gear trials not included.

3.2.2. *Monthly standardised commercial catch rate*

Standardised commercial CPUE data differed slightly from the nominal commercial CPUE (raw) but temporal trends were similar between standardised and nominal commercial CPUE (Figure 3.6). On average, standardised CPUE was 56±2% higher than nominal CPUE and nominal CPUE was only higher than standardised CPUE in May 2007, April and May 2010, and November 2011. The GLM identified that region, fishing year-month, lunar phase, lunar phase (¼ lag), effort, licence number and cloud cover were all highly significant factors affecting CPUE (Table 3.2). The model had a relatively high goodness-of-fit (adjusted R^2 value 0.79). Despite this, 78.7% of the deviance in commercial catches was explained by the model (effort accounted for 71.4% and fishing year-month accounted for 6.6%), which indicates that 21.3% of the deviance was related to unknown factors. Effort was by far the most influential variable on standardised CPUE and the large differences in nominal and standardised CPUE are likely attributed to effort being used as a fixed term in the analysis.

Historically standardised estimates of commercial CPUE have declined from November–June (Figure 3.6). In 2014/15, this decline was exacerbated by the high commercial CPUE in December at 1008 kg.block.vessel.night^{-1} and low CPUE in July 2015 at 616 kg.block.vessel.night^{-1}, 95% CIs [973, 1043] and [563, 672], respectively. In 2015/16, standardised commercial CPUE was marginally higher in all months compared to 2014/15. Standardised CPUE was again highest in December at 1,046 kg.block.vessel.night^{-1}, 95% CI [1008, 1083] but remained relatively high from March to June (range: 792–926 kg.block.vessel.night^{-1}) before decreasing to 643 kg.block.vessel.night^{-1}, 95% CI [593, 695] in July 2016.

Table 3.3. Analysis of deviance (Type II test) for the GLM used to standardise monthly commercial catch in the Gulf St Vincent Prawn Fishery. Abbreviations: SS, sum of squares; df, degrees of freedom; *F*, *F*-statistic. R^2_{adj} = 0.79.

Effect	SS	df	*F*
fishing year-month	7093.2	117.0	43.7***
region	461.6	9.0	37.0***
lunar phase	33.1	1.0	23.8***
lunar phase (¼ lag)	12.8	1.0	9.2***
effort	76355.1	1.0	55019.6***
licence no	179.1	9.0	14.3***
cloud	19.0	1.0	13.7***
residuals	22723.5	16374.0	NA

significance: *** $p < 0.001$.

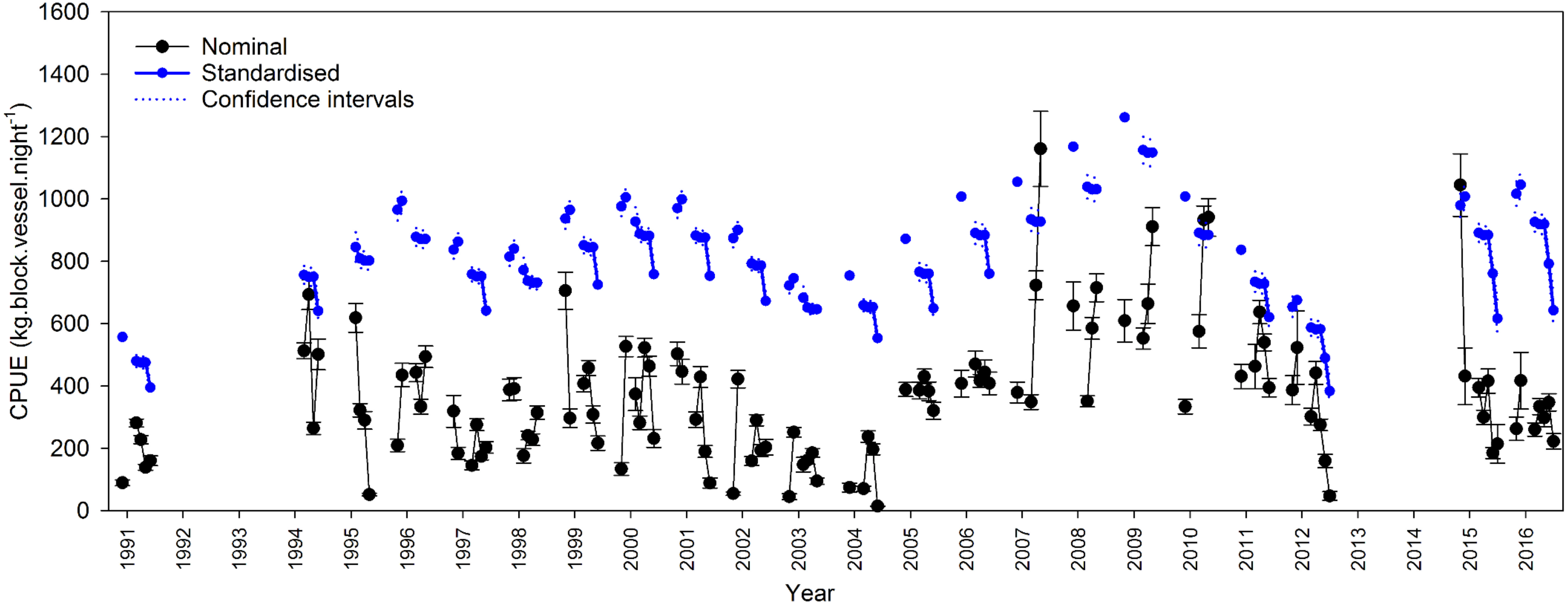

Figure 3.6 Comparison of model-predicted (standardised) mean monthly commercial catch per unit effort (CPUE, kg.block.vessel.night^{-1}, 95% confidence intervals) in the Gulf St Vincent Prawn Fishery with raw (nominal) data from December 1990– July 2016. The x axes denotes the start of each calendar year.

3.2.3. *Annual Standardised commercial catch rate*

The standardised commercial CPUE data differed slightly from the nominal commercial CPUE (raw) data but temporal trends were similar between standardised survey and nominal survey CPUE (Figure 3.7). On average, standardised CPUE was 156±21% higher than nominal CPUE, with the largest differences observed from 2000/01–2003/04 and the smallest differences observed from 2008/09–2010/11. Region, fishing year, month, lunar phase, effort, licence number and cloud cover were all highly significant factors affecting CPUE (Table 3.2). Effort was the most influential variable affecting nominal CPUE and large differences in nominal and standardised CPUE are likely attributed to effort being used as a fixed term in the analysis. A relatively high goodness-of-fit was achieved (adjusted R^2 value 0.78). Despite this, only 78.4% of the deviance in commercial catches was explained by the model (effort accounted for 73.4% and fishing year accounted for 3.8%) and 21.6% of the deviance was caused by unknown factors.

Historically estimates of standardised commercial CPUE were relatively stable from 1993/94 to 2004/05 (range: 653–891 kg.block.vessel.night^{-1}; Figure 3.7). From 2005/06, standardised commercial CPUE steadily increased, peaking at 1,160 kg.block.vessel.night^{-1}, 95% CI [1119, 1202] in 2008/09. Standardised commercial CPUE then declined reaching a low of 589 kg.block.vessel.night^{-1}, 95% CI [564, 614] in 2011/12. The fishery was closed during 2012/13 and 2013/14. Following re-opening of the fishery, standardised commercial CPUE increased 4% from 894 kg.block.vessel.night^{-1} in 2014/15 to 929 kg.vessel.night^{-1} in 2015/16, 95% CIs [867, 921] and [900, 958], respectively. This was in contrast to estimates of nominal CPUE which decreased 25% from 369.5±16.1 kg.vessel.night^{-1} in 2014/15 to 294.7±11.1 kg.vessel.night^{-1} in 2015/16. This was likely a result of reduced effort during November and December (when catch rates are high).

Table 3.4. Analysis of deviance (Type II test) for the GLM used to standardise annual commercial catch in the Gulf St Vincent Prawn Fishery. Abbreviations: SS, sum of squares; df, degrees of freedom; *F*, *F*-statistic. R^2_{adj} = 0.99.

Effect	SS	df	*F*
fishing year	4389.1	21.0	138.1***
month	657.8	7.0	62.1***
region	471.1	9.0	34.6***
lunar phase	51.0	1.0	33.7***
effort	84856.8	1.0	56058.0***
licence no	196.8	9.0	14.4***
cloud	66.1	1.0	43.7***
residuals	24922.1	16464.0	NA

significance: *** $p < 0.001$.

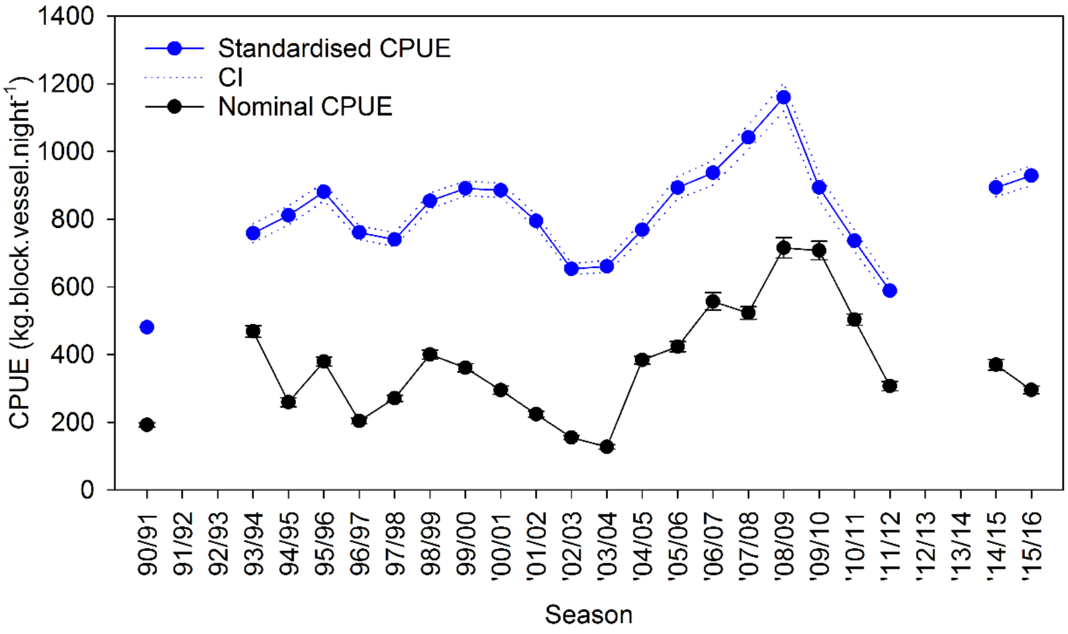

Figure 3.7 Comparison of model-predicted (standardised) mean monthly commercial catch (kg.block.vessel.night^{-1}, 95% confidence intervals) in the Gulf St Vincent Prawn Fishery with raw (nominal) data from 1990/91– 2015/2016.

3.2.4. Distribution of catch and effort

Following the introduction of a spatially stratified survey design in 2004/05, the number of blocks fished declined (Figure 3.8). From 2014/15, the number of surveys was reduced, spatial management restrictions were amended (see Section 1.2.2), and the number of blocks fished increased. In 2015/16, fishing took place in 23 blocks in November–December and in 54 blocks in the remaining months of the season. This was a 13% increase in the number of blocks fished pre–Christmas compared to 2014/15 (20 blocks) but the number of blocks fished in the remaining months remained similar.

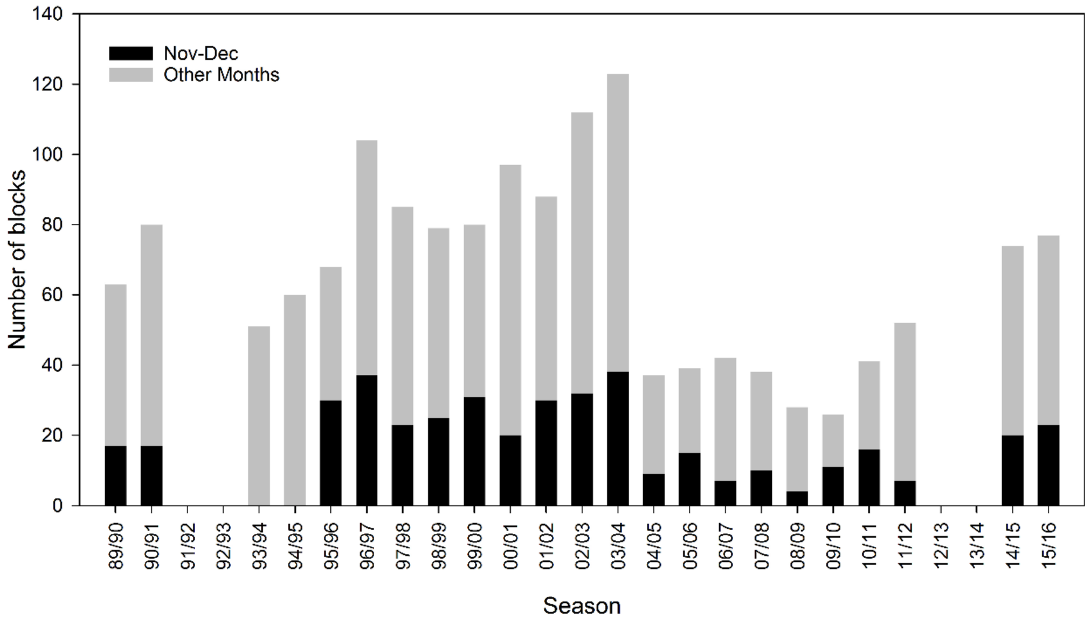

Figure 3.8 The number of blocks fished pre–Christmas (November and December) and all other months in the Gulf St Vincent Prawn Fishery from 1989/90–2015/16.

The distribution of annual catch has varied through time (Figure 3.9). Overall, the distribution of catch in 2015/16 was similar to the historic pattern with a high proportion of catch harvested in the southern gulf. The majority of the catch was harvested from Deep Hole during 2015/16 (63 t), which was only marginally higher than the 2014/15 catch (60 t) and the highest catch since 2000 (90.7 t). In 2015/16, large increases in catch were observed in the more southern areas of the gulf compared with 2014/15. For example, catch from Investigator Strait was 25 t in 2015/16, which was more than 10 times higher than 2014/15 (2 t) and the highest observed since 2009/10 (52 t). In Southern Deep Hole, 22 t was harvested, which was four times higher than the 2014/15 catch (6 t) and the highest observed since 2010/11 (32 t). A similar trend was observed in Region 3 (45 t) where catch was nearly double that recorded in 2014/15 (16 t) and the highest observed since 2008/09 (53 t). These trends resulted in a lower proportion of the total catch in 2015/16 being taken from the middle and northern areas of the gulf decreased compared to 2014/15. The largest decreases were observed in catches from Little Hole (3 t), Region 1 (15 t), and Region 2 (22 t) which were 64–86% lower than 2014/15.

Figure 3.9 The annual harvest per fishing block in the Gulf St Vincent Prawn Fishery from 2007/08–2015/16. Note, the fishery was closed in 2012/13 and 2013/14. Confidential data (<5 licence holders) are not shown.

3.2.5. *Size structure*

The annual harvests by the GSVPF from 2005/06–2015/16 comprised, on average, 38% large (L-10/15) prawns, 27% extra-large (XL- U10) prawns, 22% medium (M-10/15) prawns, 6% small (S-20+) prawns and 7% soft and broken prawns (S&B, Figure 3.10). A generally increasing trend in the proportion of small and medium prawns was observed from 2005/06–2010/11, and a corresponding decrease in the proportion of large and extra-large prawns was observed over the same period. Following the re-opening of the fishery, there was an increase in the proportion of large prawns harvested from 35.7% (35.4 t) in 2011/12 to 44.4% (104.8 t) in 2014/15 (Figure 3.10, Table 3.2). There was also a decreased proportion of small prawns harvested from 8.9% (9.1 t) in 2012/13 to 3.9% (9.1 t) in 2014/15. During 2015/16, the proportion of large prawns in the harvest decreased to 38.3% (78.7 t), while the proportion of small prawns harvested increased to 7.8% (11.9 t). The proportion of extra-large prawns also increased from 24.2% (57.1 t) in 2014/15 to 27.9% (57.3 t) in 2015/16. The proportion of soft and broken prawns has historically been relatively low. In 2015/16, soft and broken prawns contributed 8% (16 t) to the total catch and this was at the upper end of the historical range (6–8%).

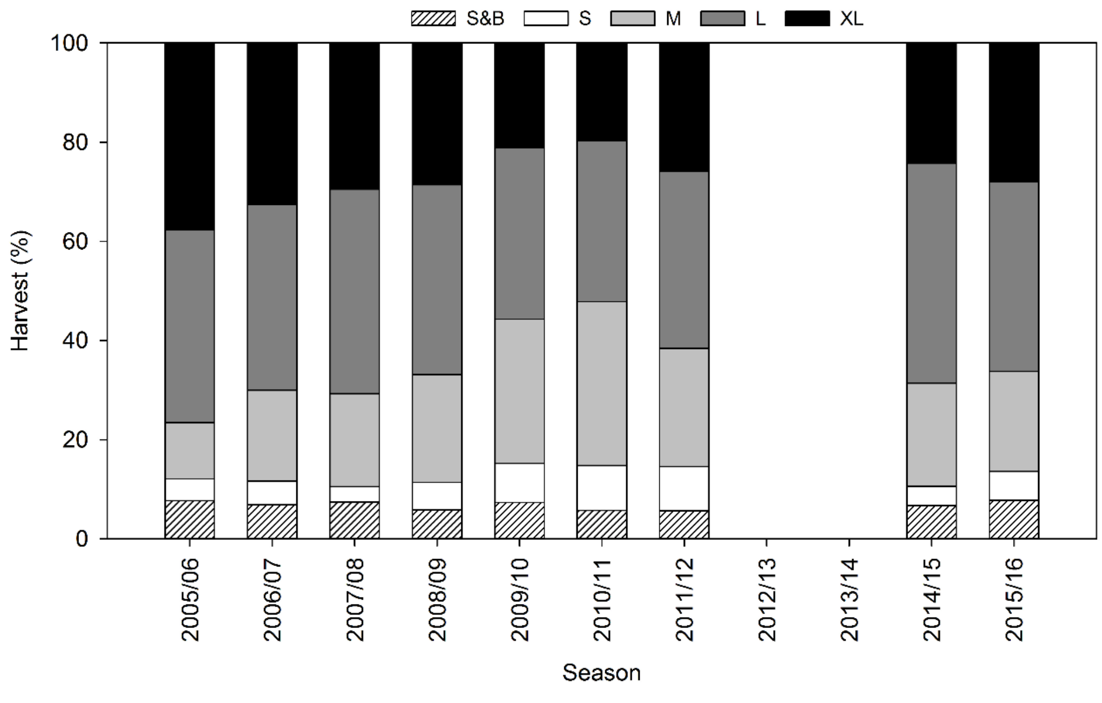

Figure 3.10 Size-grade composition (%) of monthly harvests in the Gulf St Vincent Prawn Fishery from 2005/06–2015/16. Grades include; soft and broken (S&B, not graded), small (S, 20+), medium (M, 16/20), large (L, 10/15) and extra-large (XL, U10).

Table 3.5. Size-grade composition (t) of monthly harvests in the Gulf St Vincent Prawn Fishery from 2005/06–2015/16. Grades include; soft and broken (S&B, not graded), small (S, 20+), medium (M, 16/20), large (L, 10/15) and extra-large (XL, U10).

	XL	**L**	**M**	**S**	**SB**
2005/06	29.0	30.1	8.7	3.4	5.9
2006/07	46.0	53.1	26.0	6.8	9.7
2007/08	40.2	56.1	25.6	4.2	10.1
2008/09	50.4	67.6	38.4	9.7	10.4
2009/10	36.2	59.3	49.9	13.6	12.6
2010/11	26.2	42.9	43.9	12.0	7.6
2011/12	25.6	35.4	23.7	8.8	5.6
2012/13					
2013/14					
2014/15	57.1	104.8	49.1	9.1	15.9
2015/16	57.3	78.7	41.3	11.9	16.0

4. DISCUSSION

4.1. Information sources used for assessment

The current Management Plan and harvest strategy for the fishery are being reviewed and due for completion in 2016. The fishery is currently operating under interim harvest strategy arrangements and there are no performance indicators linked to a definition of stock status. Consequently, this assessment uses a 'weight of evidence' approach to determine stock status. The primary data sources were fishery-independent data (obtained from the annual May FIS) and fishery-dependent catch, effort and prawn size data.

4.1.1. *Fishery-independent data*

From December 2004, a comprehensive survey program has been conducted to assess the status of the western king prawn stock in Gulf St Vincent. While the data collected are of high quality and have remained relatively consistent, there have been several changes to the survey program in recent years. These changes include:

1) Survey timing was moved from the dark of the moon (2004/05–2006/07) to two nights after the last quarter of the moon from 2007/08;
2) The number of stock assessment surveys was reduced from four to two in 2011/12 (April and May) and to one in 2013/14 (May);
3) No surveys were undertaken during 2012/13;
4) A spatially reduced survey was undertaken in May 2014 and this was extended over the dark phase of the moon;
5) T90 gear has been operated alongside the diamond net during surveys conducted since 2011/12.

Despite recent modifications to the FIS program, standardised survey CPUE and the fishery recruitment index are the best available indices of current and future relative biomass and key determinants in the assessment of stock status. While the distribution, extent and timing of recruitment is highly variable in Gulf St Vincent, new recruits are expected to make up a significant proportion of the biomass and should be reflected in the overall CPUE during May surveys. While December surveys were previously used to estimate egg production, the overall trends in catch rate were relatively inconsistent in comparison to other months and in comparison with commercial catch rates during the pre-Christmas period (Dixon *et al.* 2012).

4.1.2. *Fishery-dependent data*

Commercial catch and effort data from the GSVPF generally support the trends in relative biomass and prawn size observed from the fishery-independent surveys. There are, however, several key uncertainties associated with fishery-dependent data, these include;

1. The dynamic history of active management of the fishery, where spatial restrictions and sampling regimes have been inconsistent through time;
2. Modelled estimates of CPUE have relied on daily logbook data from 1991/92;
3. Prawn size data relies on accurate grading and may be biased towards the catch records of larger vessels.

Despite these uncertainties, as the GSVPF has transitioned to a research program with only one survey per year (compared to four surveys historically), fishery-dependent data are becoming increasingly important in the determination of stock status.

4.2. Status

Following the re-opening of the GSVPF in 2014/15, the most recent stock status report (Beckmann *et al*. 2015) indicated that the total relative biomass had increased during the closure. Despite this, survey CPUE declined from 2013/14 to 2014/15 and the recruitment index from the May 2015 survey was among the lowest on record but remained above the limit reference point in the previous management plan (250 recruits.h^{-1}). The low catch rates of recruits in May 2015 suggested that future recruitment to the harvestable biomass may be limited. Consequently, in line with the National Fishery Status Reporting Framework (NFSRF) for stock status classification (Flood *et al*. 2014), the status of the GSVPF in 2014/15 was defined as “transitional depleting”.

For the 2015/16 season, total allowable commercial effort (TACE) was 300 vessel nights, 99% which were fished. This was the same TACE as 2014/15, however, the number of night’s available pre-Christmas (November and December) was reduced from 50 vessel nights in 2014/15 to 30 vessel nights in 2015/16. This resulted in a 65% reduction in catch during the early spawning period in 2015/16 (20 t) compared to 2014/15 (57 t). Overall, a 12% reduction in catch was observed from 2014/15 (252 t) to 2015/16 (222 t) and this was likely due to reduced effort during early spawning (November-December) when CPUE has historically been highest. While nominal estimates of CPUE reduced by 25% from 2014/15 to 2015/16, reduced effort during November and December (when catch rates are high) and changes to the spatial patterns of fishing may have resulted in under-estimated nominal commercial CPUE. The standardised estimate of commercial CPUE removes the influence of variables not related to abundance (e.g. effort and region) and this increased 5% from 894 kg.block.vessel.night^{-1}, 95% CI [867, 921] in 2014/15 to 929 kg.vessel.night^{-1}, 95% CI [900, 958] in 2015/16.

Decreased total catch and nominal CPUE may also be a result of the changing size structure reported in the commercial harvest. During 2015/16 the proportion of large prawns harvested decreased and corresponding increase in the harvest of small prawns occurred. It is likely that the removal of active management and spatial restrictions has resulted in the targeting of mixed sized prawns, allowing a significant proportion of large size prawns to continue to contribute to the spawning biomass. A similar fishing strategy was adopted in 2010/11, where mixed prawns were targeted, aiming to conserve large prawns which are critical for spawning and recruitment success (Dixon *et al*. 2012). Targeting of mixed size prawns, is likely to continue as survey results are no longer used to identify areas of target size prawns. Commercial catch and effort data from 2015/16 also suggests that an increased proportion of the harvest was taken from the southern part of the gulf where large prawns were most abundant. Overall, survey and commercial CPUE indicate that the GSVPF adult biomass has remained relatively high since the recent closure of the fishery.

Despite increased commercial and survey CPUE since 2014/15, effort was reduced during the early spawning period in 2015/16 in response to low levels of recruitment in the May 2015 survey. The early spawning period (November–December) is when spawning success is likely to be enhanced due to warm temperatures which result in shorter larval duration and enhanced larval survival (Roberts *et al.* 2012). As a result, post-larvae produced from early spawning events are likely to grow rapidly and settle in nursery areas during summer, recruiting to the fishery in May/June during the same season. Favourable environmental conditions and reduced effort during early spawning in 2015 may have resulted in enhanced recruitment during 2016. This was supported by a 169% increase in the recruitment index from May 2015 (327.6±62.2 recruits.h^{-1}) to May 2016 (880.9±120.6 recruits.h^{-1}). The increased abundance of small prawns during the 2016 survey was also reflected in the overall survey CPUE which increased 50% from 30.9 kg.trawl-shot^{-1}, 95% CI [25.7, 36.8] in May 2015 to 46.4 kg.trawl-shot^{-1} 95% CI [40.1, 53.4] in May 2016.

In summary, data from the 2015/16 season are positive in that 1) standardised commercial CPUE was 929 kg.vessel.night^{-1}, 95% CI [900, 958], this was a 4% increase compared to 2014/15; 2) standardised survey CPUE was 46.4 kg.trawl-shot^{-1}, 95% CI [40.1, 53.4], this was a 50% increase compared to 2014/15; and 3) the recruitment index was 880.9±120.6 recruits.h^{-1}, this was a 169% increase compared to 2015. On the weight of evidence, these data indicate that the GSVPF biomass is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (that is, the stock is not recruitment overfished) and that fishing pressure is adequately controlled to avoid the stock becoming recruitment overfished. Therefore, using the national framework for stock status reporting (Flood *et al.* 2012), the GSVPF stock is classified as '**sustainable**'.

4.3. Future directions

There are several avenues of research that would reduce uncertainty in the assessment of the GSVPF. Firstly, the model-based standardisation of CPUE could be further refined to include commercial data prior to 1991/92 and to account for the change in gear configuration since 2012 (T90 cod-ends). Secondly, as there is a large amount of unexplained variance in the model based standardisation of survey CPUE, a review of survey design concentrating on sample size, vessel and region interactions is required (Dichmont 2014). This review should also incorporate further comparisons of T90 and diamond-mesh survey catch rates to facilitate the likely transition to using T90 cod-ends in the future. Third, the bio-economic model of Noell *et al.* (2015) could be further developed to be used as a tool for assessing stock status relative to model-estimated reference points and determining how the stock may respond to specific management actions. Finally, more research is required to understand how recruitment patterns in the GSVPF are affected by the interaction between oceanographic patterns and fishing during the main spawning period. A biophysical model was recently developed for the Spencer Gulf Prawn Fishery to predict patterns of larval dispersal and settlement by coupling knowledge about the biology and behaviour of a species to information about hydrodynamics (McLeay *et al.* 2015). A similar model could be developed for the GSVPF to simulate how spatial changes in fishing can maximise both recruitment and catch during periods of high catch value (i.e. pre-Christmas).

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