Fisheries

Gulf St Vincent Prawn *Penaeus (Melicertus) latisulcatus* Fishery 2016/17

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

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Fishery Assessment Report to PIRSA Fisheries and Aquaculture

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EXECUTIVE SUMMARY

This report determines the current status of Western King Prawn stock in Gulf St Vincent (GSV) through analysis of data collected by several long-term monitoring programs.

In 2016/17, the total commercial catch of Western King Prawn in the Gulf St Vincent Prawn Fishery (GSVPF) was 224.6 t, with an additional 2.9 t taken in the May 2017 fishery independent survey (FIS). Fishing was conducted over 287 vessel-nights, comprising 96% of the Total Allowable Commercial Effort (TACE) of 300 vessel-nights. A total of 49 out of the 50 allocated pre-Christmas vessel-nights were fished (Table 1).

Estimates of standardised annual commercial catch per unit effort (CPUE) have been relatively high in recent years and were ≥900 kg.block^{-1}.vessel-night^{-1} in 2015/16, and ≥750 kg.block^{-1}.vessel- night^{-1} in 2014/15 and 2016/17. Estimates of standardised FIS CPUE have also remained at high levels since 2013/14, exceeding 30 kg.trawl-shot^{-1} in the last four surveys. Similarly, the FIS recruitment index (FRI) has also been relatively high (≥600 recruits.h^{-1}) for three of the last four annual surveys (2013/14, 2015/16 and 2016/17).

Primary Industries and Regions South Australia (PIRSA) has adopted the National Fishery Status Reporting Framework (NFSRF) to determine the status of all South Australian fish stocks. The current management plan for the GSVPF provides the decision rules for classifying stock status relative to limit, trigger and target reference points defined for three performance indicators relating to stock abundance and recruitment (PIRSA 2017). The performance indicators are: 1) standardised annual CPUE; 2) standardised FIS CPUE; and 3) the FRI.

In 2016/17:

1. standardised annual commercial CPUE was 892 kg.block^{-1}.vessel-night^{-1}, which was 9.8% lower than in 2015/16 (989 kg.block^{-1}.vessel-night^{-1}), but within the target range defined for this performance indicator;

2. standardised FIS CPUE was 32.7 kg.trawl-shot^{-1}; which was 30.3% lower than in 2015/16 (46.9 kg.trawl-shot^{-1}), but within the high range defined for this performance indicator; and

3. the FRI was 784.4 recruits.h^{-1}, which was 10.1% lower than in 2015/16 (872.2 recruits.h^{-1}), but within the high range defined for this performance indicator.

When the 2016/17 estimates for each performance indicator are applied in the decision matrix used to classify the stock status of Western King Prawn in GSV, the fishery is classified as '**sustainable**'.

Table 1. Key Gulf St Vincent Prawn Fishery statistics between 2014/15 and 2016/17.

Statistic	2014/15	2015/16	2016/17
Total allowable commercial effort (TACE)	300 nights (50 pre-Christmas)	300 nights (30 pre-Christmas)	300 nights (50 pre-Christmas)
Total commercial catch	249.4 t (+2.8 t from survey)	217.8 t (+4.1 t from survey)	224.6 t (+2.9 t from survey)
Total effort	294 vessel nights (50 pre-Christmas) 2,904 hours	296 vessel nights (30 pre-Christmas) 2,799 hours	287 vessel nights (49 pre-Christmas) 2,836 hours
Standardised annual commercial CPUE	890 $kg.vessel\cdot night^{-1}$ 95% CI [863, 917]	989 $kg.vessel.night^{-1}$ 95% CI [951, 1027]	892 $kg.vessel\cdot night^{-1}$ 95% CI [866, 919]
Standardised FIS CPUE	30.7 $kg.trawl\text{-}shot^{-1}$ 95% CI [28.0, 33.7]	46.9 $kg.trawl\text{-}shot^{-1}$ 95% CI [43.6, 50.4]	32.7 $kg.trawl\text{-}shot^{-1}$ 95% CI [29.9, 35.8]
FRI	327.6 ± 62.2 $recruits.h^{-1}$	872.2 ± 119.7 $recruits.h^{-1}$	784.4 ± 116.3 $recruits.h^{-1}$
Status	Transitional Depleting	Sustainable	Sustainable

Keywords: Western King Prawn, *Penaeus* (*Melicertus*) *latisulcatus,* trawl fishery, Gulf St Vincent, South Australia.

1. INTRODUCTION

1.1. Overview

Stock assessments for the Gulf St Vincent Prawn Fishery (GSVPF) are part of the South Australian Research and Development Institute's (SARDI) (Aquatic Sciences) ongoing assessment program. This report assesses the current status of the Western King Prawn (*Penaeus (Melicertus) latisulcatus*) (Kishinouye 1996) stock in Gulf St Vincent (GSV) and includes new data from the 2016/17 fishing season.

The report has three objectives: 1) to present information relating to the fishery and biology of Western King Prawn; 2) to assess the 2016/17 status of the Western King Prawn resource in Gulf St Vincent; 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 West Coast Prawn Fishery (WCPF); and the GSVPF. The SGPF is the largest prawn fishery in South Australia in terms of 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 fishing licences issued for the GSVPF.

All three prawn fisheries use demersal otter trawls to target Western King Prawn at night between sunset and sunrise (Figure 1). Trawls tow funnel-shaped nets along the sea floor and retain the catch in bags located at the end of the net (most commonly referred to as codends) (Figure 2). Commercial licence holders in the GSVPF 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.

The fishing season occurs from 1 November to 31 July of the following year with a closure in January and February. Fishing during the season generally occurs between the last quarter and first quarter of the moon and is permitted in depths greater than 10 m north of the geodesic joining GSV, Investigator Strait and Backstairs Passage. The GSVPF is divided into 121 prawn fishing blocks for research and management purposes (Figure 3). The major home ports for the GSVPF are Port Adelaide and North Haven.

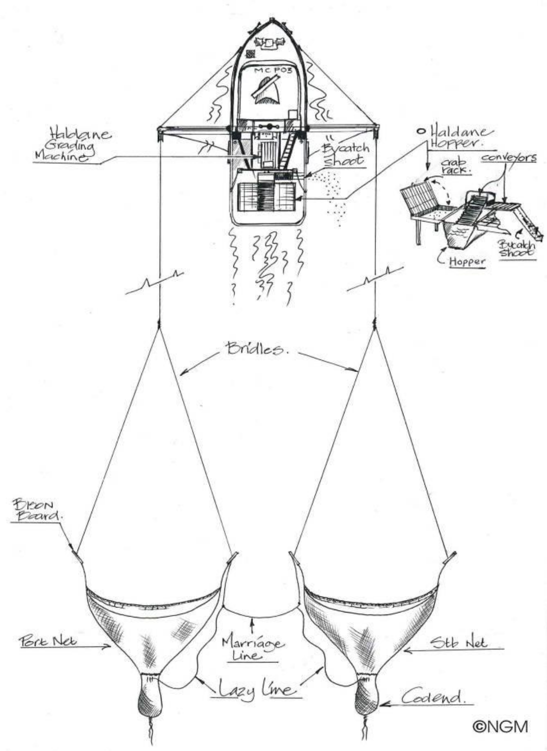

Figure 1. Double-rig trawl gear and location of hopper sorting and prawn grading systems used in the Gulf St Vincent Prawn Fishery. Figure from Carrick (2003).

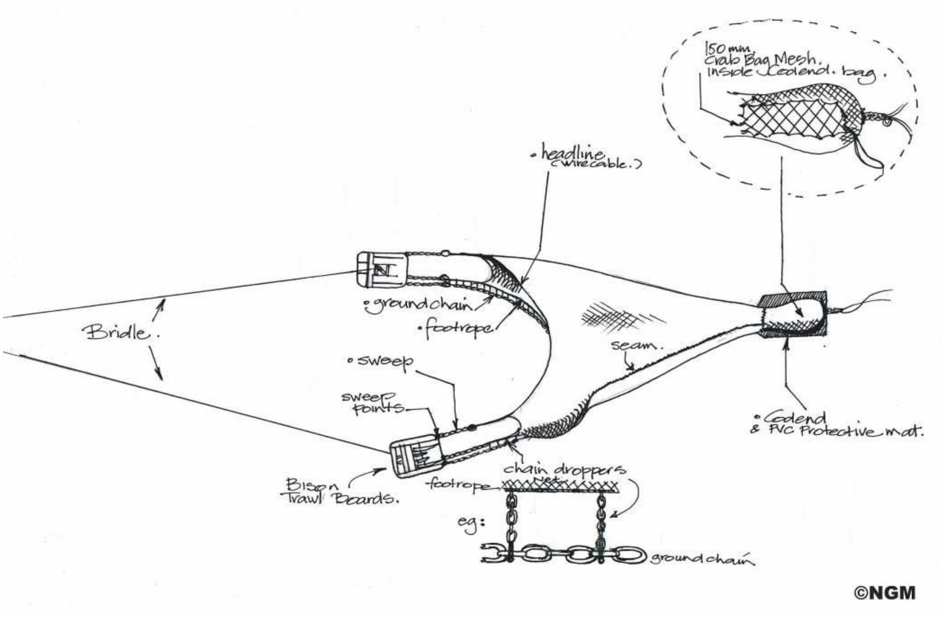

Figure 2. Trawl net configuration showing trawl boards, head rope, ground chain and cod end with crab bag as used in the Gulf St Vincent Prawn Fishery. Figure from Carrick (2003).

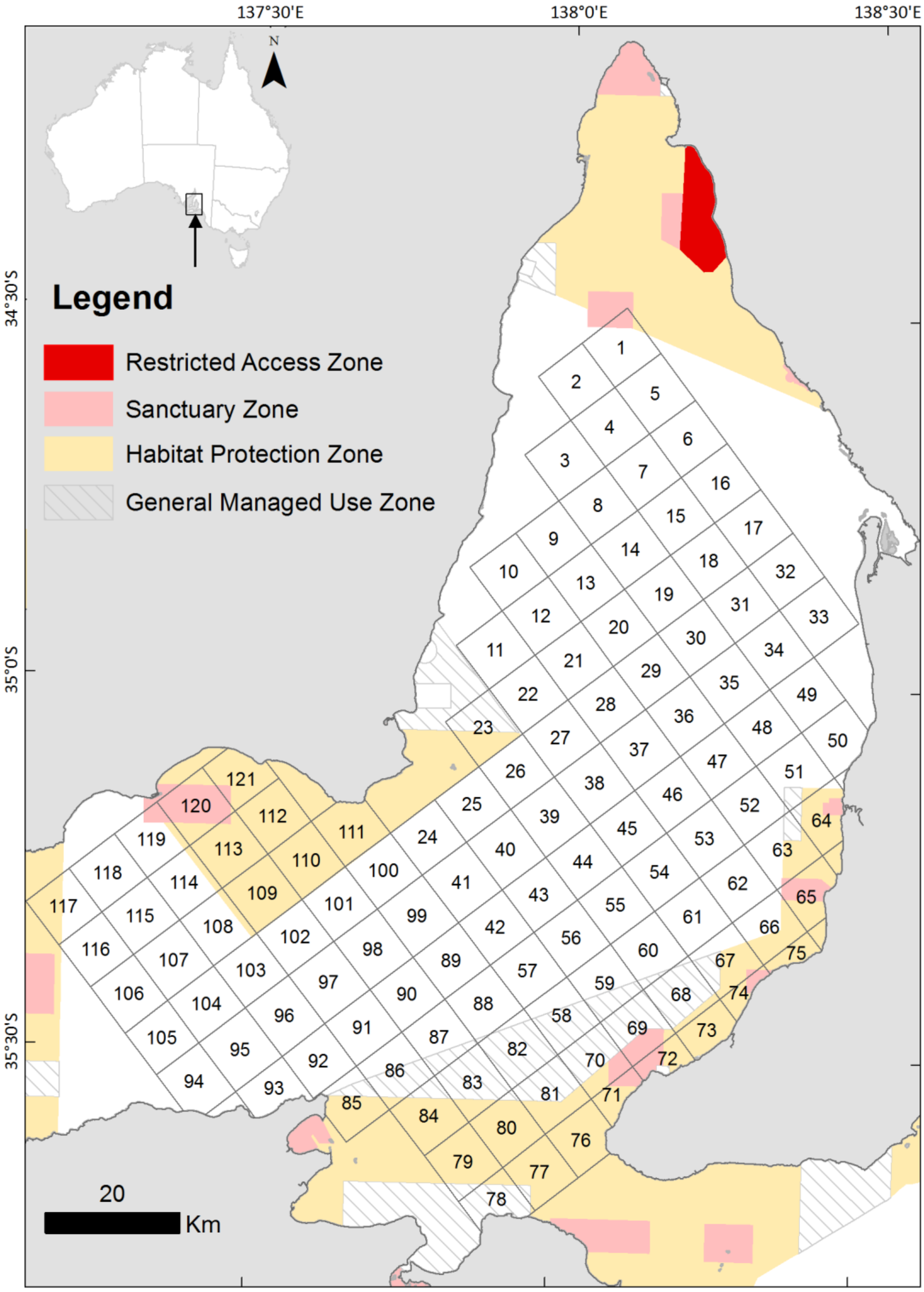

Figure 3. The research management blocks for the Gulf St Vincent Prawn Fishery.

1.2.2. *Management arrangements*

The *Fisheries Management Act 2007* provides the legislative framework for management of fisheries resources in South Australia. 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.

Management arrangements for the GSVPF have evolved since the fishery's inception in 1967 (Table 2). Between 1967 and 1979, the number of licences increased to a total of 22 before being reduced to 10 by 1990. Following licence rationalisation in 1990, the Western King Prawn stock was considered overfished and the fishery was closed during the 1991/92 and 1992/93 fishing seasons to allow recovery. The fishery reopened in 1993/94 and in 1998 the first management plan for the fishery was introduced. From 2004/05, four surveys per season were undertaken. A second management plan was implemented in 2007 (Dixon and Sloan 2007).

A review of the GSVPF in 2011 (Knuckey *et al.* 2011) recommended that the fleet improve its operating efficiencies. Two key management changes were subsequently implemented for the 2011/12 season: 1) the number of surveys used to manage the fishery 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 codends and fitted with Nørdmore grids to improve catch selectivity, reduce levels of bycatch and facilitate the escapement of small prawns (Dixon *et al.* 2013).

Due to poor economic performance, the fishery was closed again in 2012 at the request of licence holders. 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 included an individual transferrable effort (ITE) system, with transferrable fishing nights as the effort unit. From 2013/14, the number of surveys was further reduced to one in May.

From 2014/15, under the new management framework, control rules for spatial management, mean prawn size and mean nightly catches per vessel were transferred and adopted into the St Vincent Gulf Prawn Boat Owner's Association (SVGPBOA) Industry Code of Practice. The Code of Practice is a non-legislated document that describes expected activities for the GSVPF not included in regulation or licence conditions. From 2014/15, the allocated fishing nights could be used anytime during the season, however, the number of 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 provide a summary of the total catch unloaded per grade within 48 hours of unloading. Also, in November 2015, restrictions on the construction of the T90 codend 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.

The latest management plan for the fishery was implemented in April 2017 and provides the overarching policy and harvest strategy for management of the fishery (PIRSA 2017). The GSVPF is currently a limited-entry (10 licence holders) fishery, which is managed by gear restrictions and a restriction on the number of fishing nights. Fishing takes place between sunset and sunrise. No trawling is permitted in waters shallower than 10 m. Current management arrangements are summarised in Table 2.

The harvest strategy listed within the management plan for the fishery uses decision rules for setting the total allowable commercial effort (TACE) and number of pre-Christmas (November – December) fishing nights for the following season (PIRSA 2017). Decision rules are based on limit, trigger and target reference points defined for three performance indicators relating to stock abundance and recruitment, and are also used to determine the status of the Western King Prawn stock in GSV (see Section 1.6).

Table 2. 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
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 1997)
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 the T90-mesh codend
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. The fishery reopened in November 2014. Individual transferable units were introduced. *A revised framework for longer-term management of the Gulf St Vincent Prawn Fishery was* developed
2017	The third management Plan for the South Australian Commercial Gulf St Vincent Prawn Fishery was approved by the Minister for Agriculture, Food and Fisheries (PIRSA 2017)

Table 3. 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 codend 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

1.3. Biology of the Western King Prawn

1.3.1. *Distribution and habitat preferences*

The Western King Prawn is a benthic crustacean that is distributed in sand or seagrass estuarine and gulf habitats of the Indo-west Pacific (Grey *et al.* 1983; Tanner and Deakin 2001). Its distribution and abundance is also affected by levels of salinity with higher abundance associated with salinities above 30‰ (Potter *et al.* 1991).

In South Australia, its distribution is unique, as it is at the lowest end of its temperature tolerance range. Consequently, its distribution is primarily restricted to waters of Spencer Gulf, GSV and along the West Coast of South Australia (Ceduna, Venus Bay and Coffin Bay).

Both juvenile and adult prawns exhibit strong diel patterns in behaviour characterised by daytime burial and nocturnal activity (Rasheed and Bull 1992; Primavera and Lebata 2000). Levels of activity are strongly linked to the lunar cycle and higher water temperatures. Consequently, prawn catchability in fisheries is higher in the dark phases of the lunar cycle and during warmer months (Penn 1976; Penn *et al.* 1988).

Tagging experiments showed that prawn movements in GSV were predominately north to south (Kangas and Jackson 1997), with a small number of tag returns in eastern Investigator Strait also indicating a general west and north-west movement in GSV (Kangas and Jackson 1997).

1.3.2. *Reproductive biology*

Adult prawns aggregate, mature, mate and spawn in deep water (>10 m) between October and March (King 1977). Ovary development followed by spawning of fertile eggs occurs during a single intermoult period (30-40 days) where fertilisation presumably occurs immediately prior to or on release of the eggs by the female (Penn 1980). 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 Western King Prawns is typically female-biased, likely due to greater foraging activity of females (Penn 1976; 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. Research by Roberts *et al.* (2012) indicated that reproductive success may be maximised at this time of the year under relatively high gulf temperatures that cause shorter larval durations and higher rates of larval survival (Roberts *et al.* 2012).

In all three South Australian prawn fisheries, fecundity increases exponentially with carapace length (CL), however, the increase is more pronounced in the cooler waters of GSV (Carrick 2003). Consequently, larger prawns make a greater contribution to total egg production due to higher fecundity (Penn 1980; Courtney and Dredge 1988; Carrick 1996). The effect of ovarian senescence in large female Western King Prawns is unknown (Courtney *et al.* 1995).

1.3.3. *Early life history*

Western King Prawns have 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). Water temperature is considered one of the most important factors influencing larval growth and survival, with higher water temperatures resulting in faster rates of development and higher rates of survival (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 that occurred in southern GSV. However, rates of larval settlement from different spawning areas within the fishery were not quantified.

Kangas' (1999) study also indicated that post-larvae settled in inshore nursery areas at 1 mm CL, with juveniles 2–7 mm CL comprising 90% of the surveyed population. Post-larvae produced from early spawning events likely settle in nursery areas during December or January, when growth rates are high, before migrating to deeper water in May or June (at ~20 mm CL). Post-larvae produced from late spawning events (January to March) likely settle in nurseries from March, where they 'over-winter' before 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 the distribution of Western King Prawn haplotypes between South Australia and Western Australia (Carrick 2003). However, an analysis of the genetic structure of Western King Prawns 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 growth rates. 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 sexes and within years. Maximum growth occurred in April for males and in early March for females. Between October and December, there was no relationship between growth and water temperature, which may have been due to the allocation of energy to reproduction during this time rather than growth.

Length-weight relationships have not been determined for adult prawns in GSV. The relationship between prawn 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 (2.4–20.4 mm CL, sex indistinguishable) in GSV (a=0.00066, b=2.91, N=325).

1.3.6. *Natural mortality*

The instantaneous rate of natural mortality for GSV prawns (both sexes combined) was estimated by Kangas and Jackson (1997) as 0.003 per day. 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 Western King Prawns 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 a similar result (0.0031 per day for females and 0.0034 per day for males).

1.3.7. *Biosecurity and prawn health*

The health of Western King Prawn populations in South Australia 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 (focusing on viruses) collected from key nursery sites in both Spencer Gulf and Gulf St Vincent. A naturally occurring (endemic), and likely harmless, monodon-type baculovirus (MBV) was observed in ~60% of prawns. The MBV is a common virus known to occur throughout Australia.

1.4. Research program

There have been numerous fisheries' research projects relevant to the Western King Prawn stock in GSV. Research has been undertaken to investigate 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), fishing gear technology (McShane 1996; Broadhurst *et al.* 1999; Dixon *et al.* 2013; Gorman and Dixon 2015), trawling impacts (Tanner 2003) and to develop fisheries models (Xiao 2004). Previous stock assessment and stock status reports detail the biological information and the history of commercial catch used to assess the status of the Western King Prawn stock in GSV (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.* 2007a, 2007b; 2008; 2009; Hooper *et al.* 2009; Dixon *et al.* 2011; 2012; Beckmann *et al*. 2015; 2016).

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 rationalisation of the research program. The principal change was a reduction from four fishery-independent surveys (FIS) per year to one (conducted in May). The focus of the 2016/17 research program is to assess the status of the Western King Prawn stock in GSV for the 2016/17 fishing season using biological and statistical information collected from the GSVPF and FIS in May 2017.

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. Surveys were conducted in consecutive fishing periods (December, March, April and May) between 2004/05 and 2010/11. In 2011/12, the number of stock assessment surveys was reduced from four to two per season to improve GSVPF economic efficiency, with surveys conducted in April and May on the dark of the moon. Surveys were not conducted in 2012/13 and from 2013/14, the number of surveys was further reduced to one per season (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–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 trawl 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 FIS catches that are retained for sale by the SVGPBOA.

1.6. Stock status classification

A National Fishery Status Reporting Framework (NFSRF) was developed to enable the consistent assessment of the status of Australian fish stocks (Flood *et al*. 2012, 2014; FRDC 2016). 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' (Table 4). PIRSA has adopted this classification system to determine the status of all South Australian fish stocks. Status is categorised for the Western King Prawn stock in GSV from a combination of three performance indicators as defined in the harvest strategy for the fishery:

1. Standardised annual commercial catch per unit effort (CPUE) (kg.block^{-1}.vessel- night^{-1}) that is estimated from daily commercial logbook data provided to SARDI.
2. Standardised FIS CPUE (kg.trawl-shot^{-1}) that is estimated from data collected in the May fishery-independent survey (FIS).
3. FIS recruitment index (FRI) (recruits.hr^{-1}) that is estimated from data collected in the May survey.

To categorise stock status, estimates for each of the three performance indicators are assessed in relation to how they align against limit, trigger and target reference points for each performance indicator as defined in the harvest strategy for the fishery (PIRSA 2017).

Table 4. 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 GSV prior to the December, March, April and May harvest periods from 2004/05 to 2010/11, in April and May in 2011/12, and in May from 2013/14. To enable temporal comparison of the FIS data used to assess the performance of the fishery, this report uses data collected from May surveys only.

Surveys were typically done using three to six vessels over two or 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 2005 to 2016, the number of sites sampled ranged from 101–112, except for 2014 where a ‘reduced’ survey of 48 sites was completed. The survey in May 2017 includes data from 94 of 109 completed survey locations as specified in the current Management Plan (PIRSA 2017) (Figure 4).

Survey shots were done at semi-fixed sites in the ten regions of the GSVPF (Figure 4). 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 weight, catch weight 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 - a rapid measure used to estimate prawn size).

T-90 mesh codends with bycatch reduction grids were introduced into commercial fishing operations of the GSVPF in 2012 to reduce discards. However, the reference levels relating to standardised FIS CPUE (kg.trawl-shot^{-1}) and FRI (recruits.hr^{-1}) described within the current harvest strategy were derived from historical data collected from diamond mesh codends only since 2005. Consequently, only data collected from diamond mesh codends since 2005 were used to estimate standardised FIS CPUE and FRI in the 2016/17 season because these data directly inform stock status determination. Data from T-90 mesh codends are still collected during the FIS to enable potential calibration with data collected from diamond mesh codends in the future.

Estimates of mean prawn size (N prawns.kg^{-1}) 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 prawns.kg^{-1}), medium (30-33 prawns.kg^{-1}), large (28-30 prawns.kg^{-1}) and extra-large (<28 prawns.kg^{-1}), and CPUE was defined as very low (<50 kg.trawl-shot^{-1}), low (50-100 kg.trawl-shot^{-1}), moderate (100-150 kg.trawl- shot^{-1}) and high (>150 kg.trawl-shot^{-1}). The GPS locations of each trawl station were used to specify the prawn size (colour coded) and CPUE (bubble size increases with increasing 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.

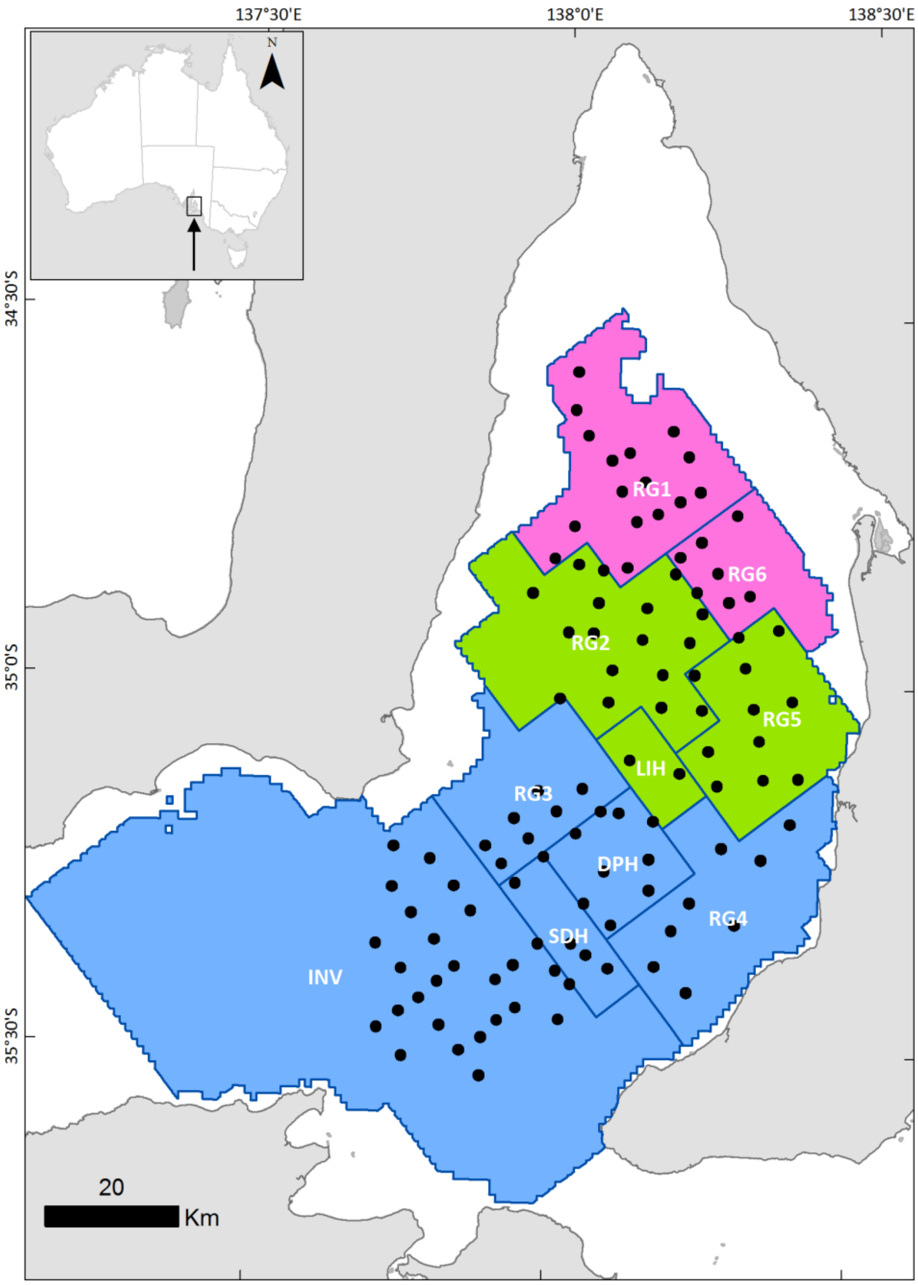

Figure 4. The 109 survey stations specified in the 2017 Management Plan and regions of the Gulf St Vincent Prawn Fishery. The northern gulf (pink) includes Region 1 (RG1) and Region 6 (RG6), the central gulf (green) includes Region 2 (RG2), Region 5 (RG5) and Little Hole (LIH), and the southern gulf (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 season' is defined as the period from 1 November to 31 July the following year. Fishery-dependent data (daily commercial logbook) are presented for all data available as of 4 October 2017. Commercial and survey catch (t) are presented and effort is presented as a function of either vessel-nights or trawl-hours. The main spawning period for Western King Prawns in GSV extends from November to March, so catch data are also presented for early (November – December), late (January – March) and non-spawning (April – October) periods. The spatial distribution of the annual harvest per fishing block is presented from 2007/08–2016/17, however, confidential data (<5 licence holders) are not presented.

2.2.2. *Prawn size*

Mandatory reporting of commercial prawn-grade data in daily logbooks was introduced in 2005/06. The grade is determined from the number of prawns to the pound (e.g. U10 = under 10 prawns per pound). To facilitate interpretation of the prawn-grade data, grades were converted to four categories (Table 5). For analysis of trends within years, a fifth category, soft and broken (S&B), was established for prawns that were not graded. Data presented are from commercial fishing nights only and reported as the proportion of the commercial catch occurring in each of the size classes (see Dixon *et al.* 2012).

Uncertainty associated with the calculation of prawn size arises from: 1) data not being available from the entire fleet for all seasons; 2) differences in the grade categories used by each vessel; and 3) uncertainty associated with the un-validated grade data provided in logbooks (Dixon *et al.* 2012).

Table 5. Categories assigned to reported prawn grades from commercial logbook data for the Gulf St Vincent Prawn Fishery.

Prawn grade	Categories in logbook
Extra Large	U6 U8, XL U10, L
Large	9/12 U12 LM 10/15 13/15 10/20 (50%), 12/18 (50%)
Medium	10/20 (50%), 12/18 (50%) 16/20, M
Small	SM, 19/25 21/25 S, 20+, 21/30 26+ 30+, 31/40
Soft & Broken	S/B, B&D, MIX, REJ, SMS, blank, ERR

2.3. Catch rate standardisation

CPUE is commonly used as an indicator of relative biomass (stock abundance) in crustacean fisheries worldwide. However, to improve the relationship between CPUE and relative biomass, it is considered important to standardise CPUE to account for the influence of variables that are not related to population size. Generalised linear modelling (GLM) was used to standardise FIS CPUE (kg.trawl-shot^{-1}) since 2005, and annual commercial CPUE (kg.block^{-1}.vessel-night^{-1}) since 1990/91, as per the methods in Noell *et al.* (2015). Variables considered from the FIS were fishing year-survey, region and vessel. Variables considered in the GLM used to standardise annual commercial CPUE were fishing year, month, region, lunar phase, effort, licence number and cloud cover. Standardised estimates of CPUE are presented with 95% confidence intervals.

3. RESULTS

3.1. Fishery-independent surveys

3.1.1. *CPUE*

Nominal FIS CPUE (diamond mesh) increased from 22.3 ± 1.6 kg.trawl-shot^{-1} in 2004/05 to 41.4 ± 3.4 kg.trawl-shot^{-1} in 2007/08, declined thereafter to a near historical low of 22.6 ± 2.2 kg.trawl-shot^{-1} in 2011/12 , after which the fishery was closed in 2012/13 and 2013/14 (Figure 5a). Nominal FIS CPUE from the ‘reduced’ survey in 2013/14 was 54.0 ± 4.8 kg.trawl-shot^{-1} but declined to 30.9 ± 2.1 kg.trawl-shot^{-1} in 2014/15. In the 2015/16 fishing season, nominal FIS CPUE increased 43% to 44.2 ± 2.9 kg.trawl-shot^{-1}, but in 2016/17 returned to a level similar to that seen in 2014/15 of 33.2 ± 2.4 kg.trawl-shot^{-1}. Nominal FIS CPUE estimated from the T90-mesh sampled since 2011/12 was generally lower than that estimated from diamond mesh but followed a similar trend (Figure 5a).

Fishing year-survey, region and vessel were all highly significant variables in the GLM used to standardise nominal estimates of FIS CPUE. However, a low overall model goodness-of-fit (adjusted R^2 value 0.14) indicates other sources of variability are unaccounted for. A total of 15.1% of the deviance in survey catches was explained by the model (fishing year-survey being the most important at 8.7%), which indicates that 84.9% of the deviance was caused by unknown factors (Table 6).

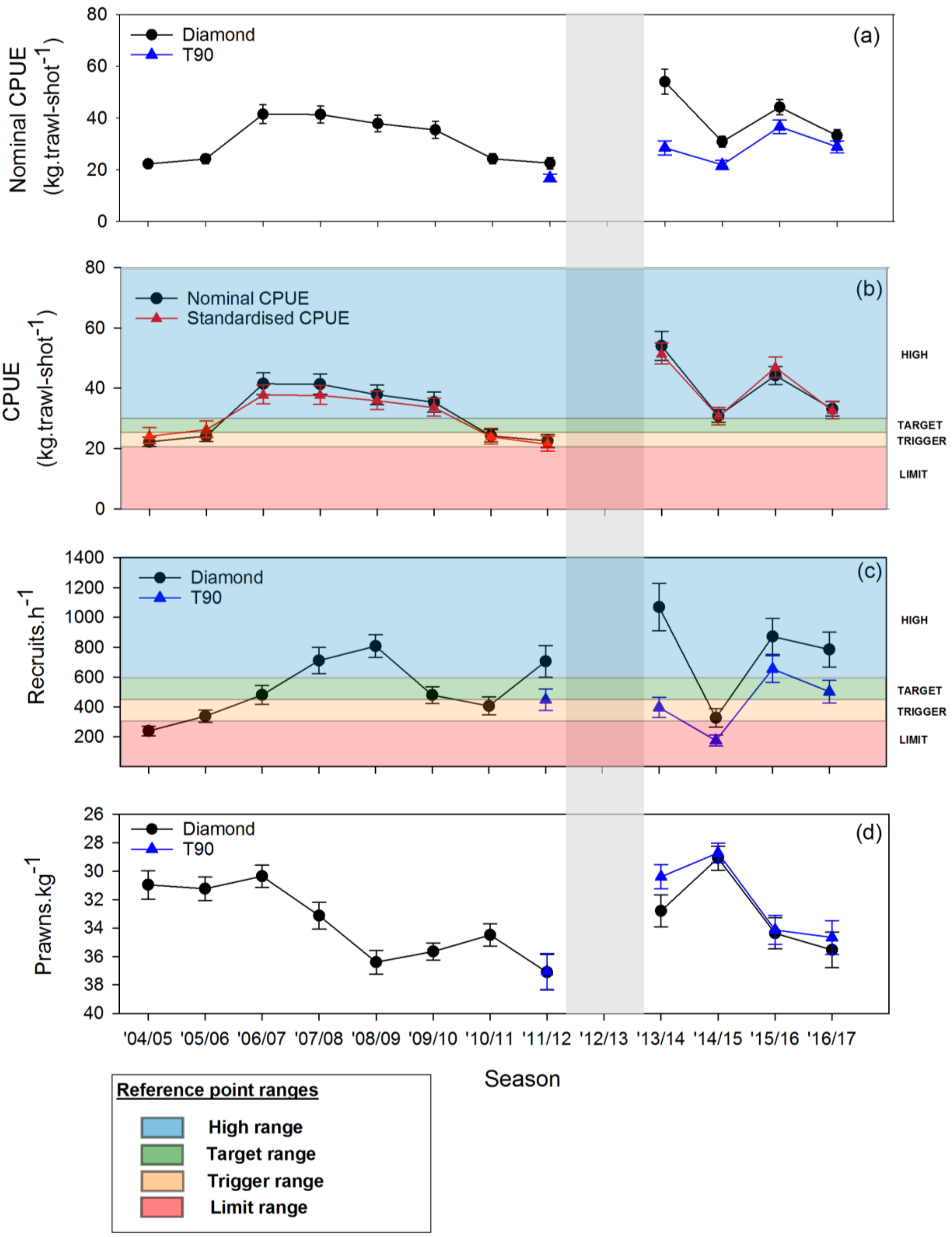

Figure 5. Key outputs from May fishery-independent surveys. (a) Nominal catch per unit effort (CPUE, kg.trawl-shot^{-1}) from diamond v T90-mesh; (b) Standardised versus nominal catch per unit effort (CPUE, kg.trawl shot^{-1}); (c) the Fishery Recruitment Index (FRI) (recruits.h^{-1}), and (d) prawn size (prawns.kg^{-1}). Indices were calculated from 94 completed survey shots in the 2017 Management Plan. 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 for all metrics except standardised CPUE where error bars are upper and lower confidence intervals. Grey area indicates lack of a survey during the fishery closure.

Table 6. Analysis of deviance (Type II test) for the GLM used to standardise survey CPUE for the GSVPF. Abbreviations: SS, sum of squares; df, degrees of freedom; *F*, *F*-statistic.

Effect	**SS**	**df**	***F***
Fishing year-survey	282.6	33.0	10.7***
Region	143.5	7.0	25.5***
Vessel	66.2	13.0	6.3***
Residuals	2762.5	3440.0	NA

Significance: *** $p < 0.001$

Trends in standardised FIS CPUE and nominal FIS CPUE measured from diamond mesh between 2004/05 and 2016/17 were similar, differing by no more than 9% in each year surveyed over this period (Figure 5b).

Estimates of standardised FIS CPUE have remained in the high range defined for this performance indicator of ≥30 kg.trawl-shot^{-1} in the last four surveys undertaken since 2013/14, ranging from 51.3 kg.trawl-shot^{-1}, 95% CI [48.0, 55.0] in 2013/14 to 30.7 kg.trawl-shot^{-1}, 95% CI [28.0, 33.7] in 2014/15 (Figure 5b). In 2016/17, standardised FIS CPUE was estimated from a total of 94 completed trawl shots and was 32.7 kg.trawl-shot^{-1}, 95% CI [29.9, 35.8].

3.1.2. *Recruitment*

In the 'reduced' survey in 2013/14, the FRI reached a historical high of 1,069 ± 158 recruits.h^{-1} (Figure 5c). Following re-opening of the fishery in November 2014, the 2014/15 FRI estimate was 327.6 ± 62.2 recruits.h^{-1}, which was the lowest estimate since 2004/05 (239.2 ± 31.5 recruits.h^{-1}). In 2015/16, the FRI was 872.2 ± 119.7 recruits.h^{-1}, more than double the FRI estimated in 2014/15 and the second highest value on record.

In 2016/17, the FRI was estimated from a total of 94 completed trawl shots and was 784.4 ± 116.3 recruits.h^{-1} (Figure 5c). Similar to the patterns in CPUE observed between diamond and T90-mesh since 2011/12 (Section 3.1.1), estimates of FRI from T90-mesh were lower (25.0-62.9%) and followed the same trend as FRI estimated from diamond mesh over the same period (Figure 5c).

3.1.3. *Size*

Mean prawn size, measured from the 7-kg subsample taken per shot, has an inverse relationship with the number of prawns per kg (i.e. larger mean prawn size = less prawns per kg). Mean prawn size has fluctuated since 2007/08 (Figure 5d). Prior to the fishery closure, mean prawn size measured in 2011/12 was the smallest on record at 37.1 ± 1.2 prawns.kg^{-1}. Following the fishery closure, mean prawn size increased 12% in 2013/14 to 32.8 ± 1.1 prawns.kg^{-1}, and in 2014/15 mean prawn size was the largest on record at 29.1 ± 0.8 prawns.kg^{-1} (Figure 5d). In 2015/16, mean prawn size decreased 18% to 34.4 ± 1.1 prawns.kg^{-1}, and in 2016/17 decreased further to 35.5 ± 1.3 prawns.kg^{-1}.

Trends in mean prawn size estimated from the T90-mesh since May 2012 are similar to those estimated from diamond mesh, however annual estimates of mean prawn size were slightly larger (0.1-7.3%) from T90-mesh than diamond mesh (Figure 5d).

3.1.4. *Spatial patterns in CPUE and size*

The areas where high catch rates (CPUE) of large (28-30 prawns.kg^{-1}) and extra-large (<28 prawns.kg^{-1}) prawns have been recorded have varied in GSV since 2007/08 (Figure 6). Relatively high CPUE (>100 kg.trawl-shot^{-1}) of large and extra-large prawns was recorded in northern GSV (RG1, RG6) between 2007/08 and 2009/10, and also in southern GSV (RG3) in 2008/09, 2013/14, 2015/16 and 2016/17 (Figure 6).

Relatively high CPUE (>100 kg.trawl-shot^{-1}) of small (>33 prawns.kg^{-1}) and medium size prawns (30-33 prawns.kg^{-1}) was also recorded from different areas of the fishery in different years. For example, high CPUE (>100 kg.trawl-shot^{-1}) of small (>33 prawns.kg^{-1}) and medium size prawns (30-33 prawns.kg^{-1}) was recorded in southern GSV (RG3) in 2007/08 and 2008/09, but also in central and northern areas of GSV in 2009/10, 2013/14 and 2015/16 (Figure 6).

In 2016/17, relatively high CPUE (>100 kg.trawl.shot^{-1}) of extra-large prawns occurred in the southern part of the gulf while moderate (50-100 kg.trawl.shot^{-1}) CPUE of small and medium prawns occurred in the northern part of the gulf (Figure 6).

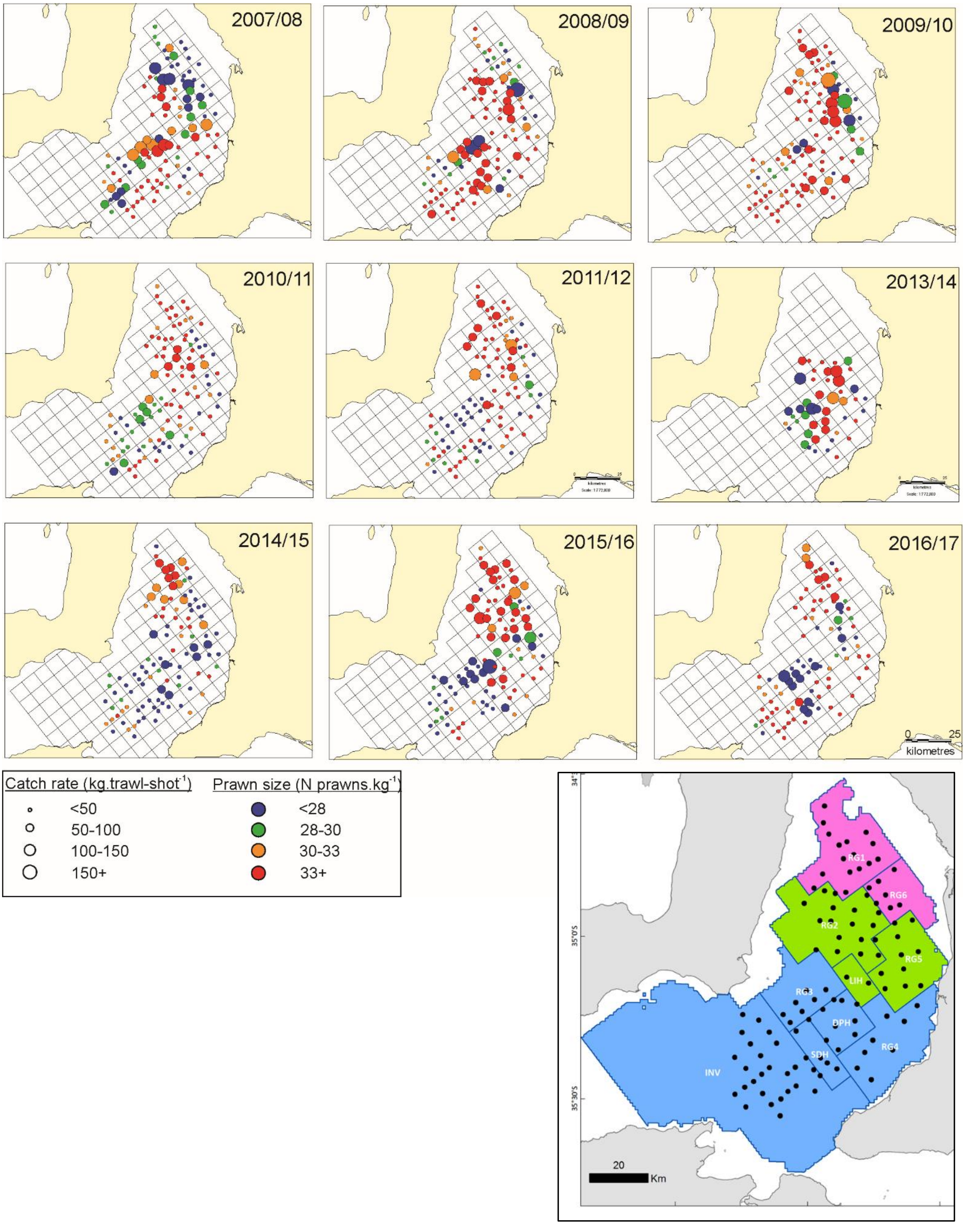

Figure 6. Catch rate and mean size from the diamond mesh codend during the May FIS' of the Gulf St Vincent Prawn Fishery. A reduced survey was undertaken in 2013/14. Map on bottom right shows regions used to describe spatial distribution of fishing.

3.2. Fishery statistics

3.2.1. *Catch and effort*

The total commercial catch of Western King Prawn in the GSVPF in 2016/17 was 224.6 t, not including 2.9 t taken in the May 2017 survey (Figure 7a, Table 7). The 2016/17 catch was similar to that taken in 2015/16 (217.8 t) and near the average catch landed by the fishery since 2000/01 (Mean since 2000/01: 228.3 ± 16.3 t, Figure 7a, Table 7).

In 2016/17, catch taken during the early spawning period (November – December) was 45.8 t, representing 20.4% of the total annual catch and an 11.2% increase compared to 2015/16 (20.1 t). The percentage of total catch taken during the late spawning period (January – March) in 2016/17 decreased 11.7% since 2015/16 from 54.4 t to 29.8 t (Table 7). Similar to 2015/16, the highest proportion of catch (149.0 t, 65.8%) was harvested during the non-spawning period (April – July) in 2016/17.

Commercial fishing was conducted over 287 vessel-nights in 2016/17, comprising 96% of the TACE of 300 vessel-nights (Figure 7b). A total of 49 out of the 50 allocated pre-Christmas vessel-nights were fished. Total effort was similar to that recorded in 2014/15 (294 vessel-nights) and 2015/16 (296 vessel-nights), but low compared to the amount of nights fished prior to 2002/03 (Figure 7b). The total commercial effort recorded in 2016/17 was 2,836 trawl-hours, which was 1.3% higher than 2015/16 (2,799 trawl-hours) and among the lowest levels of effort recorded in the fishery (Figure 7c).

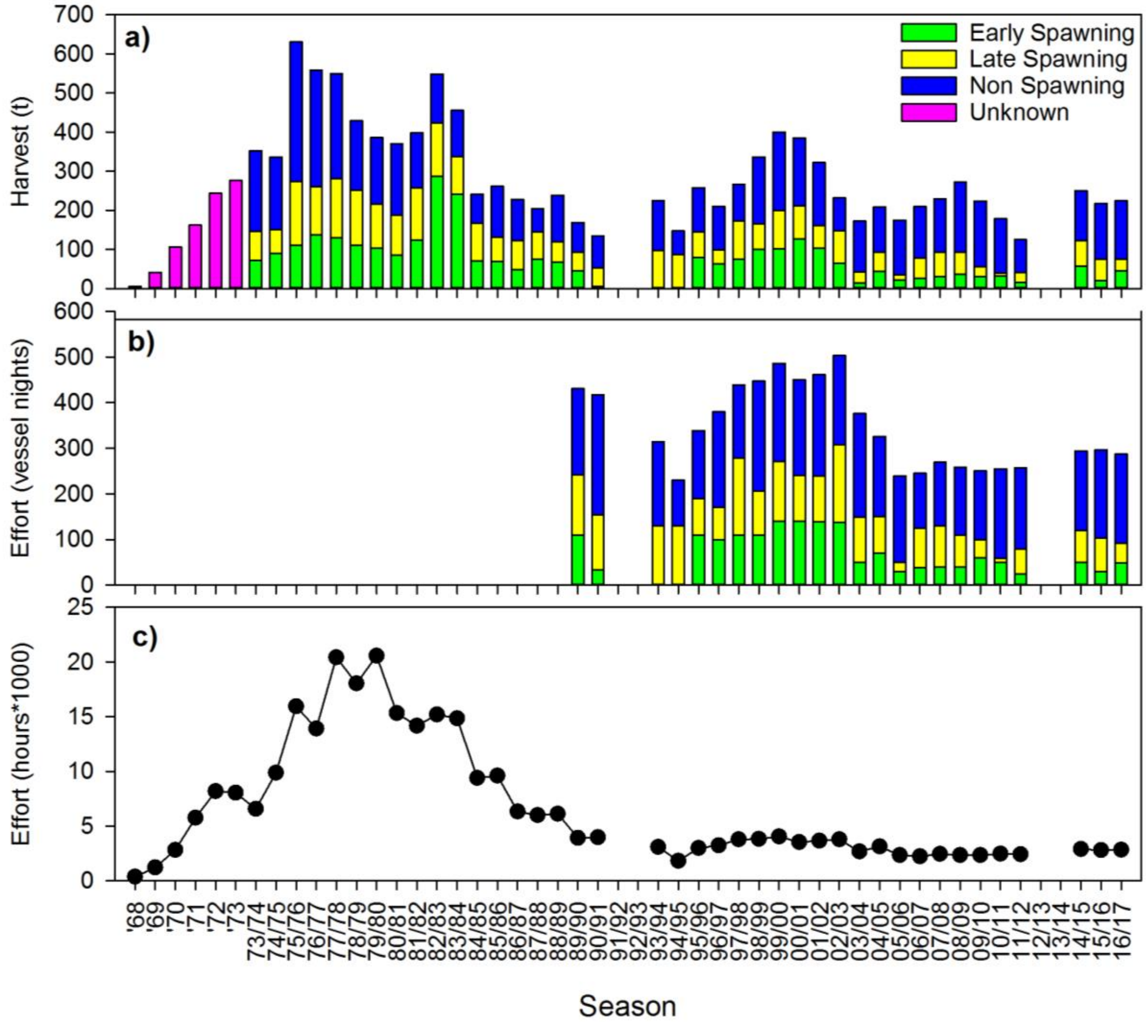

Figure 7. Fishery-dependent catch and effort data outputs for the Gulf St Vincent Prawn Fishery; (a) Annual catch (t) and (b) effort (vessel-nights) separated by early spawning (November–December), late spawning (January-March) and non-spawning (April-October) and (c) annual commercial effort (hours * 1000). Catch data from surveys not included.

Table 7. Monthly distribution of commercial (and survey) catch in the Gulf St Vincent Prawn Fishery from 1989/99–2016/17. *Data amalgamated across more than one month due to confidentiality requirements (<5 licence holders), data from gear trials not included. Survey catches since 2011/12 comprise catches from both T90 and diamond net.

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)
2016/17	21.2	24.6	-	29.8	40.2	49.3 (2.9)	59.4*		224.6 (2.9)

3.2.2. *CPUE*

Annual estimates of standardised annual commercial CPUE are on average 156 ± 20% higher than estimates of nominal CPUE but can be up to five times higher (e.g. 2003/04, Figure 8). Differences in estimates of nominal and standardised annual commercial CPUE were largest between 2000/01 and 2003/04 (Figure 8). It should also be noted that estimates of standardised annual commercial CPUE will differ each year as data from the latest season (e.g. 2016/17) are added to the GLM.

Despite the differences in scale of annual nominal and standardised CPUE estimates, the trend in both CPUE metrics was similar over time (Figure 8). Historically, estimates of standardised annual commercial CPUE were relatively stable from 1993/94 to 2004/05, ranging from 644 kg.block^{-1}.vessel-night^{-1}, 95% CI [628, 660] in 2002/03 to 881 kg.block^{-1}.vessel-night^{-1}, 95% CI [859, 903] in 1999/00 (Figure 8). From 2005/06, standardised commercial CPUE increased steadily, reaching a peak of 1,148 kg.block^{-1}.vessel-night^{-1}, 95% CI [1108, 1190] in 2008/09. Standardised commercial CPUE then declined reaching a low of 587 kg.block^{-1}.vessel-night^{-1}, 95% CI [563, 613] in 2011/12. The fishery was closed during 2012/13 and 2013/14.

Following re-opening of the fishery in 2014/15, standardised annual commercial CPUE increased up to 890 kg.block^{-1}.vessel-night^{-1}, 95% CI [863, 917] and was within the target range for this performance indicator of ≥750 and <900 kg.block^{-1}.vessel- night^{-1}. In 2015/16, standardised annual commercial CPUE increased further to 989 kg.vessel- night^{-1}, 95% CI [951, 1027] and was in the high range defined for this performance indicator of ≥900 kg.block^{-1}.vessel-night^{-1}. In 2016/17, standardised annual commercial CPUE was also within the target range defined for this performance indicator at 892 kg.block^{-1}.vessel-night^{-1}, 95% CI [866, 919] (Figure 8).

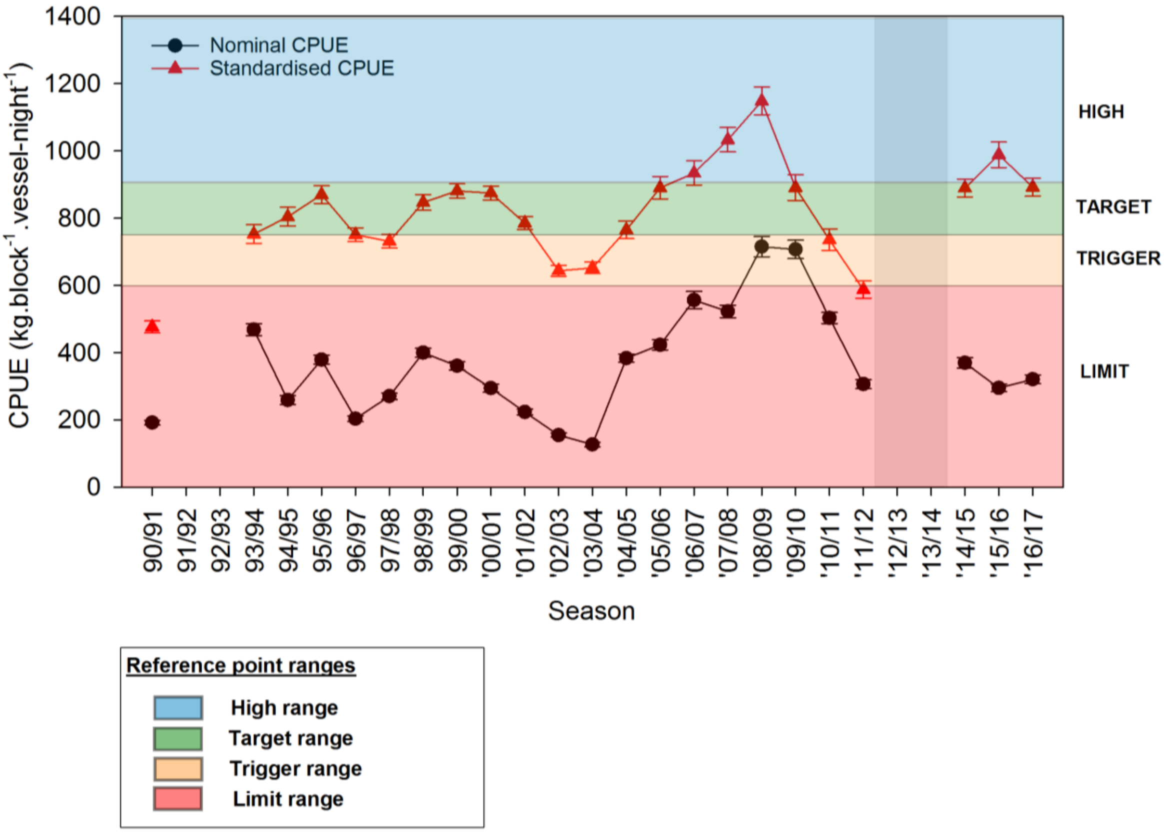

Figure 8. Comparison of model-predicted (standardised) annual CPUE with nominal CPUE (kg.block^{-1}.vessel-night^{-1}) in the Gulf St Vincent Prawn Fishery from 1990/91–2016/2017. Error bars are ± standard error for nominal CPUE, and upper and lower confidence intervals for standardised CPUE.

The GLM used to standardise nominal commercial CPUE data had a relatively high goodness-of-fit (adjusted R^2 value 0.79). Region, fishing year, month, lunar phase, effort, licence number and cloud cover were all significant variables in the GLM (Table 8). Effort was the most influential variable on estimates of nominal commercial CPUE, explaining 73.4% of the total model deviance. All other variables explained a total of 5.1% of the total model deviance and 21.5% of the deviance was caused by unknown factors. The large differences in annual estimates of nominal and standardised CPUE are likely attributed to effort being used as a fixed term in the GLM.

Table 8. 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.

Effect	SS	df	*F*
fishing year	4538.1	22	136.5***
month	838.0	7	79.2 ***
region	420.2	9	30.9***
lunar phase	48.0	1	31.7***
effort	87290.4	1	57774.3***
licence no	177.9	9	13.1***
cloud	59.7	1	39.9***
residuals	25567.2	16922	NA

significance: *** $p < 0.001$.

3.2.3. *Spatial patterns in catch and effort*

Following the use of FIS' in 2004/05 to spatially control fishing operations, the number of blocks fished declined (Figure 9). From 2014/15, the number of surveys was reduced, spatial management restrictions were amended (see Section 1.2.2), and the number of blocks that were fished increased. In 2016/17, fishing took place in 21 blocks in November–December and 62 blocks in the remaining months of the season. The number of blocks fished pre- and post-Christmas has increased slightly since the fishery reopened in 2014/15 (2014/15: 74 blocks cf. 2016/17: 83 blocks).

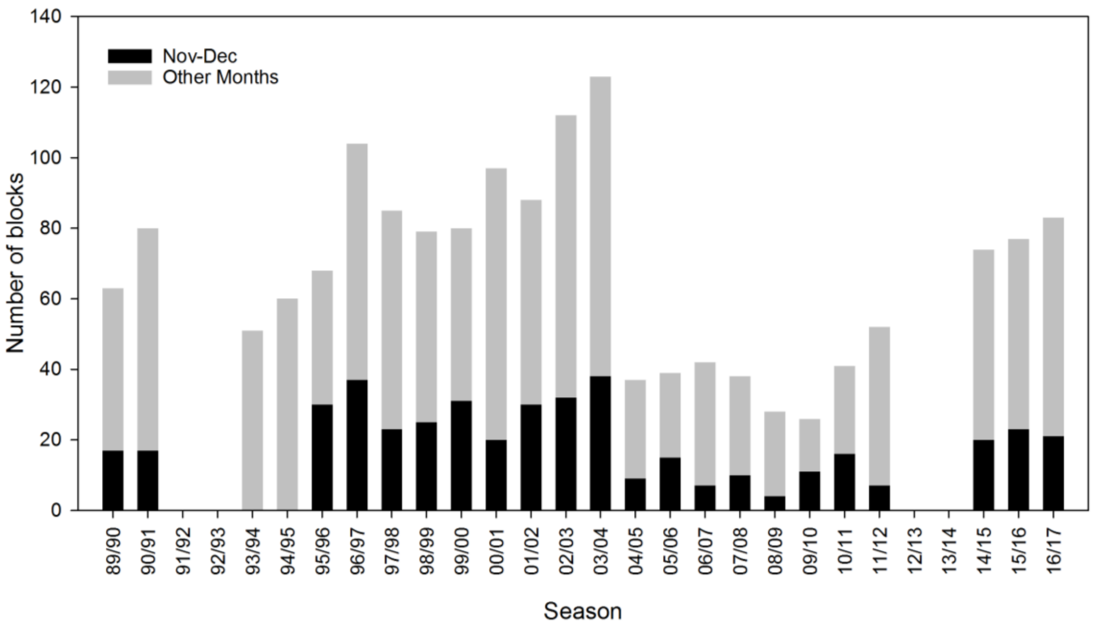

Figure 9. The number of blocks fished pre–Christmas (November and December) and all other months in the Gulf St Vincent Prawn Fishery from 1989/90–2016/17.

The spatial distribution of GSVPF commercial catch has varied annually. However, since 2014/15, a relatively high proportion of the catch has been taken in fishing blocks located in southern parts of GSV (Figure 10).

In 2016/17, 51.9% (116.5 t) of the total annual catch was taken in regions DPH, INV, RG3, RG4 and SDH. The total percentage of catch coming from these regions was less than in 2015/16, when a total of 72.6% of the total annual catch was recorded. In 2016/17, relatively high catches were also recorded in northern parts of the gulf in RG1. A total of 39 t was recorded from this region, representing 17.4% of the total annual catch of the GSVPF and over double that recorded from the same region in 2015/16.

In 2016/17, relatively low catches were recorded from RG4, RG5 and RG6 in the eastern parts of GSV. A combined total of 23.8 t was taken from these regions, representing 10.6% of the total annual catch recorded in the fishery. A similar level of catch was recorded from these regions in 2015/16 (22.2 t).

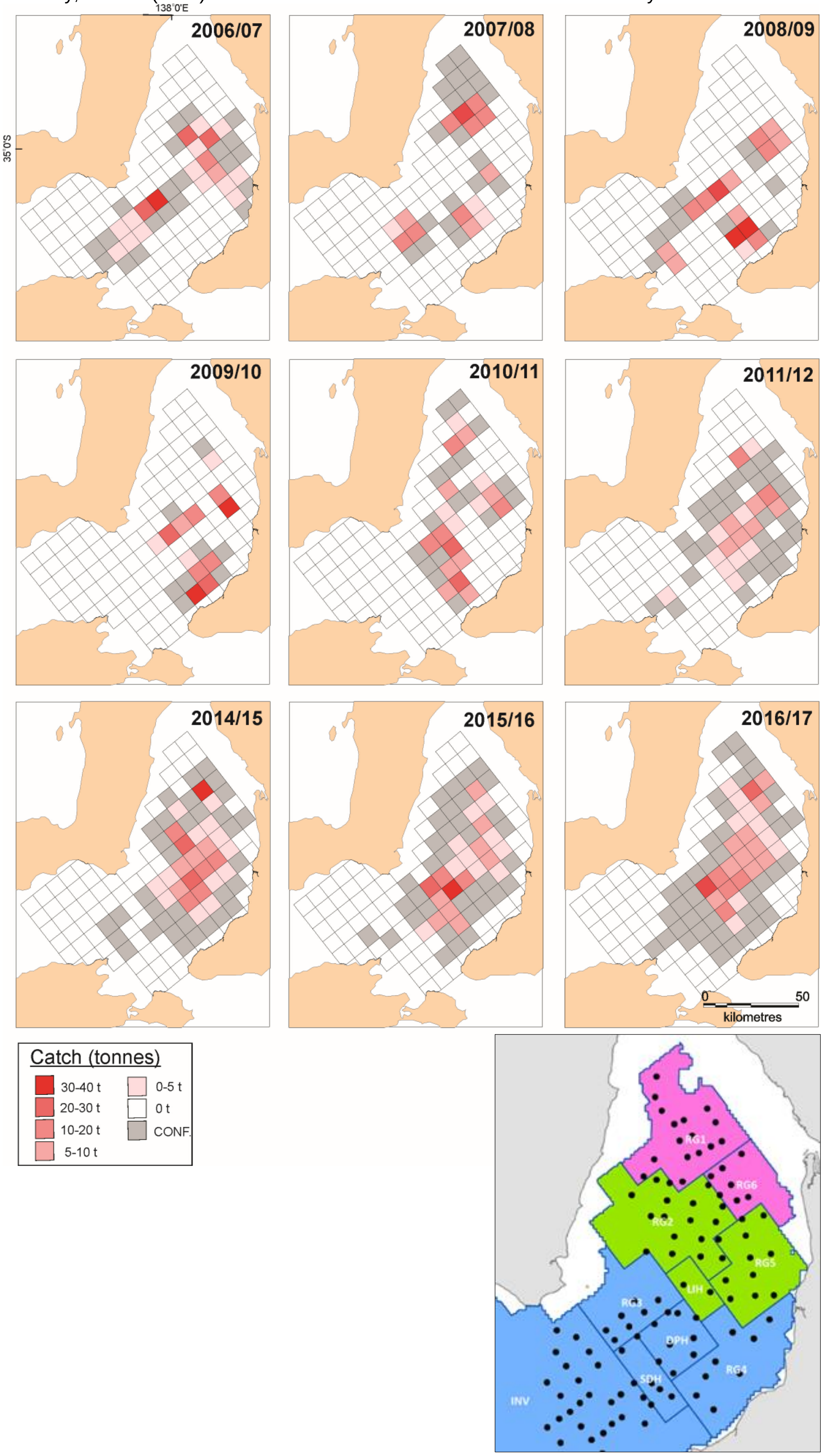

Figure 10. The annual catch per fishing block in the Gulf St Vincent Prawn Fishery from 2007/08–2016/17. Note, the fishery was closed in 2012/13 and 2013/14. Confidential data (<5 licence holders) are depicted in grey. Map on bottom right shows regions used to describe spatial distribution of fishing (see Figure 4 for more detail).

3.2.4. *Prawn size*

The annual catch of Western King Prawn in the GSVPF from 2005/06–2016/17 comprised, on average, 27% extra-large prawns, 38% large prawns, 22% medium prawns, 6% small prawns, and 7% soft & broken prawns (Figure 11). The percentage of small and medium prawns in the catch increased from 2005/06–2010/11, and a corresponding decrease in the proportion of large and extra-large prawns in the catch was recorded over the same period.

Following the re-opening of the fishery in 2014/15, extra-large and large prawns comprised a total of 69% (162 t) of the total catch, representing a 17% increase in the percentage of extra-large and large prawns recorded in the catch since 2010/11 (52%) (Figure 11, Table 9).

In 2015/16 and 2016/17, the proportion of extra-large large prawns in the catch was similar to that recorded in 2014/15, totalling 66.3% (136 t) and 68.7% (142 t) of the catch, respectively. Small prawns comprised 5.8% (11.9 t) and 4.8% (9.9 t) of the catch in 2015/16 and 2016/17, respectively (Figure 11, Table 9). The proportion of soft and broken prawns has historically been relatively low, and in 2016/17, soft and broken prawns contributed to 6.8% (14 t) of the total annual catch (Figure 11, Table 9).

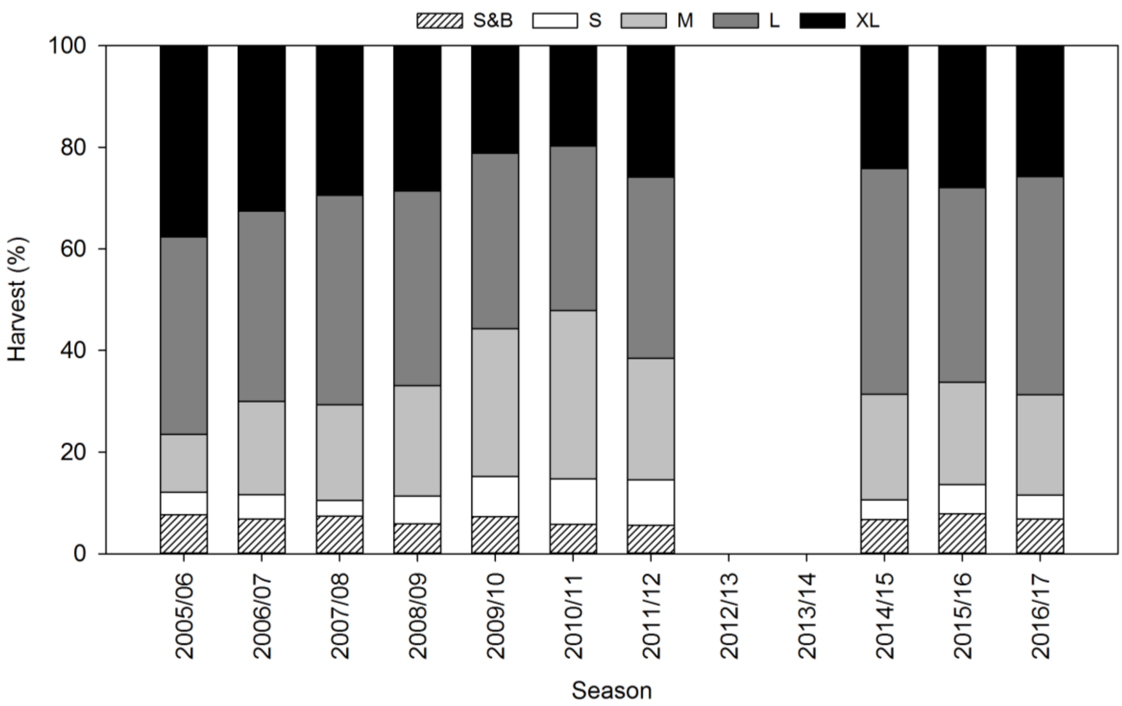

Figure 11. Size-grade composition (%) of monthly harvests in the Gulf St Vincent Prawn Fishery from 2005/06–2016/17. Grades include; soft and broken (S&B, not graded), small (S, 20+), medium (M, 16/20), large (L, 10/15) and extra-large (XL, U10).

Table 9. Size-grade composition (t) of monthly harvests in the Gulf St Vincent Prawn Fishery from 2005/06–2016/17. 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).

SEASON	XL	XL-Split			L	M	S	SB
		U10	***U8***	***U6***				
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	*36.8*	*2.5*	*17.8*	104.8	49.1	9.1	15.9
2015/16	57.3	*31.6*	*3.6*	*22.1*	78.7	41.3	11.9	16.0
2016/17	53.4	*32.2*	*3.0*	*18.2*	88.9	40.9	9.9	14.1

4. DISCUSSION

4.1. Information sources used for assessment

The current management plan for the fishery provides the decision rules for classifying the status of the Western King Prawn stock in GSV (PIRSA 2017). It uses limit, trigger and target reference points defined for three performance indicators relating to stock abundance and recruitment (PIRSA 2017). The performance indicators relating to stock abundance are: 1) standardised annual commercial CPUE estimated from fishery-dependent data recorded in daily commercial logbooks; and 2) standardised FIS CPUE estimated from data collected in the May FIS. The FIS recruitment index (FRI) is also estimated from data collected in the May FIS.

4.1.1. *Fishery-independent data*

From December 2004, a comprehensive survey program has been conducted to contribute towards the assessment of the status of the Western King Prawn stock in GSV. The methods used to collect the data have remained relatively consistent and are considered high quality, however, 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 FIS' 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 FIS was undertaken in May 2014 and this was extended over the dark phase of the moon; and
5) T90-mesh codends have been operated alongside diamond-mesh codends during surveys conducted since 2011/12.

Despite recent modifications to the FIS program, the locations sampled in the May FIS have remained relatively consistent over time, and standardised FIS CPUE and the FRI are considered the best available indices of current and future relative biomass. Also, while the distribution, extent and timing of recruitment is highly variable in GSV, new recruits are expected to be adequately represented in the catch during the FIS in May.

The introduction of T90-mesh codends fitted with Nørdmore grids into the GSVPF in 2012 was based on the results of FRDC Project 2009/069 (Dixon *et al.* 2013), which indicated that this trawl-gear modification improved catch selectivity, reduced levels of bycatch and facilitated the escapement of small prawns in the fishery. Ongoing data collection from T90-mesh codends during the FIS will enable potential calibration with fishery-dependent data collected from diamond-mesh codends in the future.

4.1.2. *Fishery-dependent data*

The trends in standardised annual commercial CPUE estimated from data recorded in daily commercial logbooks resemble the trends in standardised FIS CPUE since 2004/05. However, there remain sources of uncertainty associated with data collected from the fishery. Firstly, the spatial distribution of fishing effort has changed over time due to changes in spatial management of the fishery. Secondly, estimates of standardised annual commercial CPUE are based on daily logbook data from 1991/92 because nightly catch data available prior to this time are either not available or considered unreliable. Consequently, estimates of standardised CPUE from 1991/92 do not take into account the period in the fishery when catches were higher.

4.2. Status

Since its inception in 1967, the GSVPF has gone through a number of cycles characterised by steady or increasing catches and catch rates, subsequent declines in recruitment and fishery performance, and resulting closure periods (1991/92 to 1992/93 and 2012/13 to 2013/14). The current harvest strategy for the fishery (PIRSA 2017) was developed considering the history of fishery performance, previous stock assessments and reviews of the fishery conducted by Knuckey *et al.* (2011), Morgan and Cartwright (2013), and Dichmont (2014).

In 2016/17, the total commercial catch of Western King Prawn in the GSVPF was 224.6 t, with an additional 2.9 t taken in the May 2017 survey. This catch was near the average catch landed by the fishery since 2000/01. Fishing was conducted over 287 vessel-nights, comprising 96% of the TACE of 300 vessel-nights. A total of 49 out of the 50 allocated pre-Christmas vessel-nights were fished.

Estimates of standardised annual commercial CPUE were in the high range defined for this performance indicator of ≥900 kg.block^{-1}.vessel-night^{-1} in 2015/16, and within the target range defined for this performance indicator of ≥750 and <900 kg.block^{-1}.vessel- night^{-1} in 2014/15 and 2016/17 (PIRSA 2017). Estimates of standardised FIS CPUE have remained in the high range defined for this performance indicator of ≥30 kg.trawl-shot^{-1} in the last four surveys since 2013/14. Similarly, the FRI has remained in the high range defined for this performance indicator of ≥600 recruits.h^{-1} for three of the last four annual surveys (2013/14, 2015/16 and 2016/17).

PIRSA has adopted the NFSRF stock status classification system to determine the status of all South Australian fish stocks. The framework was used to assess the status of the Western King Prawn stock in GSV using a 'weight-of-evidence' approach in 2014/15 and 2015/16. In 2014/15, using a weight-of-evidence approach, the stock was classified as 'transitional depleting' based on the relatively low level of recruits recorded in the May 2015 survey (2014/15 fishing season). In the May 2016 FIS (2015/16 fishing season), levels of estimated recruitment were more than double that estimated in 2014/15. Coupled with the relatively high levels of standardised annual commercial CPUE and FIS CPUE observed in 2015/16, using a weight-of-evidence approach, the stock was classified as 'sustainable' in 2015/16.

The current harvest strategy provides a more prescriptive approach to determining the status of the Western King Prawn stock in GSV (PIRSA 2017). Stock status is determined within the harvest strategy by assessing how each of the three performance indicators align against pre-defined limit, trigger and target reference points (Table 10) (PIRSA 2017).

In 2016/17:

1. standardised annual commercial CPUE was 892 kg.block^{-1}.vessel-night^{-1}.
2. standardised FIS CPUE was 32.7 kg.trawl-shot^{-1}; and
3. the FRI was 784.4 ± 116.3 recruits.h^{-1}.

Standardised annual commercial CPUE and FIS CPUE are given equal weighting in the decision rules used to categorise the status of the stock (Table 10) (reproduced from Table 10, PIRSA 2017). The FRI is used as a meta-rule that "*recognises that low levels of abundance of total prawns would not be considered recruitment overfished if recruitment levels were above trigger levels"* (PIRSA 2017). When the 2016/17 estimates for each performance indicator are applied in the decision matrix used to determine the status of the Western King Prawn stock in GSV (Table 10), the stock is classified as '**sustainable**'.

Table 10. Decision rules for classifying the status of Western King Prawn stock in GSV (PIRSA 2017). * Transitional may refer to Transitional Depleting, or Transitional Recovering. Transitional Depleting will be determined based on the definition in Flood et al. (2014) as “biomass is not yet recruitment overfished, but fishing pressure is too high and moving the stock in the direction of becoming recruitment overfished”. Transitional Recovering would be determined based on the definition in Flood et al. (2014) as “biomass is recruitment overfished but management measures are in place to promote stock recovery and recovery is occurring”.

		Performance Indicator – Standardised Annual Commercial CPUE (kg.block^{-1}.vessel-night^{-1})			
		Limit <600	**Trigger** ≥600 - <750	**Target** ≥750 - <900	**High** ≥900
Performance Indicator - Standardised FIS CPUE (kg.trawl-shot^{-1})	**Limit** <20	**Overfished**	**Transitional*** OR **Overfished** when FRI <450 recruits.hr^{-1}	**Transitional*** OR **Sustainable** when FRI ≥450 recruits.hr^{-1}	
	Trigger ≥20-<25	**Transitional*** OR **Overfished** when FRI <450 recruits.hr^{-1}	**Transitional*** OR **Sustainable** when FRI ≥450 recruits.hr^{-1}		
	Target ≥25-<30	**Transitional*** OR **Sustainable** when FRI ≥450 recruits.hr^{-1}		**Sustainable**	
	High ≥30				

4.3. Management Implications

Under the current harvest strategy (PIRSA 2017), the total annual TACE and number of pre-Christmas (November – December) fishing nights for the following season is also determined through a decision matrix that considers how each performance indicator aligns with pre-defined limit, trigger and target reference points (Tables 11 and 12) (PIRSA 2017).

Table 11. Decision rules for setting total annual commercial effort (nights) for a fishing season in the Gulf St Vincent Prawn Fishery.

		Performance Indicator – Standardised Annual Commercial CPUE ($kg.block^{-1}.vessel\text{-}night^{-1}$)			
		Limit <600	**Trigger** ≥600 - <750	**Target** ≥750 - <900	**High** ≥900
Performance Indicator - Standardised FIS CPUE ($kg.trawl\text{-}shot^{-1}$)	**Limit** <20	0 nights	80 nights	130 nights	160 nights
	Trigger ≥20-<25	80 nights	130 nights	200 nights	230 nights
	Target ≥25-<30	130 nights	200 nights	250 nights	300 nights
	High ≥30	160 nights	230 nights	300 nights	320 nights

Table 12. Decision rules for setting pre-Christmas effort (nights) in the Gulf St Vincent Prawn Fishery. Adapted from PIRSA (2017).

FRI	Pre-Christmas Fishing effort or catch
Limit <300 recruits/hr OR The fishery is classified as overfished or transitional depleting	0 nights
Trigger ≥300 - <450 recruits/hr	5% of annual TACE rounded down to the nearest multiple of 10
Target ≥450 - <600 recruits/hr	10% of annual TACE rounded down to the nearest multiple of 10 for numbers ending in ≤5, and rounded up to the nearest multiple of 10 for numbers ending in >5.
High ≥600 recruits/hr	15% of total annual commercial effort rounded to the nearest multiple of 10.

The cutoff date for the provision of fishery-dependent data (daily commercial logbook) to estimate standardised annual commercial CPUE for TACE setting is 15 August each year. The total TACE is based on estimates of standardised annual commercial CPUE and standardised FIS CPUE using the data available up to this time. Applying the 2016/17 estimates of standardised annual commercial CPUE and standardised FIS CPUE in the decision matrix, the TACE for the 2017/18 fishing season was set at 300 nights (Table 11). Pre-Christmas TACE is set based on estimates of FRI calculated from the May FIS. Applying the 2016/17 FRI estimate in the decision matrix for setting pre-Christmas TACE (Table 12), the total number of pre-Christmas fishing nights in the 2017/18 fishing season was set at 50 nights.

4.4. Future directions

The 'sustainable' classification of the Western King Prawn stock in GSV is a positive sign for the fishery. However, the history of serial declines in fishery performance and current operational objectives for the GSVPF to "*rebuild prawn biomass in the short to medium-term and maintain ecologically sustainable prawn biomass thereafter*" (PIRSA 2017) necessitate that the sources of uncertainty are highlighted and addressed in the future.

The status of the Western King Prawn stock in GSV in 2016/17 has been determined under the newly adopted harvest strategy for the GSVPF and is based on fishery-dependent data available since 1991/92 and FIS data available since 2004/05. The assessment does not take into account the period prior to 1991/92 when catches were higher. Consequently, the assessment is made against a 'baseline' that has shifted from an era of relatively high productivity. Historically, the GSVPF has suffered multi-year declines in recruitment and subsequent biomass, and the efficacy of the newly adopted harvest strategy in buffering reductions in recruitment, or in maintaining its operational objectives, is currently unknown (PIRSA 2017). The efficacy of the harvest strategy in achieving the operational objectives of the GSVPF should be assessed in future stock assessments once the harvest strategy has been in operation for several fishing seasons. The bio-economic model of Noell *et al.* (2015) may provide a useful tool for undertaking this evaluation.

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 (November–December). A biophysical model was recently developed for the Spencer Gulf Prawn Fishery to predict patterns of larval dispersal and settlement by coupling knowledge of the biology and behaviour of Western King Prawn larvae to a hydrodynamic model (McLeay *et al.* 2015). A similar model could be developed for the GSVPF to simulate how changes in spatial fishing patterns and/or environmental conditions may maximise both recruitment and catch during periods of high catch value (i.e. pre-Christmas).

The outputs of the GLM used to standardise commercial and FIS CPUE indicate large amounts of unexplained variance. Standardisation procedures for commercial CPUE would benefit from incorporating information that accounts for factors that affect CPUE but are not related to prawn biomass e.g. changes in gear configuration since 2012 (T90 codends). Further analyses are also required to assess the influence of survey design and other variables on FIS CPUE. Any review or analysis of the FIS data would also benefit from detailed comparisons of CPUE estimated from T90 and diamond-mesh codends, and would help to facilitate the likely transition to using only T90 codends in surveys in the future.

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