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Gulf St Vincent Prawn *Penaeus* (*Melicertus*) *latisulcatus* Fishery 2018/19

L.J. McLeay and G. E. Hooper

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Fishery Assessment Report to PIRSA Fisheries and Aquaculture

SOUTH AUSTRALIA

Government of South Australia
Primary Industries and Regions SA

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EXECUTIVE SUMMARY

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

In 2018/19, the total commercial catch of Western King Prawn in the Gulf St Vincent Prawn Fishery (GSVPF) was 212.2 t, with an additional 2.5 t taken in the May 2019 fishery-independent survey (FIS). Fishing was conducted over 300 vessel-nights, comprising 100% of the Total Allowable Commercial Effort (TACE). All 50 allocated pre-Christmas vessel-nights were fished (Table 1).

Estimates of standardised annual commercial CPUE were in the high range (≥900 kg.block^{-1}.vessel-night^{-1}) in 2015/16 and within the target range (≥750 and <900 kg.block^{-1}.vessel- night^{-1}) from 2016/17 to 2018/19. Estimates of standardised Fishery Independent Survey (FIS) CPUE remained in the high range (≥30 kg.trawl-shot^{-1}) between 2013/14 and 2017/18. However, in 2018/19, FIS CPUE declined to the target range (≥25 and <30 kg.trawl-shot^{-1}). The Fishery Recruitment Index (FRI) has remained in the high range (≥600 recruits.h^{-1}) defined for this performance indicator in the last four annual surveys (2015/16–2018/19).

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 commercial CPUE; 2) standardised FIS CPUE; and 3) the FRI.

In 2018/19:

- Standardised annual commercial CPUE was 867 kg.block^{-1}.vessel-night^{-1}, which is 2.9% lower than in 2017/18 (893 kg.block^{-1}.vessel-night^{-1}), and within the target range defined for this performance indicator;
- Standardised FIS CPUE was 28.5 kg.trawl-shot^{-1}, which is a 20.4% decrease since 2017/18 (35.8 kg.trawl-shot^{-1}), but within the target range defined for this performance indicator; and
- The FRI was 834.8 recruits.h^{-1}, which is 24.5% higher than in 2017/18 (670.3 recruits.h^{-1}), and within the high range defined for this performance indicator.

When the 2018/19 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**'.

The 'sustainable' classification of the Western King Prawn stock in GSV is a positive sign for the fishery. However, caution is warranted in relation to the GSVPF's future performance. Concurrent declines in standardised annual commercial CPUE and standardised FIS CPUE since the fishery reopened in 2014/15 indicate that the current level of fishing mortality may be causing reductions in prawn abundance. Also of concern are the decreases in prawn size estimated from the FIS' and commercial prawn-grade data since 2014/15. In this period, mean prawn size measured from FIS' has steadily decreased, and in 2018/19 was the smallest on record at 43.2 ± 1.7 prawns.kg^{-1}. The composition of extra-large (U6-U10 prawns per pound) and large (10/15 prawns per pound) prawns in the catch has also decreased by approximately 10% since 2017/18.

These trends indicate that fishing mortality is most likely causing changes in the stock size-structure and exceeding that which produces maximum yield per recruit. Moreover, the smaller size of the prawns in the catch implies that the number of prawns being removed annually may be higher than in recent years, since the annual total weight of catch has remained relatively stable. As a consequence, if the decreasing trends in prawn size continue, there is an increased risk of recruitment overfishing in the future. Reductions in fishery exploitation rates triggered by decision rules within the harvest strategy need to be sufficient to stabilise stock biomass and reverse the declines in prawn size since 2014/15 to ensure that future recruitment is adequate.

Table 1. Key Gulf St Vincent Prawn Fishery statistics between 2016/17 and 2018/19. Note, estimates of standardised annual commercial CPUE and standardised FIS CPUE will differ in each status report as data are updated within the Generalised Linear Model.

Statistic	2016/17	2017/18	2018/19
Total allowable commercial effort (TACE)	300 nights (50 pre-Christmas)	300 nights (50 pre-Christmas)	300 nights (50 pre-Christmas)
Total commercial catch	224.6 t (+2.9 t from survey)	236.6 t (+3.5 t from survey)	212.2 t (+2.5 t from survey)
Total effort	287 vessel nights (49 pre-Christmas) 2,836 hours	295 vessel nights (50 pre-Christmas) 2,892 hours	300 vessel nights (50 pre-Christmas) 2,935 hours
Standardised annual commercial CPUE	883 $kg.block^{-1}.vessel\text{-}night^{-1}$	893 $kg.block^{-1}.vessel\text{-}night^{-1}$	867 $kg.block^{-1}.vessel\text{-}night^{-1}$
Standardised FIS CPUE	32.4 $kg.trawl\text{-}shot^{-1}$	35.8 $kg.trawl\text{-}shot^{-1}$	28.5 $kg.trawl\text{-}shot^{-1}$
FRI	784.4 $recruits.h^{-1}$	670.3 $recruits.h^{-1}$	834.8 $recruits.h^{-1}$
Status	**Sustainable**	**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 2018/19 fishing season.

The report has three objectives: 1) present information relating to the fishery and biology of Western King Prawn; 2) assess the 2018/19 status of the Western King Prawn resource in Gulf St Vincent; and 3) 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 number of licences (39). The WCPF is the smallest of the 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 low commercial value.

The fishing season of the GSVPF 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 GSVPF vessels are Port Adelaide and North Haven.

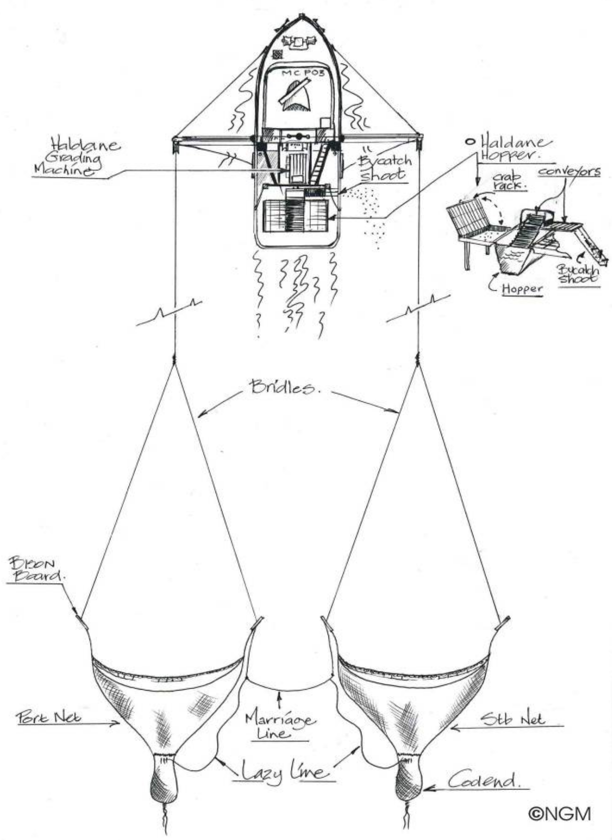


Figure 1. Double-rig trawl gear and location of hopper sorting and prawn grading systems used in the Gulf St Vincent Prawn Fishery. Figure from Carrick (2003).

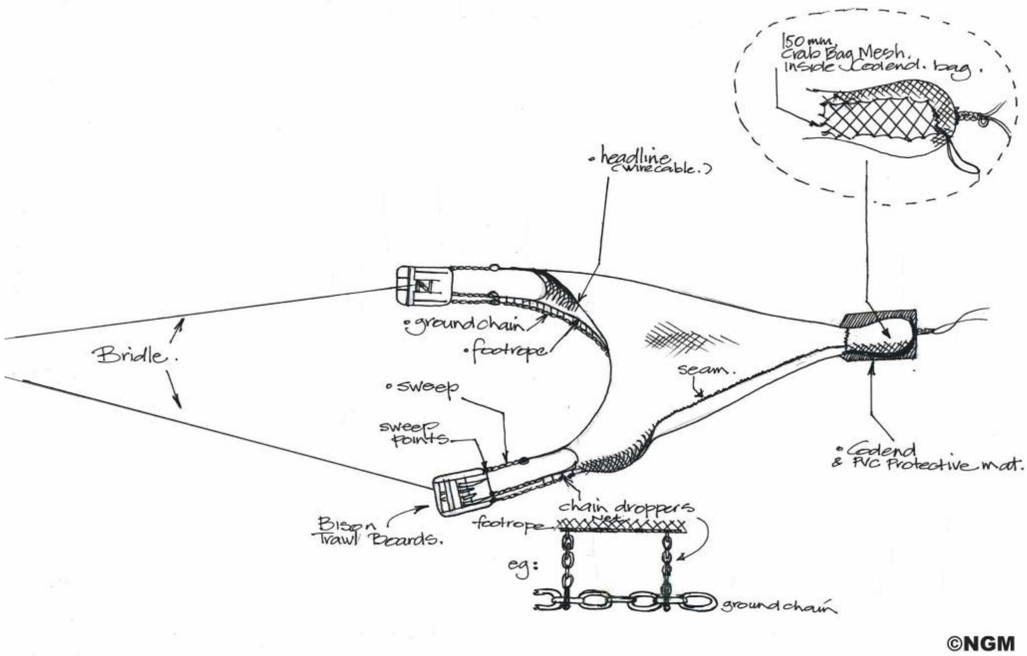


Figure 2. Trawl net configuration showing trawl boards, head rope, ground chain and codend with crab bag as used in the Gulf St Vincent Prawn Fishery. Figure from Carrick (2003).

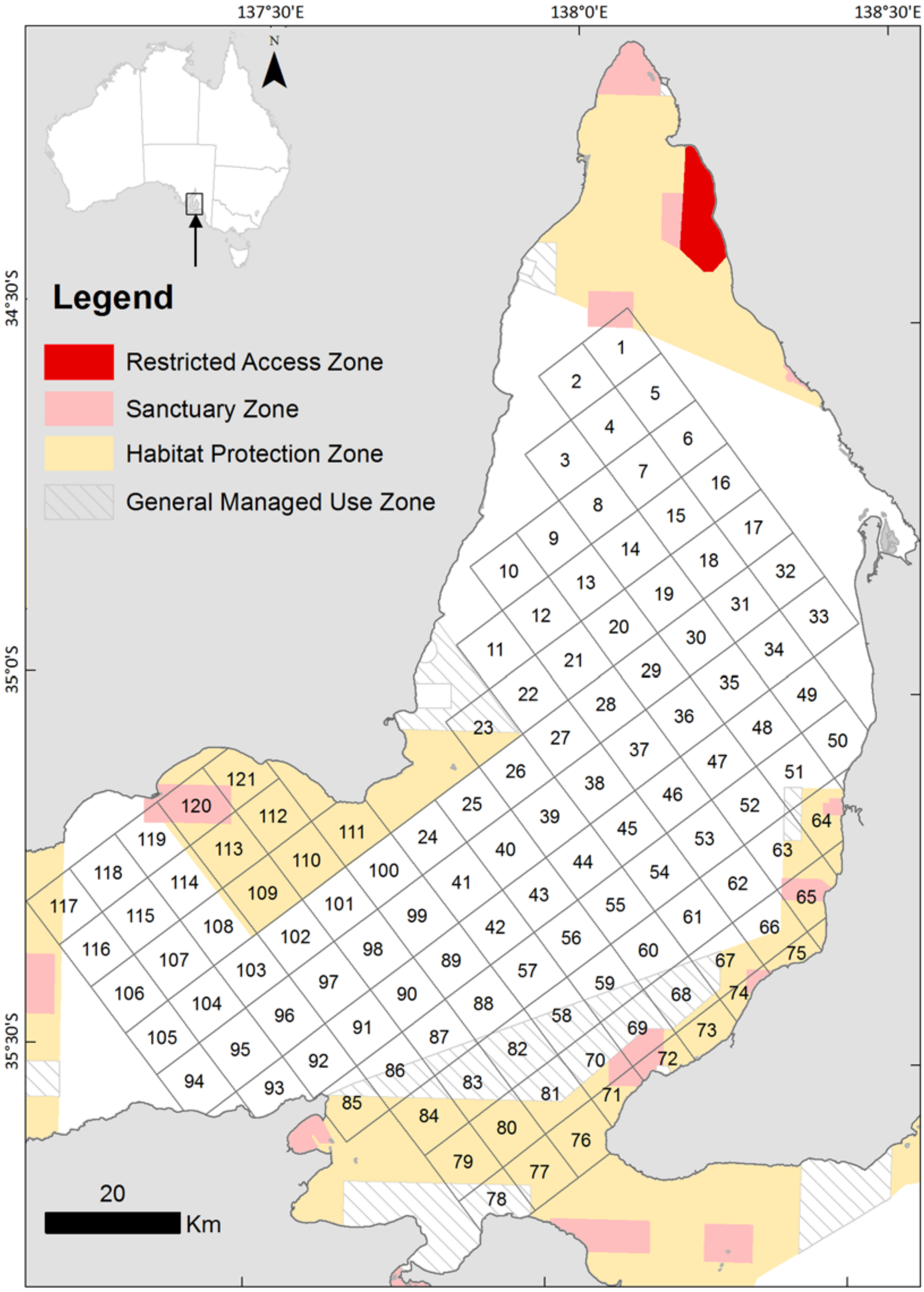


Figure 3. The research management blocks for the Gulf St Vincent Prawn Fishery. South Australian Marine Park Zoning also shown.

1.2.2. *Management arrangements*

The *Fisheries Management Act 2007* provides the legislative framework for the 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 overarching 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 Nordmøre-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, a new 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 undertaken 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 adopted within the St Vincent Gulf Prawn Boat Owner's Association (SVGPBOA) Industry Code of Practice. The Industry Code of Practice is a non-legislated document that describes the expected activities for licence holders in the GSVPF. Transferrable 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 principal policy arrangements 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 3.

The harvest strategy listed within the management plan for the fishery uses decision rules for setting the total number of fishing nights (TACE) and number of pre-Christmas fishing nights each season (PIRSA 2017). The decision rules are based on limit, trigger and target reference points defined for three performance indicators relating to stock abundance and recruitment: 1) standardised annual catch per unit effort (CPUE); 2) standardised fishery-independent survey (FIS) CPUE; and 3) the FIS recruitment index (FRI). These indicators 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	Western King Prawn *(Penaeus (Melicertus) latisulcatus)*, Balmain Bug (*Ibacus* spp.), Southern Calamari (*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
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 inhabits sand and seagrass habitats within estuarine and gulf waters of the Indo-west Pacific (Grey *et al.* 1983; Tanner and Deakin 2001). In South Australia, its distribution is primarily restricted to the relatively warm and reproductively favourable waters of Spencer Gulf, GSV and along the West Coast of South Australia (Ceduna, Venus Bay and Coffin Bay) (Penn 1980; Courtney and Dredge 1988).

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 water temperature. 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 to be predominately north to south (Kangas and Jackson 1997), with a small number of tag recaptures 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 the spawning of fertile eggs occurs during a single intermoult period (30–40 days), where fertilisation likely 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 their higher fecundity (Penn 1980; Courtney and Dredge 1988; Carrick 1996).

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 accepted to be one of the most important factors affecting larval growth and survival, with higher water temperatures, up to 20ºC, resulting in faster rates of development and higher rates of survival (Hudinaga 1942; Rodgers *et al*. 2013).

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) 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 settle in nursery areas during December or January, when growth rates are high, before migrating to deeper water in May or June as juvenile prawns (~20 mm CL). Post-larvae produced from late spawning events (January to March) 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*

Genetic analyses using ribosomal-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 genetically homogenous stock within 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. No relationship was identified between growth and water temperature between October and December, likely due to prawns allocating more energy to reproduction during this time than growth.

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), on the West Coast of South Australia (0.001 to 0.014; Wallner 1985) and in Western Australia (0.002 to 0.005; Penn 1976). Sex-specific estimates of natural mortality from Xiao and McShane (2000) provided equivalent results (0.003 per day for males and females).

1.3.7. *Biosecurity and prawn health*

The potential effects of coastal pollutants, parasites and disease on growth, survival, reproduction and the overall health of Western King Prawn populations in South Australia 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.

White spot disease (WSD) is a highly contagious and lethal viral disease that was first detected in farmed prawns in south-east Queensland in December 2016. The virus can cause high rates of mortality in affected prawns and is currently the subject of a national surveillance program. To date, all samples that have been collected and tested within jurisdictions outside of Queensland have returned negative results (National Pest and Disease Outbreaks).

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; McLeay *et al.* 2017; 2018).

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 2018/19 research program is to assess the status of the Western King Prawn stock in GSV using fishery-independent and -dependent information collected from the GSVPF during the 2018/19 fishing season.

1.5. Information sources used for assessment

Fishery-independent data have been collected for the GSVPF using surveys coordinated by SARDI since 1984. SARDI also maintains a comprehensive fishery-dependent catch and effort database for the GSVPF using data obtained from the South Australian Fishing Industry Council (SAFIC) annual reports between 1968 and 1987. Data from July 1987 were obtained from daily commercial logbooks provided to SARDI by licence holders.

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; Stewardson *et al.* 2016, 2018). The NFSRF of Flood *et al.* (2014), which the management plan for the GSVPF refers to, considers whether the current level of fishing pressure is adequately controlled to ensure that stock abundance is not reduced to a point where recruitment is impaired. 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. The stock is then classified as 'sustainable', 'transitional-recovering', 'transitional-depleting', 'overfished', 'environmentally limited', or 'undefined' (Table 4).

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

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 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 FIS.
3. FRI (recruits.h^{-1}) that is estimated from data collected in the May FIS.

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 (Table 5) (PIRSA 2017).

Table 5. 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 is 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 is 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.h^{-1}	Transitional* OR Sustainable when FRI ≥450 recruits.h^{-1}	
	Trigger ≥20-<25	Transitional* OR Overfished when FRI <450 recruits.h^{-1}	Transitional* OR Sustainable when FRI ≥450 recruits.h^{-1}		
	Target ≥25-<30	Transitional* OR Sustainable when FRI ≥450 recruits.h^{-1}		Sustainable	
	High ≥30				

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. This report used data from May surveys only to enable temporal comparison of the FIS data collected since 2004/05.

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 2018, the number of sites sampled ranged from 94–112, except for 2014 where a reduced survey of 47 sites was completed. The survey in May 2019 included data from 101 of the 109 survey locations 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 (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 included 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' - recorded before grading of the catch has occurred and used as a rapid measure to estimate prawn size).

The number of prawns in a 7 kg subsample was used to estimate mean prawn size (N prawns.kg^{-1}), with higher estimates representing smaller prawns and lower estimates representing larger prawns. The GPS locations of each trawl station were used to map prawn size and CPUE across the survey area. To depict the spatial distribution of catch rate and prawn size, prawns were defined as 'small' (>32 prawns.kg^{-1}), 'medium' (30-32 prawns.kg^{-1}), 'large' (28-30 prawns.kg^{-1}) and 'extra-large' (<28 prawns.kg^{-1}), and CPUE was defined as 'very low' (<10 kg.trawl-shot^{-1}), 'low' (10-20 kg.trawl-shot^{-1}), 'moderate' (20-40 kg.trawl-shot^{-1}), 'high' (40-60 kg.trawl-shot^{-1}) and very high (>60 kg.trawl-shot^{-1}).

A random sample of 100 prawns is also taken from each shot to obtain information on sex ratio and length-frequency. Length frequency measurements are used to determine the FRI that is estimated from the catch rate of recruits per trawl-hour, with ‘recruits’ defined by prawn size: <33 mm CL for males and <35 mm CL for females.

T90-mesh (conventional diamond net turned 90 degrees) 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.h^{-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 2018/19 season because these data directly inform stock status determination. Data from T90 mesh codends are still collected during the FIS to enable potential calibration with data collected from diamond-mesh codends in the future.

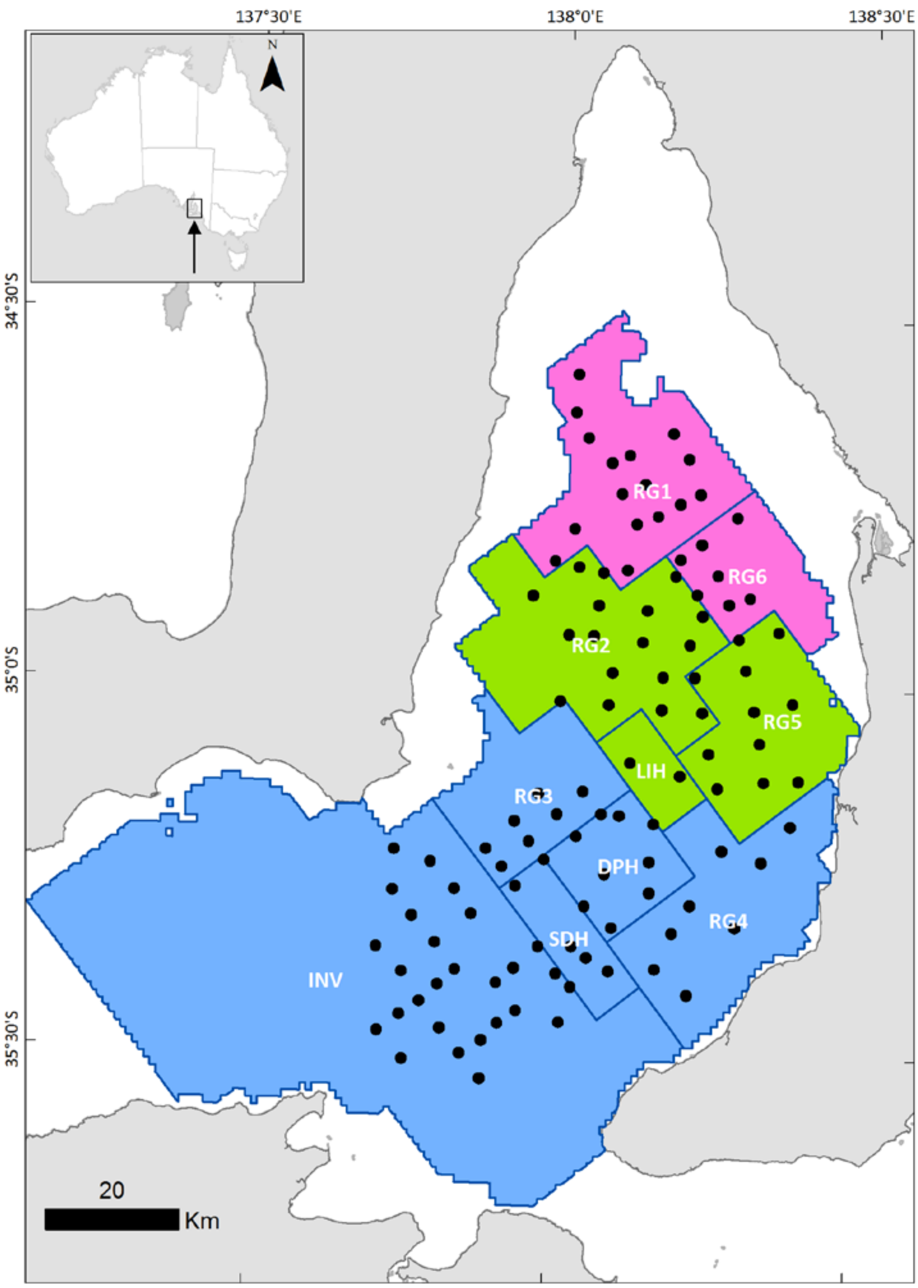


Figure 4. The 109 survey stations specified in the 2017 Management Plan and regions of the Gulf St Vincent Prawn Fishery. The northern gulf (pink) includes Region 1 (RG1) and Region 6 (RG6), the central gulf (green) includes Region 2 (RG2), Region 5 (RG5) and Little Hole (LIH), and the southern gulf (blue) includes Deep Hole (DPH), Southern Deep Hole (SDH), Region 3 (RG3), Region 4 (RG4) and Investigator Strait (INV).

2.2. Fishery statistics

2.2.1. Catch and effort

Fishery catch (t) and effort (vessel-nights or trawl hours) data are presented for available data since the 1968/69 fishing season. In this report, a 'fishing season' is defined as the period from 1 November to 31 July of the following year. Fisher-estimated prawn catch for each shot was adjusted using validated post-harvest catches reported in monthly logbooks. Catch and effort data include fishery-dependent 'searching' and spot survey catches, as well as FIS catches that are retained for sale by the SVGPBOA.

The main spawning period for Western King Prawns in GSV extends from November to March, so catch and effort 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 2006/07–2018/19, however, confidential data (<5 licence holders) are not shown.

All data are entered and maintained by SARDI Aquatic Sciences. Data are checked for errors during data entry, and further validated via electronic lookup tables and code-driven software that is activated during data entry and reporting operations. SARDI staff contact licence holders to correct any errors or missing information identified in the quality assurance process.

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 assigned to four size categories (Table 6). Soft and broken prawns that were not graded, were assigned to a fifth category ('S&B'). Data presented are from commercial fishing nights only and reported as the proportion of the total catch occurring in each of the size classes (see Dixon *et al.* 2012).

Uncertainty associated with the calculation of prawn size from grade data arises from: 1) data not being available from the entire fleet for all seasons; 2) differences in the grading among the vessels; and 3) uncertainty associated with the unvalidated grade data provided in logbooks (Dixon *et al.* 2012).

Table 6. Categories assigned to reported prawn grades from commercial logbook data for the Gulf St Vincent Prawn Fishery. The grade is determined from the number of prawns to the pound (e.g. ‘U10’ = under 10 prawns per pound).

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 important to standardise CPUE to account for the influence of variables that are not related to population size. Generalised linear models (GLMs) were 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). Candidate variables for standardising FIS CPUE were fishing year-survey, region and vessel, while those for standardising 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 22.8 ± 1.6 kg.trawl-shot^{-1} in 2004/05 to 42.3 ± 3.5 kg.trawl-shot^{-1} in 2007/08, but then declined to a near historical low of 22.3 ± 2.1 kg.trawl-shot^{-1} in 2011/12 before the fishery was closed in 2012/13 and 2013/14 (Figure 5a). Nominal FIS CPUE from a reduced survey in 2013/14 was 56.5 ± 5.0 kg.trawl-shot^{-1} but declined to 31.5 ± 2.1 kg.trawl-shot^{-1} in 2014/15. In the 2015/16 fishing season, nominal FIS CPUE increased 45.2% to 45.7 ± 3.1 kg.trawl-shot^{-1}, but in 2016/17 declined to 33.1 ± 2.4 kg.trawl-shot^{-1}. In 2017/18, the nominal FIS CPUE estimate of 36.2 ± 2.7 kg.trawl-shot^{-1} was similar to that recorded in 2016/17. In 2018/19, the estimate of nominal FIS CPUE was 28.1 ± 2.1 kg.trawl-shot^{-1}, a decrease of 22.2% since 2017/18. Thus, a decline in nominal FIS CPUE (diamond mesh) since the last closure of 2011/12–2012/13 is evident, though not to levels reached prior to the closure. Nominal seasonal estimates of FIS CPUE measured from the T90-mesh since 2011/12 were 12.3–46.6% lower than those 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 15.3% of the deviance in survey catches was explained by the model. The model term fishing year-survey explained 8.5% of the deviance and region explained 5.1% of the deviance, indicating that 84.7% of the deviance was caused by unknown factors (Table 7).

Trends in standardised FIS CPUE and nominal FIS CPUE measured from diamond mesh between 2004/05 and 2018/19 were similar, differing by less than 10.3% in each year surveyed over this period (Figure 5b). Estimates of standardised FIS CPUE remained in the high range for this performance indicator (≥30 kg.trawl-shot^{-1}) in surveys undertaken between 2013/14 and 2017/18, ranging from 30.3 kg.trawl-shot^{-1}, 95% CI [25.5, 35.7] in 2014/15 to 51.9 kg.trawl-shot^{-1}, 95% CI [42.0, 63.3] in 2013/14 (Figure 5b).

In 2018/19, standardised FIS CPUE was estimated from a total of 101 trawl shots and was 28.5 kg.trawl-shot^{-1}, 95% CI [24.2, 33.4], which was a 20.4% decrease in standardised FIS CPUE since 2017/18, but within the target range for this performance indicator (≥25 - <30 kg.trawl-shot^{-1}).

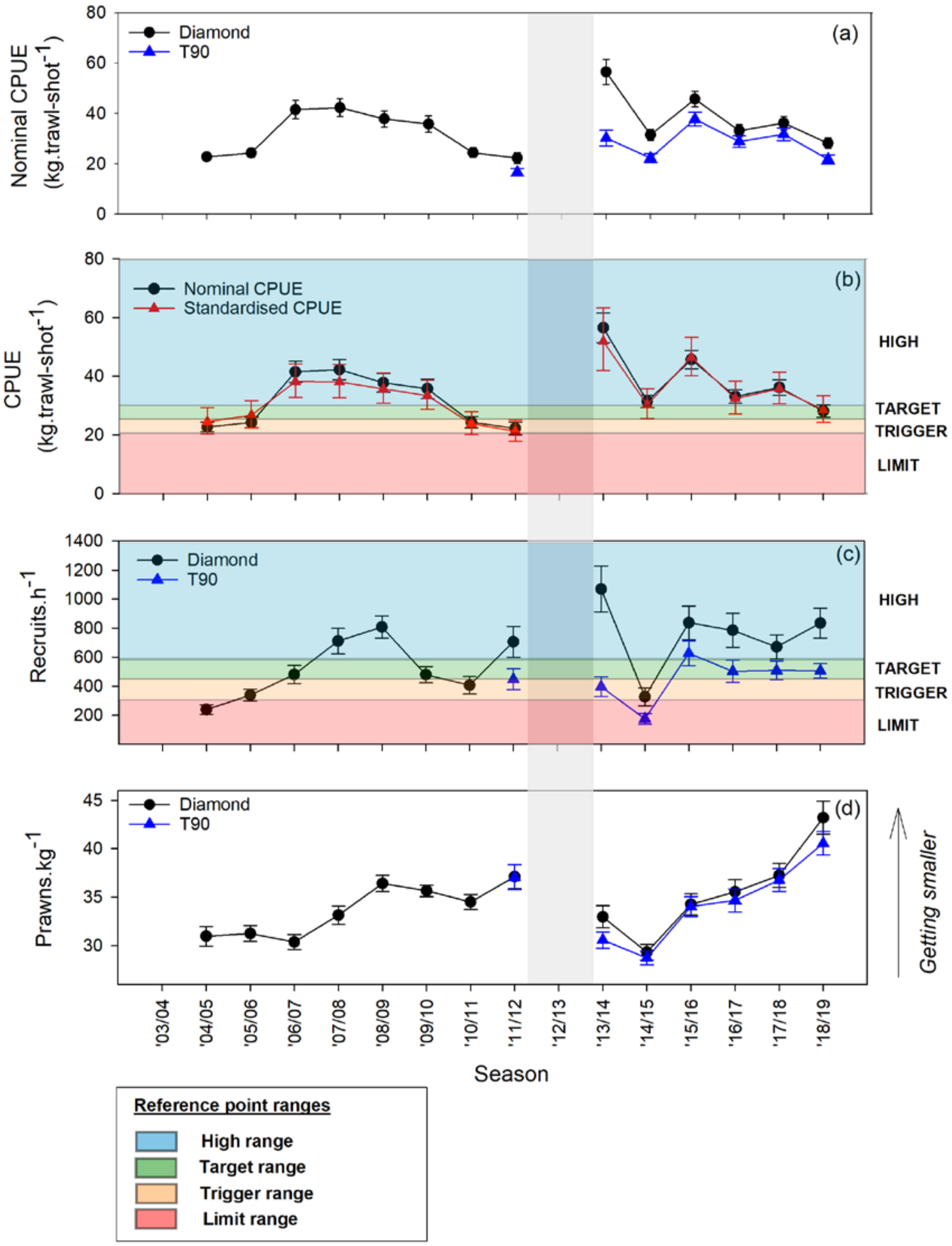


Figure 5. Key outputs from May fishery-independent surveys: (a) nominal catch per unit effort (CPUE, kg.trawl-shot^{-1}) from diamond and T90-mesh; (b) standardised versus nominal catch per unit effort (CPUE, kg.trawl shot^{-1}) (diamond net); (c) the fishery recruitment index (FRI) (recruits.h^{-1}); and (d) prawn size (prawns.kg^{-1}). Indices were calculated from 101 completed survey shots in the 2017 Management Plan. Note: T90 and diamond gear were 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 (95%) confidence intervals. Grey area indicates the period when no survey occurred during the fishery closure.

Table 7. 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	288.6	35.0	10.4***
Region	172.3	7.0	31.0***
Vessel	59.3	13	5.8***
Residuals	2882.9	3635	NA

Significance: *** $p < 0.001$

3.1.2. Recruitment

In 2013/14, the FRI estimate recorded in the 'reduced' survey was the highest on record at 1,086.6 ± 160.7 recruits.h^{-1} (Figure 5c). Following re-opening of the fishery in November 2014, the FRI estimate in 2014/15 was 330.7 ± 62.7 recruits.h^{-1}, which was the lowest estimate since 2004/05 (239.2 ± 31.5 recruits.h^{-1}). In 2015/16, the FRI was 837.1 ± 115.6 recruits.h^{-1}, more than double the FRI estimated in 2014/15 and the second highest value on record. 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 (24.1–63.5%) than those estimated from diamond mesh but followed the same trend (Figure 5c).

In 2018/19, the FRI was estimated from a total of 101 completed trawl shots and was 834.8 ± 102.6 recruits.h^{-1} (Figure 5c). This estimate is 24.5% higher than the FRI estimate recorded in 2017/18 (670.3 ± 82.8 recruits.h^{-1}).

3.1.3. Prawn Size

Mean prawn size (N prawns.kg^{-1}), 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). From 2004/05 to 2011/12, mean prawn size measured from diamond mesh decreased steadily from 31.0 ± 1.0 to 37.1 ± 1.2 prawns.kg^{-1} (Figure 5d). Following the fishery closure, mean prawn size in 2013/14 increased 11.2% to 33.0 ± 1.1 prawns.kg^{-1}, and in 2014/15 mean prawn size was the largest on record at 29.3 ± 0.8 prawns.kg^{-1} (Figure 5d). Since 2014/15, mean prawn size has steadily decreased, and in 2018/19 was the smallest on record at 43.2 ± 1.7 prawns.kg^{-1} (Figure 5d).

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 from T90-mesh are slightly larger (0.1–7.3%) than diamond mesh (Figure 5d).

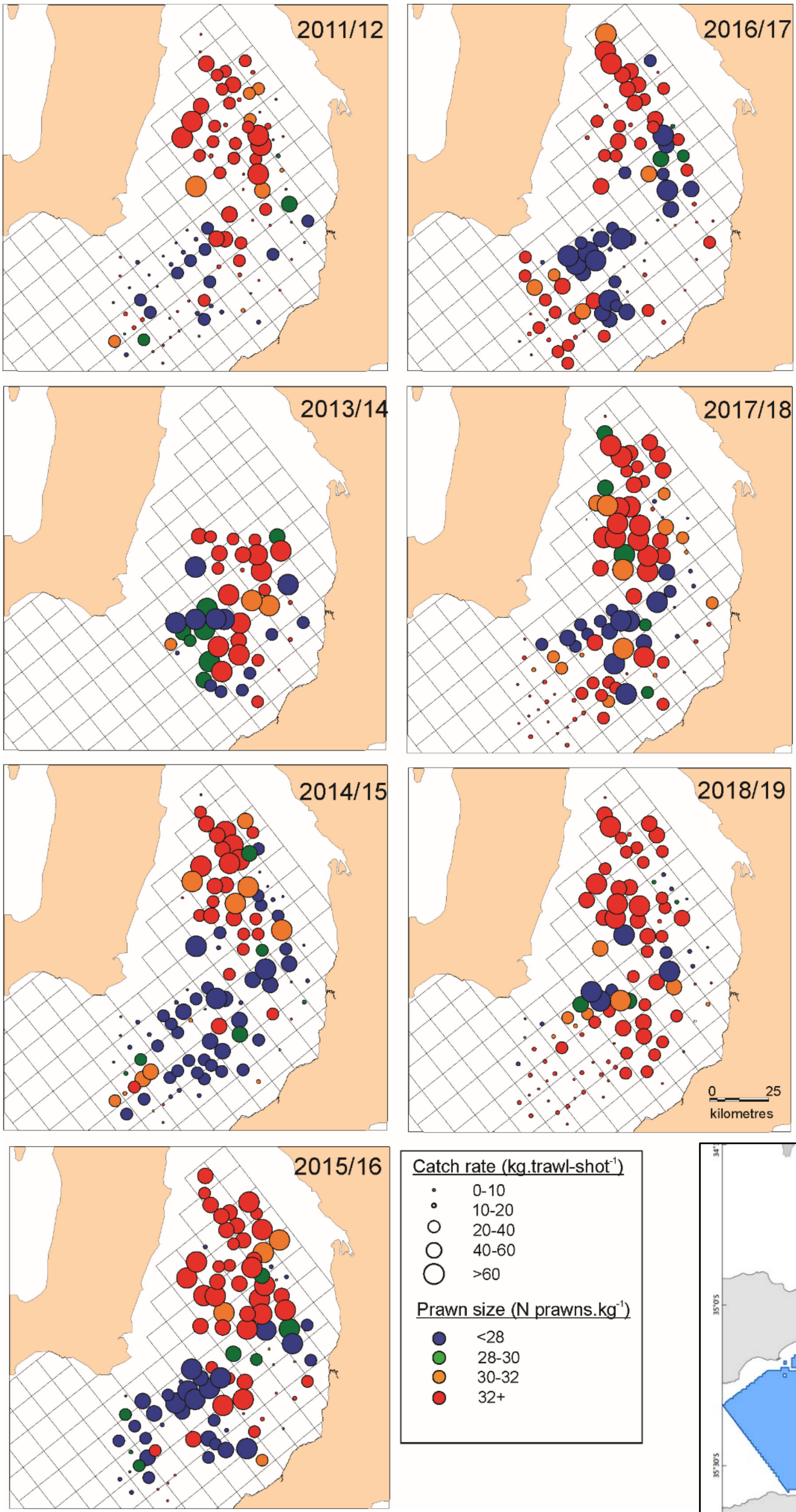
3.1.4. *Spatial patterns in CPUE and size*

Between 2011/12 and 2018/19, there was generally a north to south gradient in the size of prawns sampled in each May FIS, with relatively high estimates of CPUE recorded for small and medium prawns (≥30 prawns.kg^{-1}) in northern GSV and extra-large prawns (<28 prawns.kg^{-1}) in southern GSV.

Prior to the closure of the fishery between 2012/13 and 2013/14, 13.2% of survey sites had ‘High’ to ‘Very High’ estimates of CPUE (≥40 kg.trawl.shot^{-1}) (≥2.9 lb.min^{-1}). In 2013/14, prior to the fishery reopening, 56.5% of sites in the reduced survey recorded ‘High’ to ‘Very High’ estimates of CPUE (≥40 kg.trawl.shot^{-1}). In 2015/16, 52% of sites recorded ‘High’ to ‘Very High’ estimates of CPUE. Since 2015/16, the percentage of sites with ‘High’ to ‘Very High’ estimates of CPUE has decreased, and in 2018/19, 27.7% of sites recorded estimates of CPUE ≥40 kg.trawl.shot^{-1}.

In 2017/18, estimates of CPUE of ≥40 kg.trawl.shot^{-1} (≥2.9 lb.min^{-1}) of extra-large prawns (<28 prawns.kg^{-1}) were recorded from nine sites in the southern part of the gulf, within the Deep Hole (region DPH), Little Hole (region LH), Southern Deep Hole (region SDH), and in Region 3 (2017/18, Figure 6). In contrast, in 2018/19, estimates of CPUE of ≥40 kg.trawl.shot^{-1} (≥2.9 lb.min^{-1}) of extra-large prawns (<28 prawns.kg^{-1}) were recorded from four sites in the south-central parts of the gulf in Regions 2, 3 and 5 (2018/19, Figure 6).

In summary, the spatial representation of FIS data supports the steady decrease in the relative abundance (CPUE) and average size (PPKG) of prawns estimated across the area of the May FIS since the fishery reopened in 2014/15 (c.f. Figure 5b,d).



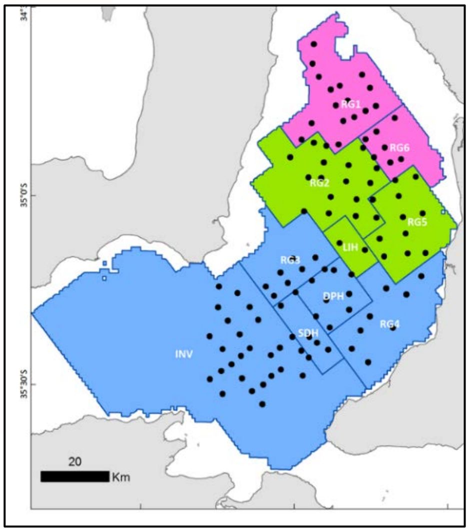


Figure 6. Catch rate and mean size of prawns sampled from the diamond-mesh codend during May FIS' in the GSVPF between 2011/12 and 2018/19. A reduced survey was undertaken in 2013/14 following the fishery closure between 2012/13 & 2013/14. Map on bottom right shows the regions used to describe the spatial distribution of catch rate and mean prawn size.

3.2. Fishery statistics

3.2.1. *Catch and effort*

The total commercial catch of Western King Prawn in the GSVPF in 2018/19 was 212.2 t, with an additional 2.5 t taken in the May 2019 survey (Figure 7a, Table 8). The 2018/19 catch was less than that taken in 2015/16 (217.8 t), 2016/17 (224.6 t) and 2017/18 (236.6 t), and was also less than the average catch reported since 2000/01 (227.8 ± 14.4 t; Figure 7a, Table 8).

In 2018/19, 43.5 t of the catch was taken during the early spawning period prior to Christmas (November–December), which was 20.5% of the total annual catch, and 25.0% less than that taken in the same period in 2017/18 (58.0 t). The amount of catch taken during the late spawning period (January–March) in 2018/19 (25.0 t) was similar to that taken in 2017/18 (25.2 t) (Table 8). Similar to previous seasons, the highest proportion of catch (143.7 t, 67.7%) taken in 2018/19 was harvested during the non-spawning period (April–July).

Commercial fishing was conducted over 300 vessel-nights in 2018/19, comprising 100% of the TACE (Figure 7b). All 50 allocated pre-Christmas vessel-nights were fished. Total effort was similar to that recorded since the fishery reopened in 2014/15 (287–296 vessel-nights), but low compared to the amount of nights fished prior to 2003/04 (Average 1989/90–2003/04: 405 nights) (Figure 7b). The total commercial effort recorded in 2018/19 was 2,935 trawl-hours, which was similar to that recorded in 2016/17 (2,836 trawl-hours) and 2017/18 (2,892 trawl-hours) (Figure 7c). Effort in the five years since the fishery closure in 2012/13–2013/14 has been stable (at the TACE), and is slightly higher than the average in the seven years preceding the closure (Average 2005/06–2011/12: 2,369 trawl-hours).

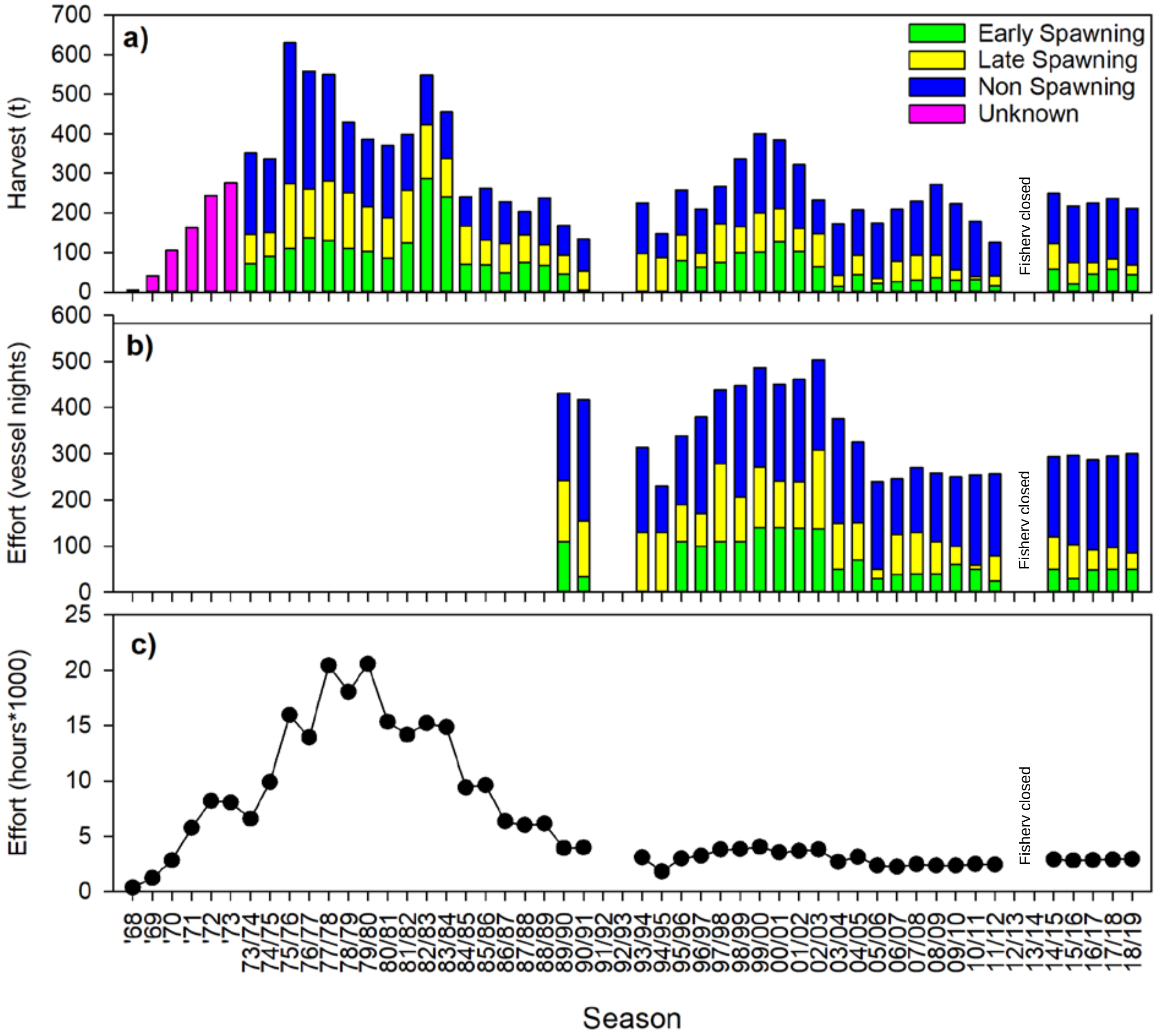


Figure 7. Fishery-dependent catch and effort data outputs for the Gulf St Vincent Prawn Fishery; (a) Annual catch (t) and (b) effort (vessel-nights) separated by early spawning (November–December), late spawning (January–March) and non-spawning (April–October) and (c) annual commercial effort (hours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

Table 8. Monthly distribution of commercial (and survey) catch in the Gulf St Vincent Prawn Fishery from 1989/90–2018/19.

Season	Nov	Dec	Feb	Mar	Apr	May	Jun	Jul	Total
1989/90	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)
2017/18	58.0*		-	25.2	60.0	49.2 (3.5)	44.3*	-	236.6 (3.5)
2018/19	43.5*		-	25.0	52.2	32.0 (2.5)	59.5*	-	212.2 (2.5)

*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.

3.2.2. CPUE

The GLM used to standardise nominal commercial CPUE data had a relatively high goodness-of-fit (adjusted R^2 value = 0.78). Region, fishing year, month, lunar phase, effort, licence number and cloud cover were all significant variables in the final model (Table 9). Effort was by far the most influential variable, explaining 73.1% of the total model deviance. All other variables explained a total of 5.1% of the total model deviance and 21.9% of the deviance was caused by unknown factors.

Table 9. 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	4685.9	24	128.2***
month	1156.6	7	108.5***
region	425.9	9	31.1***
lunar phase	109.6	1	72.0***
effort	95014.1	1	62402.0***
licence no	175.6	9	12.8***
cloud	51.4	1	33.8***
residuals	28419.6	18665	NA

significance: *** $p < 0.001$.

Estimates of standardised annual commercial CPUE since 1990/91 are higher than estimates of nominal CPUE, which is likely attributed to effort being used as a fixed term in the GLM (Figure 8). Importantly, despite the differences in scale of annual nominal and standardised CPUE estimates, the trend in both CPUE metrics was similar over time. It should be noted that estimates of standardised annual commercial CPUE will differ from previous reports as new data from the latest season (e.g. 2018/19) are added to the GLM.

Historically, estimates of standardised annual commercial CPUE were relatively stable from 1993/94 to 2004/05, ranging from 639 kg.block^{-1}.vessel-night^{-1}, 95% CI [623, 655] in 2002/03 to 876 kg.block^{-1}.vessel-night^{-1}, 95% CI [854, 897] in 1999/00 (Figure 8). From 2003/04, standardised commercial CPUE increased steadily, reaching a peak of 1,142 kg.block^{-1}.vessel-night^{-1}, 95% CI [1102, 1184] in 2008/09. From 2008/09, standardised commercial CPUE declined, reaching a low of 584 kg.block^{-1}.vessel-night^{-1}, 95% CI [560, 610] in 2011/12. The fishery was then closed in 2012/13 and 2013/14.

Following reopening of the fishery in 2014/15, the estimate of standardised annual commercial CPUE was 885 kg.block^{-1}.vessel-night^{-1}, 95% CI [859, 912], which was within the current 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 924 kg.vessel- night^{-1}, 95% CI [898, 952], which was in the high range defined for this performance indicator (≥900 kg.block^{-1}.vessel-night^{-1}). From 2015/16, standardised annual commercial CPUE then decreased slightly, falling within the target range for this performance indicator of ≥750 and <900 kg.block^{-1}.vessel- night^{-1} in 2016/17 (883 kg.block^{-1}.vessel-night^{-1}, 95% CI [858, 910]) and 2017/18 (893 kg.block^{-1}.vessel-night^{-1}, 95% CI [866, 920]).

In 2018/19, standardised annual commercial CPUE was 867 kg.block^{-1}.vessel-night^{-1}, 95% CI [841, 893], a decrease of 2.9% since 2017/18, and within the target range defined for this performance indicator (Figure 8).

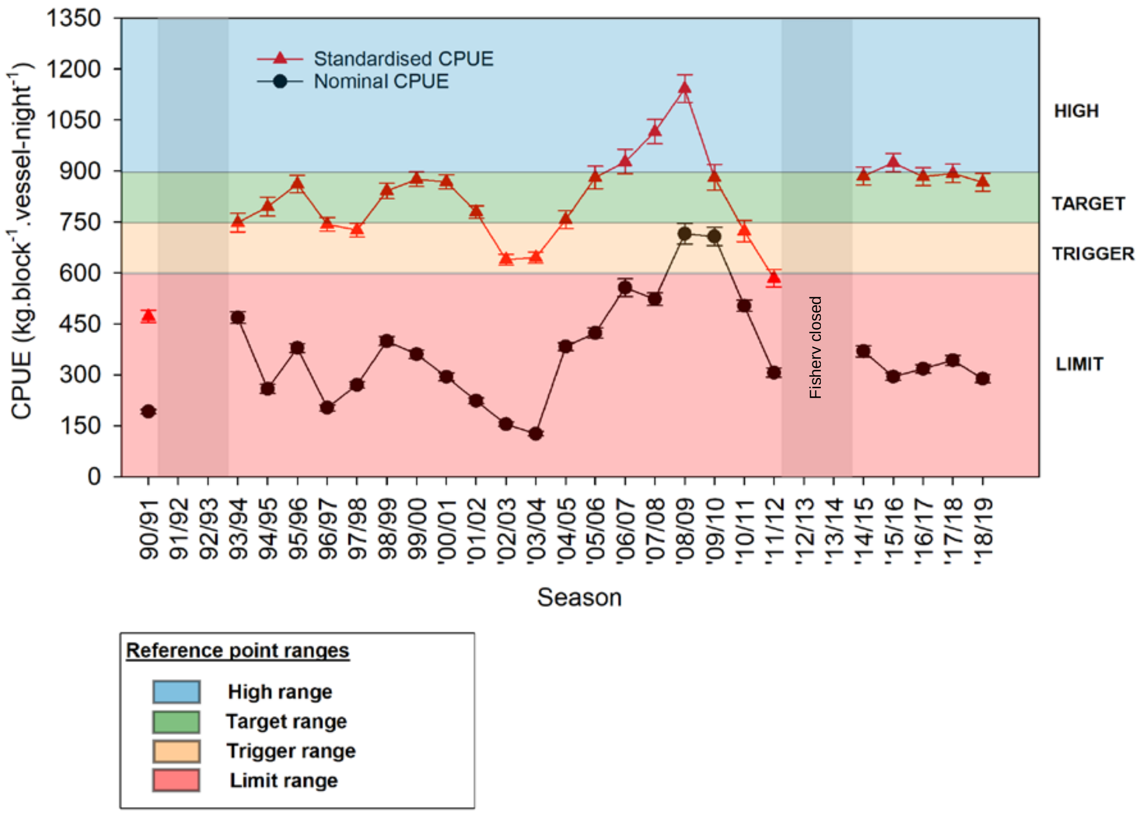


Figure 8. Comparison of standardised annual commercial CPUE and nominal annual commercial CPUE (kg.block^{-1}.vessel-night^{-1}) in the Gulf St Vincent Prawn Fishery from 1990/91–2018/2019. Error bars are ± standard error for nominal CPUE, and upper and lower (95%) confidence intervals for standardised CPUE.

3.2.3. Spatial patterns in catch and effort

Following the use of FIS' in 2004/05 to spatially control the areas harvested in GSV, the number of prawn fishing blocks that were fished increased slightly until 2006/07and then declined until 2009/10 (Figure 9). From 2014/15, the number of surveys was reduced, control rules for spatial management were transferred and adopted into the SVGPBOA Industry Code of Practice (see Section 1.2.2), and the number of blocks that were fished subsequently increased. In 2018/19, fishing took place in 21 blocks in November–December and 39 blocks in the remaining months of the season. The total number of blocks fished in 2018/19 (60) was slightly higher than in 2017/18 (55), yet at a relatively high level compared to that recorded between 2004/05 and 2011/12 (range: 26–52).

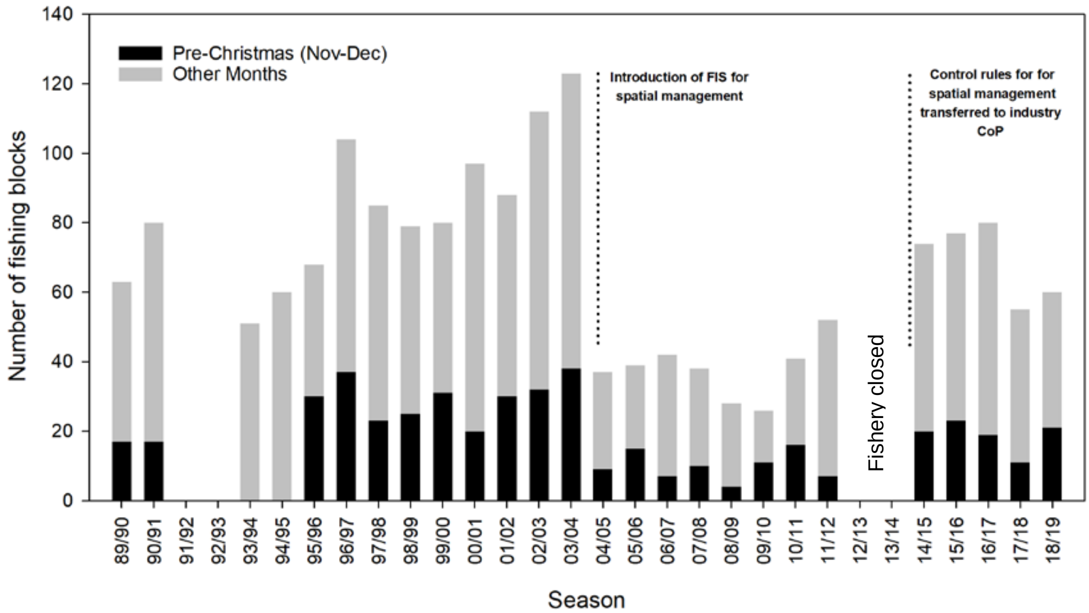


Figure 9. The number of blocks fished pre–Christmas (November and December) and all other months in the Gulf St Vincent Prawn Fishery from 1989/90–2018/19.

The spatial distribution of the GSVPF 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 2018/19, 57.9% (122.8 t) of the total annual catch was taken from southern GSV in the regions DPH, INV, RG3, RG4 and SDH. Relatively high catches were also recorded in parts of northern GSV, with 41.6 t recorded from RG1, representing 19.6% of the total annual catch (Figure 10).

Similar to previous seasons, relatively low catches were recorded from RG4, RG5 and RG6 in the eastern parts of GSV in 2018/19. A combined total of 18.2 t was taken from these regions, representing 8.6% of the total annual catch recorded in the fishery in 2018/19.

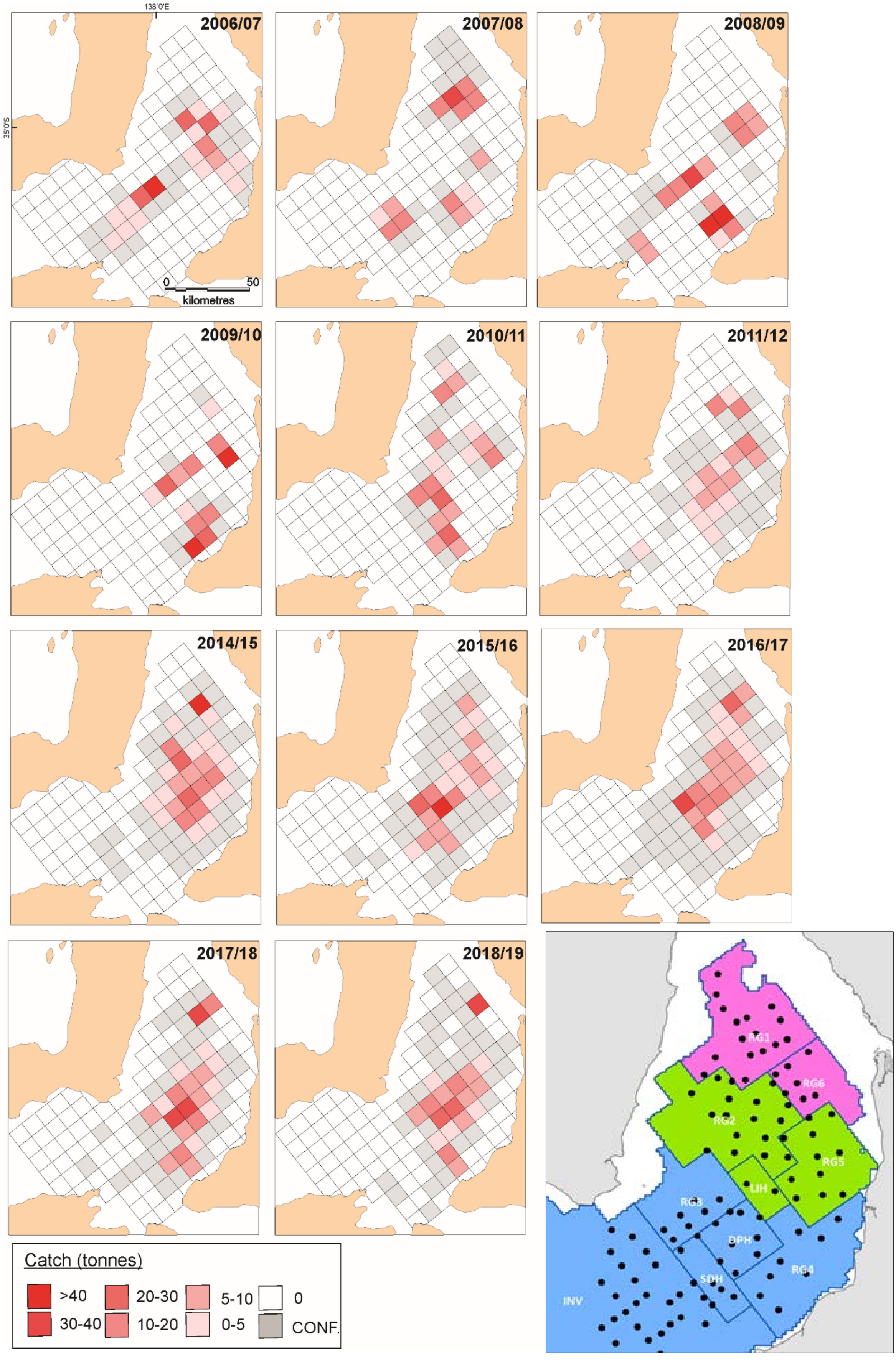


Figure 10. The annual catch per fishing block in the Gulf St Vincent Prawn Fishery from 2007/08–2018/19. Note, the fishery was closed in 2012/13 and 2013/14. Confidential data from <5 licence holders are depicted in grey and typically <5 t. Map on bottom right shows regions used to describe spatial distribution of fishing (see Figure 4 for more detail).

3.2.4. *Prawn size*

The annual catch of Western King Prawn in the GSVPF since 2005/06 comprised, on average, 26% extra-large prawns, 39% large prawns, 22% medium prawns, 6% small prawns, and 7% soft & broken prawns (Figure 11). The percentage of large and extra-large prawns in the catch decreased from 2005/06 to 2010/11, and a corresponding increase in the proportion of small and medium prawns was recorded over the same period (Figure 11). The percentage of soft and broken prawns has historically been relatively low (Average since 2005/06: 7 ± 0.3%) and in 2018/19 comprised 8% of the total annual catch (Figure 11, Table 10).

Following the re-opening of the fishery in 2014/15, extra-large and large prawns comprised a total of 69% of the total catch (Figure 11, Table 10). The percentage of extra-large (U6-U10 prawns per pound) and large (10/15 prawns per pound) prawns in the catch remained similar between 2014/15 and 2017/18 (66–69%), however, in 2018/19, extra-large and large prawns comprised a total of 55.0% of the total catch. The percentage of small and medium prawns (10/20 to 30+ prawns per pound) comprising the catch also remained similar between 2014/15 and 2017/18 (25–28%). However, in 2018/19 small and medium prawns comprised 37% of the catch (Figure 11, Table 10).

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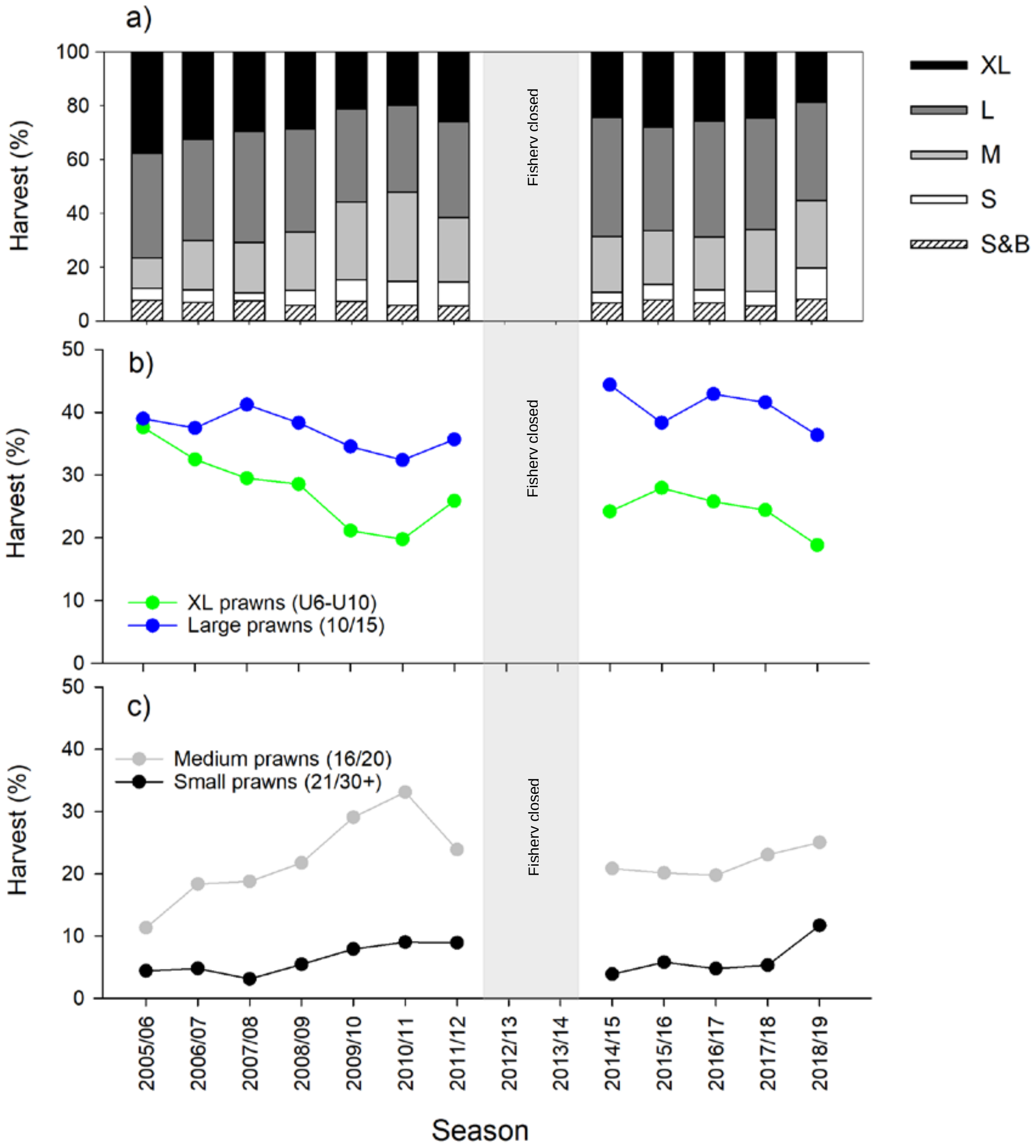

Figure 11. a) Size-grade composition (%) of annual harvests in the Gulf St Vincent Prawn Fishery from 2005/06–2018/19; b) Temporal trends in harvest composition of extra-large (XL) and large prawns; c) Temporal rends in harvest composition of medium and small prawns (see Table 6 for prawn grade composition categories).

Table 10. Size-grade composition (t) of annual harvests in the Gulf St Vincent Prawn Fishery from 2005/06–2018/19. Grades include; soft and broken (SB), small (S), medium (M), large (L) and extra-large (XL). Note: grade weight totals are estimated from daily fishing logbooks and are not adjusted relative to Catch Disposal Records (CDRs).

SEASON	**XL**	**XL-Split**			**L**	**M**	**S**	**SB**
		U10	***U8***	***U6***	**10/15**	**16/20**	**20+**	
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*	*17.8*	*2.5*	104.8	49.1	9.1	15.9
2015/16	57.3	*31.6*	*22.1*	*3.6*	78.7	41.3	11.9	16.0
2016/17	53.4	*32.2*	*18.2*	*3.0*	88.9	40.9	9.9	14.1
2017/18	52.3	*30.6*	*19.3*	*2.4*	89.0	49.4	11.4	12.1
2018/19	38.7	*21.9*	*14.9*	*1.9*	74.9	51.5	24.1	16.6

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 performance indicator relating to recruitment, the 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 contributed towards 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, despite adaptations to the survey program in recent years (see Section 2.1). The locations sampled in the May FIS have remained 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 Nordmøre-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. Under the current management plan, data collected from diamond-mesh codends in the May FIS are used to estimate standardised FIS CPUE and the FRI. Ongoing data collection from T90-mesh codends during the FIS will potentially enable calibration of 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: 1) the spatial distribution of fishing effort has changed over time due to changes in spatial management of the fishery; 2) estimates of standardised annual commercial CPUE are based on daily logbook data from 1990/91 because catch data available prior to this time are either not available or considered unreliable; and consequently, (3) estimates of standardised CPUE from 1991/92 do not take into account the period when catches were considerably higher (1975/76–1983/84).

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 (1991/92–1992/93, and 2012/13–2013/14). 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 2018/19, the total commercial catch of Western King Prawn in the GSVPF was 212.2 t, with an additional 2.5 t taken in the May 2019 survey. This catch was less than the average catch landed by the fishery since 2000/01 (227.8 ± 14.4 t). Fishing was conducted over 300 vessel-nights, comprising 100% of the TACE. All 50 allocated pre-Christmas vessel-nights were fished.

Estimates of standardised annual commercial CPUE were in the high range (≥900 kg.block^{-1}.vessel-night^{-1}) in 2015/16 and within the target range (≥750 and <900 kg.block^{-1}.vessel- night^{-1}) from 2016/17 to 2018/19 (PIRSA 2017). Estimates of standardised FIS CPUE remained in the high range (≥30 kg.trawl-shot^{-1}) between 2013/14 and 2017/18. However, in 2018/19, standardised FIS CPUE declined to the target range (≥25 and <30 kg.trawl-shot^{-1}). The FRI has remained in the high range (≥600 recruits.h^{-1}) defined for this performance indicator the last four annual surveys (2015/16–2018/19).

It is a positive sign for the GSVPF that standardised annual commercial CPUE, standardised FIS CPUE and the FRI have remained at, or above, the target range defined for these performance indicators since the harvest strategy was first implemented in 2016/17 (PIRSA 2017). However, caution is warranted in relation to the GSVPF's future performance. Concurrent declines in standardised annual commercial CPUE and standardised FIS CPUE since the fishery reopened in 2014/15 indicate that the current level of fishing mortality is causing reductions in prawn abundance. Also of concern are the decreases in prawn size estimated from the FIS' and commercial prawn-grade data since 2014/15. In this period, mean prawn size measured from FIS' has steadily decreased, and in 2018/19 was the smallest on record at 43.2 ± 1.7 prawns.kg^{-1}. The composition of extra-large (U6-U10 prawns per pound) and large (10/15 prawns per pound) prawns in the catch has also decreased by approximately 10% since 2017/18.

These trends indicate that fishing mortality is most likely causing changes in the stock size-structure and exceeding that which produces maximum yield per recruit. Moreover, the smaller size of the prawns in the catch implies that the number of prawns being removed annually may be higher than in recent years, since the annual total weight of catch has remained relatively stable. As a consequence, if the decreasing trends in prawn size continue, there is an increased risk of recruitment impairment in the future. Reductions in fishery exploitation rates triggered by decision rules within the harvest strategy need to be sufficient to stabilise stock biomass and reverse the declines in prawn size since 2014/15 to ensure that future recruitment is adequate.

PIRSA has adopted the NFSRF stock status classification system to determine the status of all South Australian fish stocks (Flood *et al.* 2014; Stewardson *et al*. 2018). The 2014 NFSRF was used to assess the status of the Western King Prawn stock in GSV as 'transitional-depleting' in 2014/15 (Beckmann *et al.* 2015) and 'sustainable' in 2015/16 (Beckmann and Hooper 2016) using a 'weight-of-evidence' approach. The current harvest strategy also uses the 2014 NFSRF of Flood *et al.* (2014) in a 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 5) (PIRSA 2017). Under the harvest strategy, in 2016/17 and 2017/18, the status of the Western King Prawn stock in GSV was classified as sustainable (McLeay *et al.* 2017, 2018).

In 2018/19:

- Standardised annual commercial CPUE was 867 kg.block^{-1}.vessel-night^{-1}.
- Standardised FIS CPUE was 28.5 kg.trawl-shot^{-1}; and
- The FRI was 834.8 recruits.h^{-1}.

When the 2018/19 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 5), the stock is classified as '**sustainable**'.

4.3. Future directions

The 'sustainable' classification of the Western King Prawn stock in GSV in the last four seasons is a positive sign for the fishery. Despite this classification, the long history of serial declines in fishery performance, and recent declines in prawn size estimated from the FIS' and commercial catch grade data, warrant caution in relation to the GSVPF's future performance. In addition, it is necessary that the sources of uncertainty associated with the assessment are highlighted and addressed in the future.

The status of the Western King Prawn stock in GSV in 2018/19 has been determined under the newly adopted harvest strategy for the GSVPF (PIRSA 2017) 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 away from an era of relatively high productivity, and the efficacy of the current harvest strategy in buffering reductions in recruitment, or in maintaining its operational objectives in the long term is currently unknown. Under the management plan for the fishery, a review of the harvest strategy is due 2½ years after its implementation - 1 July 2017 (PIRSA 2017). A workshop to review the data used as inputs in the harvest strategy is planned in October 2019 and will assess how data collected from recent fishing seasons (2015/16–2018/19), which were not previously included in development of the harvest strategy, influence the trends in each performance indicator and associated levels of TACE.

A research planning workshop is also scheduled for October 2019 to direct future research needs for the GSVPF. In relation to stock assessment, the outputs of the GLMs used to standardise commercial and FIS CPUE indicate large amounts of unexplained variance and suggest that standardisation procedures would benefit from incorporating additional information that affect CPUE (e.g. oceanographic data or information relating to fishing effort creep). Further analyses are also required to assess the influence of survey design on FIS CPUE. Any review of FIS data would also benefit from comparisons of CPUE and FRI from T90 and diamond-mesh codends and help to facilitate a potential transition to using only T90 codends in surveys in the future.

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 beneficial to the GSVPF to simulate how spatial changes in fishing patterns and/or environmental conditions could maximise both recruitment and catch during parts of the fishing season when catch value is highest (e.g. pre-Christmas).

Finally, the development of prawn-trawl gear technologies and their integration into fisheries management policy has the potential to maximise economic, social and environmental benefits for commercial fisheries. Previous research indicated the benefits of T90-mesh codends to both non-target size prawns and bycatch in the GSVPF (Dixon *et al*. 2013). Future research could assess whether further improvements in catch selectivity can be realised through advances in prawn-trawl design.

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