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Status of the Gulf St Vincent Prawn *Penaeus (Melicertus) latisulcatus* Fishery in 2014/15

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

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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

October 2015

Fishery Status Report to PIRSA Fisheries and Aquaculture

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

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

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

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Author(s):	C. L. Beckmann, C. J. Noell and G. E. Hooper
Reviewer(s):	S. Mayfield, M. Steer, T. Ward (SARDI) and A. Fistr and A. Jones (PIRSA)
Approved by:	S. Mayfield Science Leader - Fisheries
Signed:	
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EXECUTIVE SUMMARY

This report assesses the current status of the Gulf St Vincent Prawn Fishery (GSVPF).

The GSVPF was closed during 2012/13 and 2013/14. The 2014/15 season ran from 1 November 2014 to 31 July 2015. Total effort in 2014/15 was 294 vessel nights (2,904 trawl hours), 14% higher than 2011/12 (257 vessel nights; 2,428 trawl hours) and the highest since 2004/05 (325 vessel nights; 3,137 trawl hours).

The total commercial catch was 249.4 t in 2014/15, 57.5% higher than 2011/12 (125 t) and the highest catch since 2008/09 (273 t). In 2014/15, catch during the spawning period (November–March) was 123 t, the highest since 2002/03 (148 t). During the early spawning period (November-December) in 2014/15, 57 t was harvested, the highest since 2002/03 (64 t).

The nominal commercial catch per unit effort (CPUE) in 2014/15 was 85.9 $kg.h^{-1}$, 67% higher than 2011/12 (51.5 $kg.h^{-1}$) and the highest since 2009/10 (95.3 $kg.h^{-1}$).

The nominal 'gulf-wide' survey catch rate was 60.4 $kg.h^{-1}$ in May 2015. This was 39% higher than in May 2012 (before the fishery closure) but 45% lower than the 'reduced' survey catch rate in May 2014 (prior to fishery re-opening). The May 2014 survey result is likely to be positively biased compared to previous years because it was conducted during the dark moon. 'Adult' catch rate (>20+ grade) was 56.5 $kg.h^{-1}$ in May 2015 and followed a similar trend to total catch rate. The catch rate of 'new recruits' (6.4 $kg.hr^{-1}$) and the recruitment index (306 $recruits.h^{-1}$) in May 2015 were among the lowest on record.

In summary, the commercial and survey catch rates demonstrate that adult biomass increased following the closure from 2012/13–13/14. However, the low catch rates of recruits in May 2015 suggest that future recruitment to the harvestable biomass may be limited. Using a 'weight-of-evidence' approach and the national framework for stock status reporting, the GSVPF is classified as '**transitional-depleting'**.

1. INTRODUCTION

1.1. Overview

This fishery stock status report assesses the current status of the Gulf St Vincent Prawn Fishery (GSVPF). It includes new data from the 2011/12 (1 November 2011 to 31 October 2012) and 2014/15 (1 November 2014 to 31 July 2015) fishing seasons.

1.2. Description of the fishery

The GSVPF is one of three commercial prawn fisheries in South Australia targeting the western king prawn *Penaeus* (*Melicertus) latisulcatus*. Historically, the GSVPF is the second largest prawn fishery in terms of production, value and number of licensed fishers. Prawns are harvested at night using demersal otter-trawls. There are currently ten licence holders in the fishery. Recreational catches of *P. latisulcatus* are low as prawns can only be taken using hand held nets in waters >10 m in depth. Levels of traditional Aboriginal traditional catch and illegal fishing are considered negligible.

The GSVPF is managed by the South Australian State Government's Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture in accordance with the legislative framework provided within the *Fisheries Management Act 2007* and *Fisheries Management (General) Regulations 2007* and the *Fisheries Management (Prawn Fisheries) Regulations 2006.*

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

Following the fishery's closure in 2012/13-13/14, a revised management framework was developed with stakeholder input and implemented in November 2014. The management framework includes an individual transferrable effort (ITE) system, which adopts transferrable nights as the effort unit, until 2016/17 when the ITE system will be transferred to a total allowable commercial catch (TACC), in the form of individual transferable quota, set for each fishing season. Under the new management

framework, a number of control rules have been removed from the fishery. Specifically, fishing activity during each fishing period was previously guided by harvest strategy decision rules which involved closure lines based on mean prawn size from surveys. At sea decision rules around prawn size, maximum total catch and minimum average catch were also in place to adjust closure lines or close areas to fishing. In 2014/15, spatial management arrangements were amended, with Zone 1 (North of 35°09' South) open for pre-Christmas fishing and from 1 March to 15 April and Zone 2 (South of 34°55' South) open from 16 April to 31 July. In 2014/15, control rules for mean prawn size and mean nightly catches per vessel were removed and the St Vincent Gulf Prawn Boat Owner's Association developed a code of conduct for catching target size prawns. The industry code of conduct specifies that the target size of prawns should be larger than 28 prawns per kg. If prawns in any shot are smaller than 32 prawns per kg skippers must implement the move-on provision. It is, however, a requirement that all vessels use the T90 cod-end mesh which facilitates the escapement of small prawns. From March 2012, the T90 cod-end was constructed so that no more than the last 10 meshes were made up of standard mesh and from November 2015, this was increased to 33 meshes. A minimum catch move-on provision was also trialed for the 2014/15 season so that where catches were less than 350 kg per vessel per night, over two consecutive nights, the licence holder should move-on (i.e. requires skippers to move the vessel away from the path of the previous shot by a buffer of one nautical mile).

The previous management arrangements revolved around "harvest periods," which were generally between the last quarter of the moon, through the phase of the new moon to the first quarter. In 2014/15, there were no harvest periods and the allocated nights could be used anytime during the season. In 2011/12 and 2014/15, the fishing season was from 1 November to 31 July with a closed period from 25 December to the last day in February each year and this was generally reflective of historical fishing runs. The total fishing effort for the 2014/15 fishing season was set at 300 vessel-nights. Whilst this was higher than the range from 2007/08 to 2011/12 (250–269 vessel nights), this increase reflected implementation of T90 mesh and bycatch grids. A revised daily logbook and nightly fishing reports were also implemented from 2014/15. The daily reports require licence holders to provide more detailed spatial information (start and end coordinates of each trawl shot) and the nightly fishing reports require a summary of total catch unloaded per grade which is reported within 48 hours of unloading. The current management arrangements are described in Table 1.1.

Table 1.1 Management arrangements for the Gulf St Vincent Prawn Fishery for the 2014-15 fishing season.

Management tool	**Current restriction**
Permitted species	*Penaeus* (*Melicertus) latisulcatus, Ibacus spp* and *Sepioteuthis australis*
Licensing year	1 November – 31 July
Limited entry	10 licences
Method of capture	Demersal otter trawl
Trawl net configuration	Double or triple rig with T90 cod-end and bycatch reduction grid
Licence transferability	Permitted
Corporate ownership	Permitted
Effort scheme (ITE)	Yes
Unit transferability	Yes – permanently and temporarily
Total Allowable Commercial Effort (2014-15)	300 fishing nights (50 pre-Christmas and 250 post-Christmas)
Spatial closures	Yes
Temporal closures	Yes (25 December– 28 February)
Maximum vessel length	22 metres
Maximum vessel power	336 kilowatts
Monitoring tool	Requirement
Catch and effort data	Daily logbook submitted within 48 hrs upon landing
Catch and Disposal Records	Unloading logbook submitted within 48 hrs upon landing
Prior to fishing reports	2 hrs prior to leaving port and 1 hr prior to fishing any night after leaving port
Prior to landing reports	2 hrs prior to unloading to designated area or 3 hrs prior to unloading to non-designated are

1.3. Research Program

From 2011 to 2014, three separate independent reviews of the stock assessment and harvest strategy for the GSVPF were conducted (Knuckey *et al.* 2011; Morgan and Cartwright 2013; Dichmont 2014). As a result of these reviews, there has been a substantial rationalisation of the research program. The principal change is a reduction from four to one fishery-independent surveys (FIS) per year (conducted in May). The 2014/15 research program included the collection of basic fisheries statistics, biological and FIS information and the production of this stock status report that assesses the status of the GSVPF.

1.4. Determination of stock status

A formal harvest strategy is being developed as part of a new management plan under the *Fisheries Management Act 2007* and this is due for completion in 2016. As the fishery was closed in 2012/13 and 2013/14 and only one survey was conducted in 2014 and 2015, some of the reference points and PIs specified in the Management Plan (Dixon and Sloan 2007) that require December, March and April FIS or commercial data which will be impacted by changed management arrangements are no longer appropriate. Therefore, a ‘weight-of–evidence’ approach has been used to

assess stock status. The primary measures that have been used to determine stock status in the GSVPF are average catch rates (adults and recruits) obtained during the FIS conducted in May and catch rates from fishery-dependent data. Furthermore, as there are currently no explicit decision rules or performance indicators (PIs) linked to the maximum number of fishing nights, the annual status will be used to provide a measure of relative biomass to inform the TAE limit.

A national stock status classification system was recently developed for the consistent assessment of key Australian fish stocks (Flood et al. 2014). It considers whether the current level of fishing pressure is adequately controlled to ensure that stock abundance is not reduced to a point where the production of juveniles is significantly compromised. The system combines information on both the current stock size and level of catch into a single classification for each stock against defined biological reference points. Each stock is then classified as ‘sustainable’, ‘transitional-recovering’, ‘transitional-depleting’, ‘overfished’, ‘environmentally limited’, or ‘undefined’ (Table 1.2). PIRSA has adopted this classification system to determine the status of all South Australian fish stocks.

Table 1.2 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

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

Since December 2004, a rigorous survey design consisting of approximately 110 survey shots has been undertaken as per Dixon *et al*. (2012). Survey shots were undertaken at semi-fixed sites (Figure 1.1).

A reduced survey of 53 trawl locations (compared to a normal full survey of 112 trawl locations) was planned to be undertaken using one vessel over five nights in May 2014. However, the survey was interrupted by bad weather, eventually requiring eight nights (23-30 May 2014), with 40% of the trawl shots completed on the new (dark) moon and the night after, when catch rates are expected to be higher. Based on previous advice and trends in relative biomass, PIRSA Fisheries and Aquaculture established a reference level for the mean catch rate of prawns larger than 20+ grade (‘adults’) of 2.5 $lb.min^{-1}$ (68.2 $kg.h^{-1}$) for re-opening the fishery. The mean catch rate of prawns larger than 20+ grade was above this level in May 2014 and the fishery was re-opened from 1 November 2014. The full suite of survey locations were sampled in May 2015.

From 2012, surveys were conducted using T90-mesh cod-ends and grids for one net and the traditional diamond mesh in the alternate net and the catch was sorted separately for each net. In May 2012 and 2014, the T90 cod-end was constructed so that no more than the last 10 meshes were made up of standard mesh. In May 2015, this was increased to 33 meshes. To enable comparisons between years, only the diamond-mesh cod-ends have been included in the analysis of survey data.

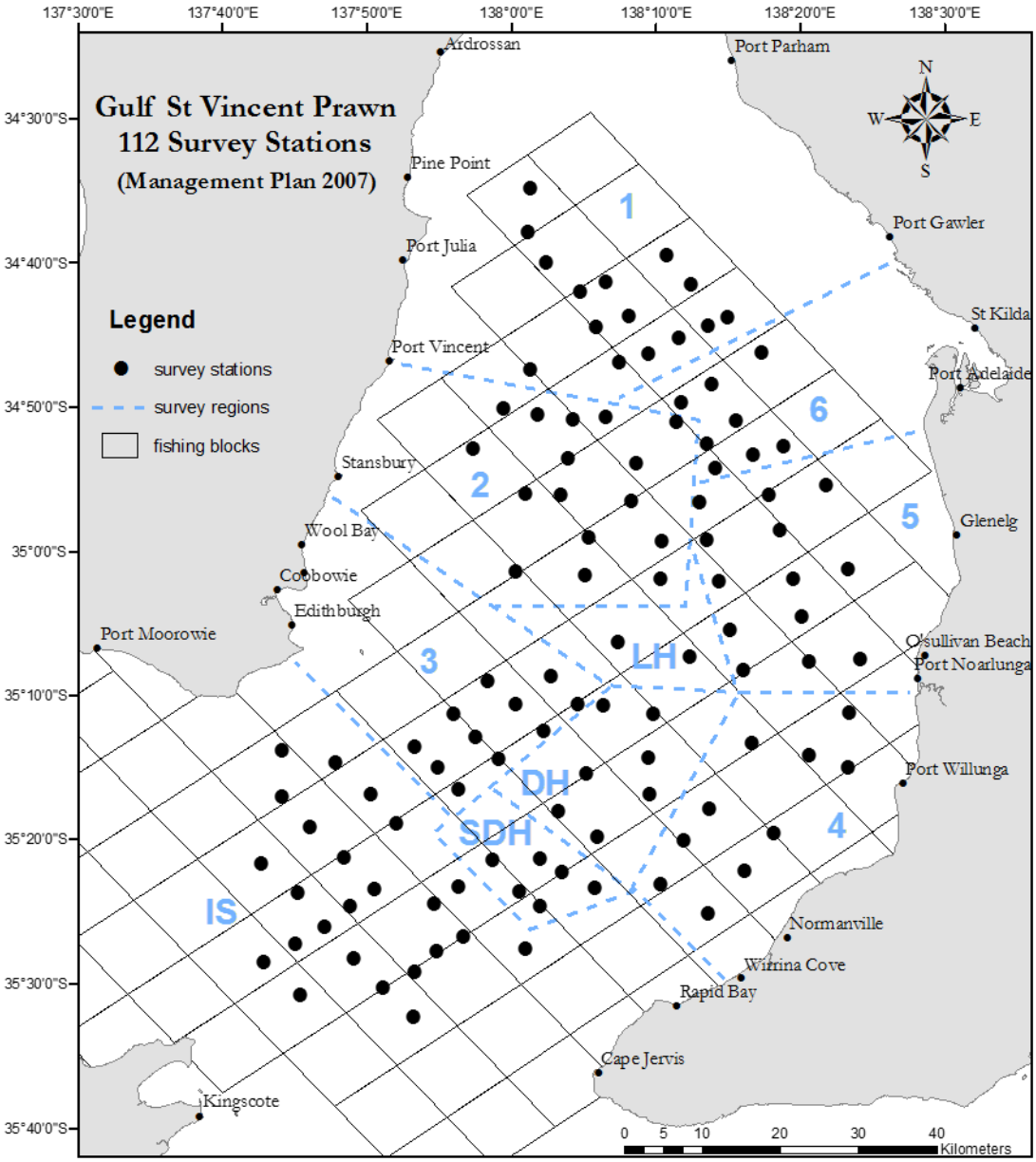

Figure 2.1 Survey stations, regions and fishing blocks of the GSVPF. Little Hole, LH, Deep Hole, DH; Southern Deep Hole, SDH; Investigator Strait, IS.

2.2. Catch and effort statistics

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).

In this report, a "fishing year" is defined as the period from November to October the following year. As the main spawning period for *P. latisulcatus* in GSV extends from November to March (Dixon *et al.* 2012), catch is presented for early (November – December), late (January – March) and non-spawning (April – October) periods. Annual nominal catch per unit effort (CPUE) was estimated by dividing total commercial catch by total commercial effort.

2.3. Catch rate standardisation

Catch rates obtained from stock assessment surveys or fishing are assumed to be proportional to prawn abundance. However, to improve relationships between catch rates and relative biomass, it is often important to standardise catch rates to remove the influence of variables that are not related to abundance.

Analyses were conducted on survey data (standard diamond cod-end only) obtained from the Management Plan shot locations from 2004/05–2014/15 and daily logbook data from 1990/91–2014/15, aggregated to catch (survey: kg trawl-shot^{-1}; fishery: kg block-vessel-night^{-1}). Survey catches (per 30-min trawl-shot) were adjusted to the standard measure of two nets where necessary. The logbook database prior to 1991 was incomplete, particularly by block and vessel, and therefore not included in the standardisation. Generalised linear modelling (GLM) was employed for the standardisation of catches as per the methods in Noell *et al*. (2015). Environmental variables found to be non-significant were not included in the model.

3. RESULTS

3.1. Fishery-independent surveys

3.1.1. *Regional distribution of catch rates*

While recruitment varies temporally and spatially, regional assessment of recruit catch rates indicated that historical mean annual recruitment was highest in the northern regions of Gulf St Vincent (Figure 3.1). In May 2015, the highest 'new recruit' catch rates were observed in Region 1, Region 2, Little Hole and Deep hole. Compared to the historical mean, catch rates of recruits in May 2015 were low in many regions. The highest 'adult' catch rates in May 2015 occurred in Region 1 and Deep Hole. Compared to historical trends, catch rates of adult prawns in May 2015 were relatively high in Region 1 and Deep Hole, but relatively low in Region 6 and Region 3.

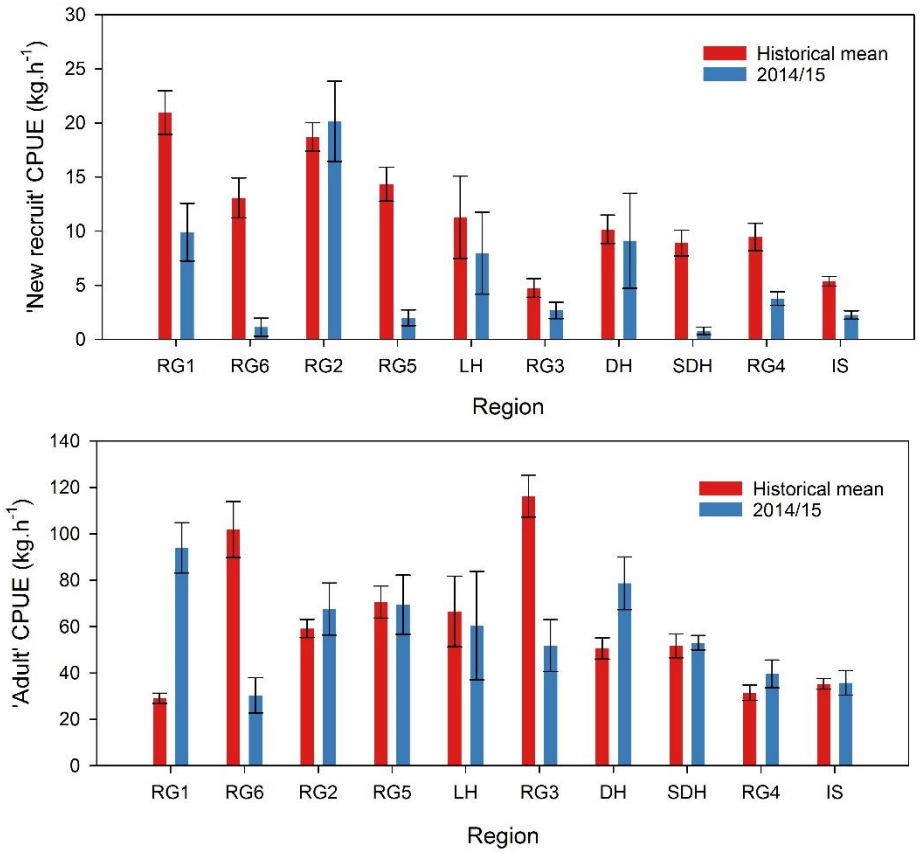

Figure 3.1 Comparison 'new recruit' and 'adult' catch per unit effort (CPUE, $kg.h^{-1}$) in each region during May surveys compared with the historical mean (2004/05–11/12). See Figure 2.1 for abbreviations of regions. Error bars, standard error.

3.1.2. *Nominal indices*

Nominal catch rates from the reduced survey (53 shots) undertaken in May 2014 generally followed a similar trend to the full set of shots specified in the management plan (112 shots; Figure 3.2). The survey results using the May 2014 shots were, however, almost always higher than those from the full set of shots specified in the Management Plan. Consequently, the May 2014 survey catch rates are likely to be positively biased, with this bias exacerbated by the survey being protracted over the dark phase of the moon when catch rates are expected to be higher.

Nominal survey catch rates increased from 2004/05 to 2007/08 and declined thereafter (Figure 3.2). Prior to the closure, survey catch rate had declined to a historical low of 43.5 $kg.h^{-1}$ in May 2012. The catch rate from the 'reduced' May 2014 survey was 110.4 $kg.h^{-1}$, but declined to 60.4 $kg.h^{-1}$ in May 2015. The May 2015 survey catch rate remained 39% higher than that in May 2012. A similar trend was observed for 'adult' catch rate (>20+ grade from the entire graded catch) which was 56.5 $kg.h^{-1}$ in May 2015, and 62% higher than May 2012 (34.8 $kg.h^{-1}$).

The survey catch rate of 'new recruits' (20+ grade from the entire graded catch), has fluctuated through time (Figure 3.2). Prior to the fishery closure, the catch rate of 'new recruits' more than doubled between consecutive May surveys in 2011 and 2012. Following the fishery closure, the 'new recruit' catch rate from the 'reduced' May 2014 survey was 25.1 $kg.h^{-1}$. In May 2015, the 'new recruit' catch rate was 6.4 $kg.h^{-1}$, which was the lowest recorded since 2006 (5.5 $kg.h^{-1}$). The recruitment index, calculated from a 7 kg subsample per shot, reached a historical high of 1,060 $recruits.h^{-1}$ during the 'reduced' survey in May 2014. This was a 56% increase compared to 2012. In May 2015, the recruitment index was 306 $recruits.h^{-1}$, 55% lower than 2012 (681 $recruits.h^{-1}$) and the lowest on record. However, it was above the limit reference point of 250 $recruits.h^{-1}$ identified in the Management Plan for the fishery.

Estimated mean prawn size, has fluctuated since 2007/08 (Figure 3.2). Prior to the fishery closure, mean prawn size was the smallest on record at 37 $prawns.kg^{-1}$ in May 2012. Following the fishery closure, mean prawn size increased 13% in May 2014 (33 $prawns.kg^{-1}$) and in 2015, mean prawn size was the largest on record at 29 $prawns.kg^{-1}$.

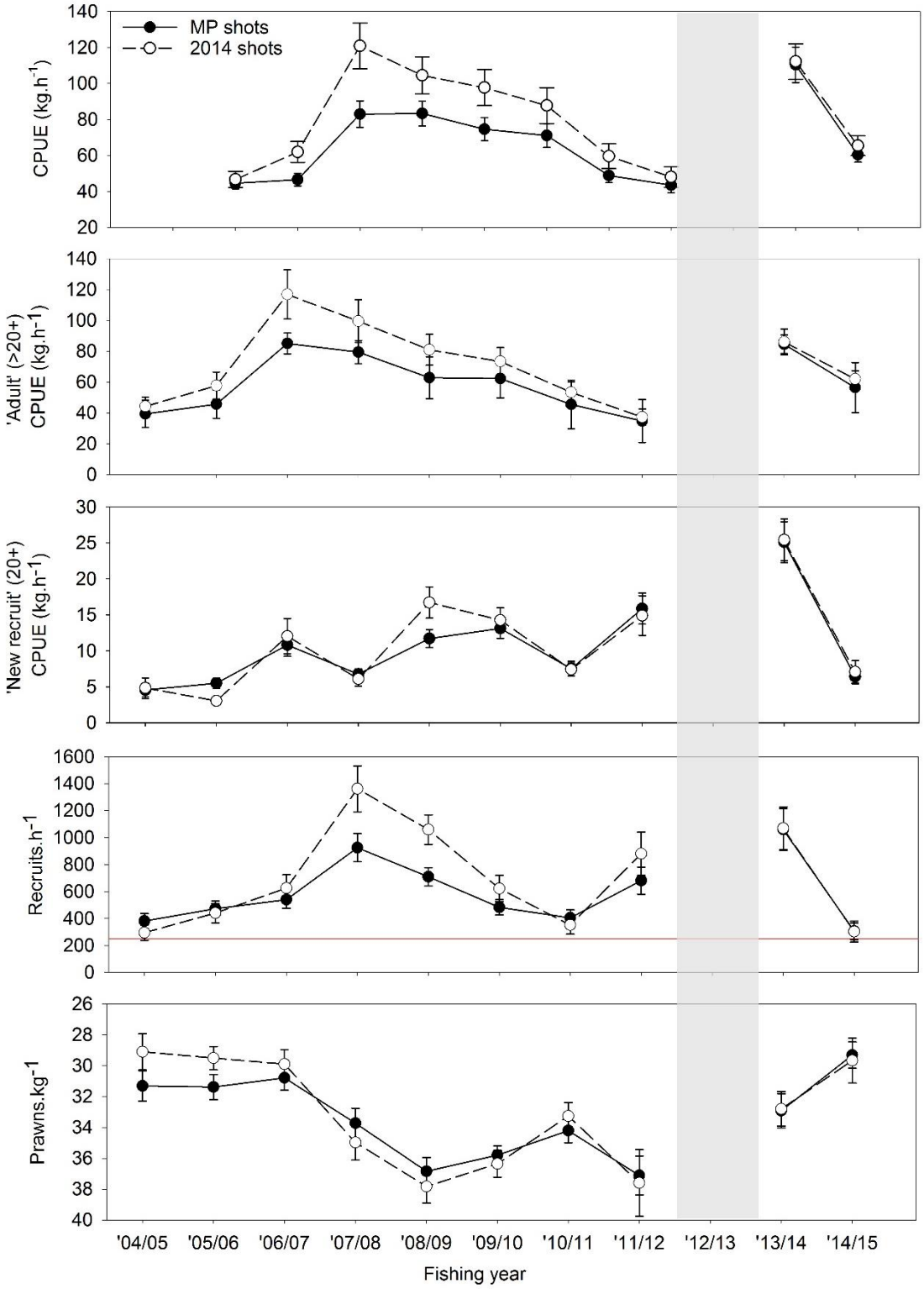

Figure 3.2 Key outputs from May fishery-independent surveys used to assess the status of the GSVPF. From top; total catch per unit effort (CPUE, kg.h^{-1}), 'adult' (>20+) CPUE (kg.h^{-1}), 'new recruit' (20+ grade) CPUE (kg.h^{-1}), the recruitment index (recruits.h^{-1}) estimated from a 7kg subsample per shot, and prawn size (prawns.kg^{-1}) estimated from a 7kg subsample per shot. Indices were calculated from shots in the management plan (MP) and the reduced suite of shots completed in 2014. Red lines refer to the LRP for the recruitment index as specified in the management plan (250 recruits.h^{-1}). Note, T90 and diamond gear was sampled side by side from 2011/12. Error bars, standard error.

3.1.3. *Standardised survey catch rate*

Survey CPUE generally increased from December–May, with peak catch rates most often occurring in April or May (Figure 3.3). The standardised model fit for survey catch rate showed some difference from raw data over the available time series, but not in overall trend. Region (β_2), year-survey (β_1) and vessel (β_3) were all highly significant (Table 3.1); however, a low overall goodness-of-fit (adjusted R^2 value 0.34) suggests other unaccounted sources of variability. Only 34.4% of the deviance in survey catches was explained by the model (region being the most important at 25%), which indicates that 66% of the deviance was caused by unknown factors.

Table 3.1. Analysis of deviance (Type II test) for the GLM used to standardise survey CPUE. Abbreviations: SS, sum of squares; df, degrees of freedom; *F*, *F*-statistic. R^2_{adj} = 0.34.

Effect	SS	df	*F*
Fishing year-survey (β_1)	242.9	31	9.7***
Region (β_2)	141.9	7	25.1***
Vessel (β_3)	63.1	13	6.0***
Residuals	2651.7	3287	NA

Significance: *** $p < 0.001$.

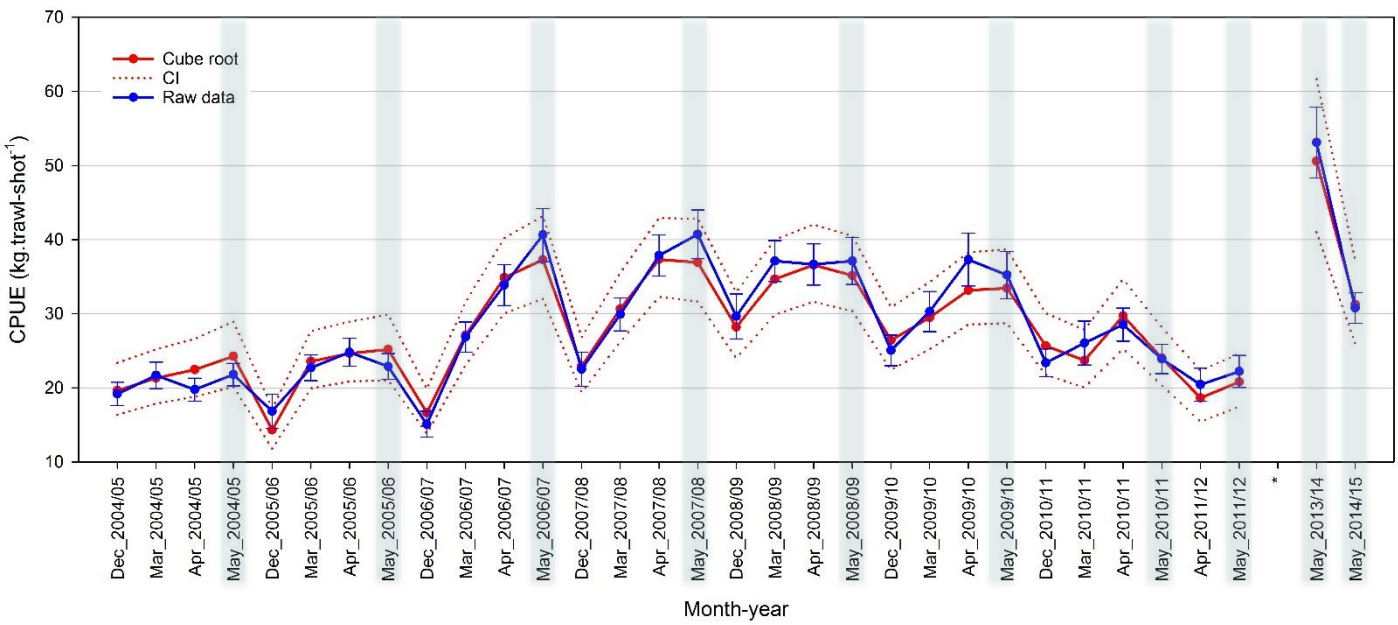

Figure 3.3 Comparison of model-predicted mean survey CPUE (kg.trawl-shot^{-1}) in the GSVPF with raw data from 2004/05–2014/15, May surveys are highlighted. *No surveys were undertaken in 2012/13.

3.2. Fishery-dependent catch and effort

3.2.1. *Regional distribution of catch and effort*

Following the introduction of a rigorous survey design in 2004/05, the number of blocks fished steeply declined (Figure 3.4). In 2014/15, the number of surveys and level of spatial management was reduced, and the number of blocks fished increased – likely reflecting the change in management arrangements that removed the requirement to fish within identified fishing blocks each fishing period. In 2014/15, fishing took place in 20 blocks in November–December and in 54 blocks in the remaining months of the season. This was the highest number of blocks fished pre–Christmas since 2003/04 when 38 blocks were fished pre-Christmas and 85 blocks were fished in other months).

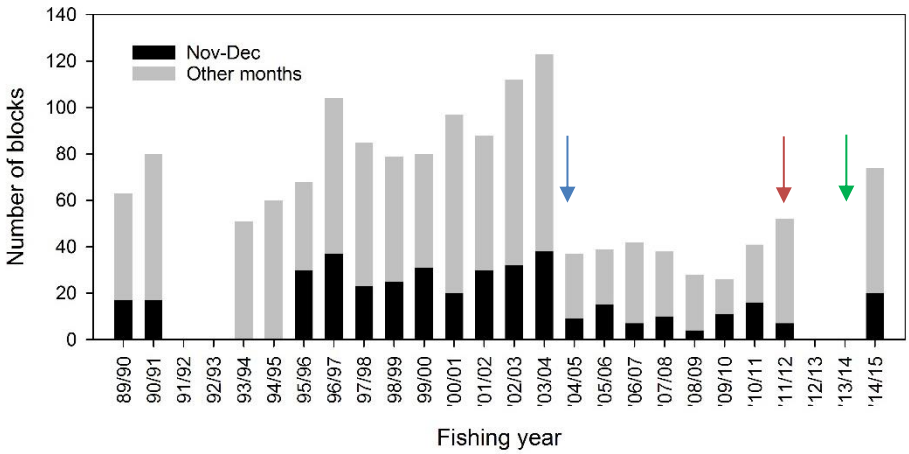

Figure 3.4 The number of blocks fished Pre–Christmas (November and December) and all other months from 1989/90–2014/15. ↓ Introduction of 4 surveys per year, ↓ reduced to 2 surveys per year, ↓ reduced to 1 survey per year.

The distribution of annual catch by region has varied substantially through time (Figure 3.5). Historically, an average of 38% of total catch has been harvested from Deep Hole (DH) and Region 2 (RG2). The distribution of catch in 2014/15 was similar to the historic pattern with Deep Hole and Region 2 accounting for approximately 50% (121 t) of total catch while a further 21% (54 t) of catch was harvested from Region 1 (RG1). In the northern gulf, the level of catch from Region 1 was the highest since 2007/08

(103 t) and the 4th highest on record, while Region 2 recorded the highest total catch since 2006/07. For the southern gulf, catch from Deep Hole was the highest since 2000/01 (91 t).

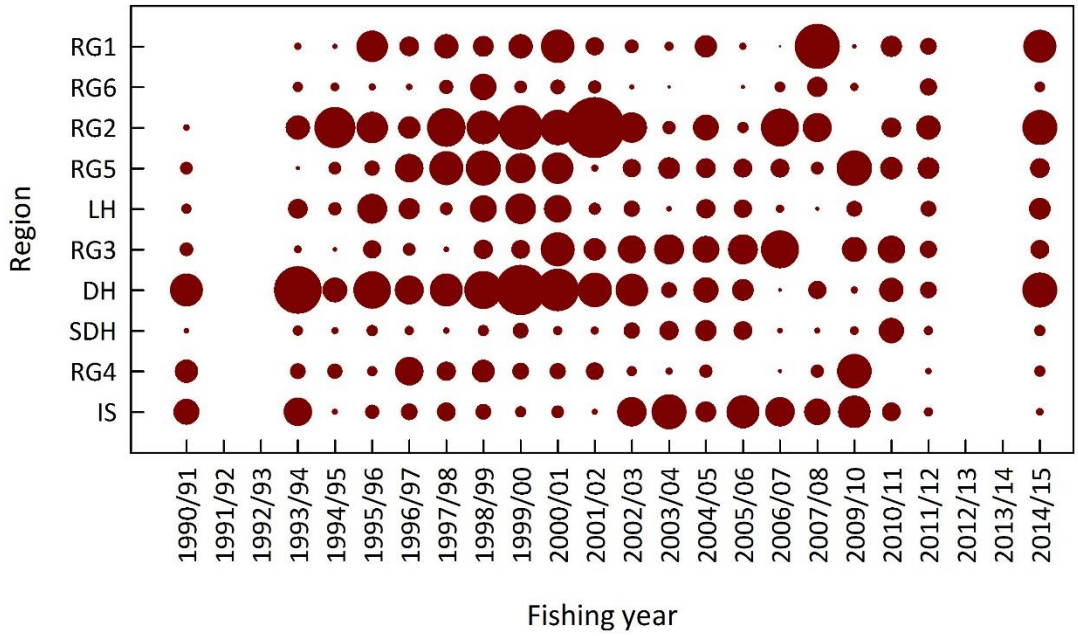

Figure 3.5 Regional distribution of annual catch harvested from 1990/91–2014/15. Note: bubble area is proportional to regional catch. See Figure 2.1 for abbreviations of regions

3.2.2. *Nominal indices*

The total catch in 2014/15 was 252.4 t (including 2.8 t survey catch), 93% higher than 2011/12 (130.7 t, including 5.7 t survey catch) and the highest historical catch since 2008/09 (288.1 t, including 15.4 t survey catch; Figure 3.6). Harvest during the early spawning period (November–December) was 57.1 t in 2014/15 and this represented 22.6% of the total annual catch and was the largest catch during early spawning since 2002/03 (64 t). A high proportion of catch (26.1%) was also harvested during the late spawning period from January to March 2015 (65.9 t) and this was the largest catch during the late spawning period since 2007/08 (66.7 t). The remaining 129.2 t (51.2%) of catch was harvested during the non-spawning season.

Fishing was conducted over 294 vessel nights in 2014/15, 14% more vessel nights than 2011/12 (257 vessel nights), but low compared to historical levels (Figure 3.4). During early spawning (November–December), 50 vessel nights were fished. This was a substantial increase compared to the 24 vessel nights fished in 2011/12 and more than 10% above the ten year mean (45 vessel nights).

The total effort in 2014/15 was 2,904 trawl hours, 20% higher than 2011/12 (2,428 hours). This was the highest effort since 2004/05 (3,137 trawl hours), but remains among the lowest levels of nominal effort observed for the fishery.

Annual nominal commercial CPUE in 2014/15 was 85.9 kg.hr^{-1}. This was 67% higher than 2011/12 (51.5 kg.hr^{-1}) and the highest since 2009/10 (95.5 kg.hr^{-1}).

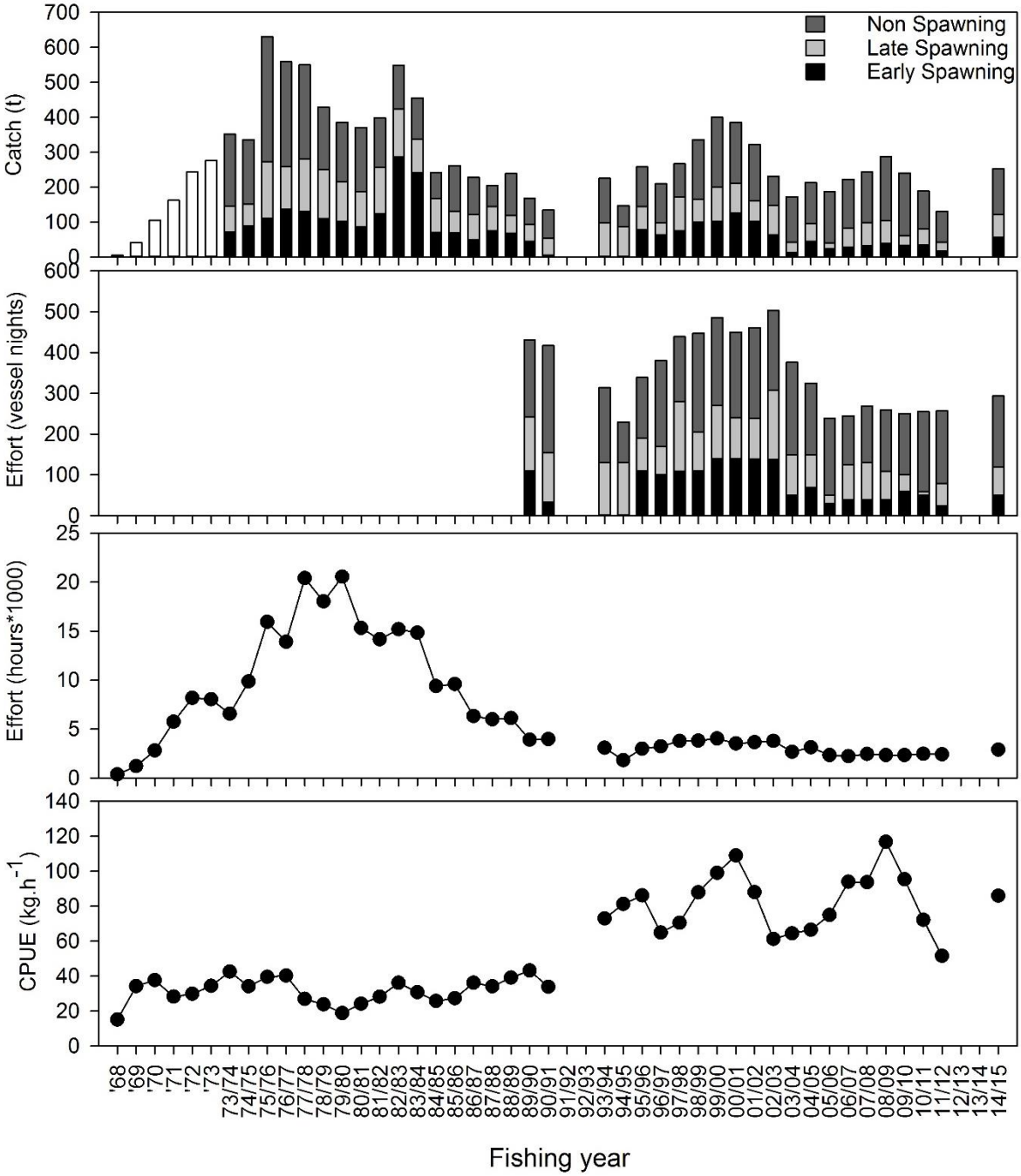

Figure 3.6 Key outputs from fishery-dependent catch and effort data used to assess the status of the GSVPF. From top; annual catch (t) and effort (vessel nights) including surveys and separated by early spawning (November–December), late spawning (January-March) and non-spawning (April-October), commercial effort (hours * 1000) andcatch per unit effort (CPUE, kg.h^{-1}).

3.2.3. *Standardised commercial catch rate*

The standardised model fit for commercial catches showed some difference from raw data over the available time series, but adequately captured the overall trend (Figure 3.7). Region (β_2), fishing year-month (β_1), lunar phase (β_7), lunar phase (¼ lag) (β_8), cloud cover (β_9) and vessel (β_3) were all highly significant (Table 3.2); and a relatively high goodness-of-fit was achieved (adjusted R^2 value 0.79). Despite this, only 79.1% of the deviance in commercial catches was explained by the model (effort accounted for 72% and fishing year-month accounted for 7%), which indicates that 21% of the deviance was caused by unknown factors.

Historically standardised estimates of CPUE have declined from November–June (Figure 3.7). In 2011/12 and 2014/15, the rate of CPUE decline was steeper than the historical trend. In 2014/15, this decline was exacerbated by the high CPUE in November (1,492 kg.block.vessel.night^{-1}) and December (1,248 kg.block.vessel.night^{-1}) and low CPUE in June (601 kg.block.vessel.night^{-1}) and July 2015 CPUE (346 kg.vessel.night^{-1}).

Table 3.2. Analysis of deviance (Type II test) for the GLM used to standardise commercial catch. Abbreviations: SS, sum of squares; df, degrees of freedom; *F*, *F*-statistic. $R^2_{adj} = 0.79$.

Effect	SS	df	*F*
fishing year-month (β_1)	66915	110	46***
region (β_2)	445	9	36***
vessel (β_3)	181	9	15***
lunar phase (β_7)	21	1	16***
lunar phase (¼ lag) (β_8)	14	1	10***
cloud cover (β_9)	18	1	13***
effort (β_{10})	73923	1	53994***
residuals	21513	53994	NA

significance: *** $p < 0.001$.

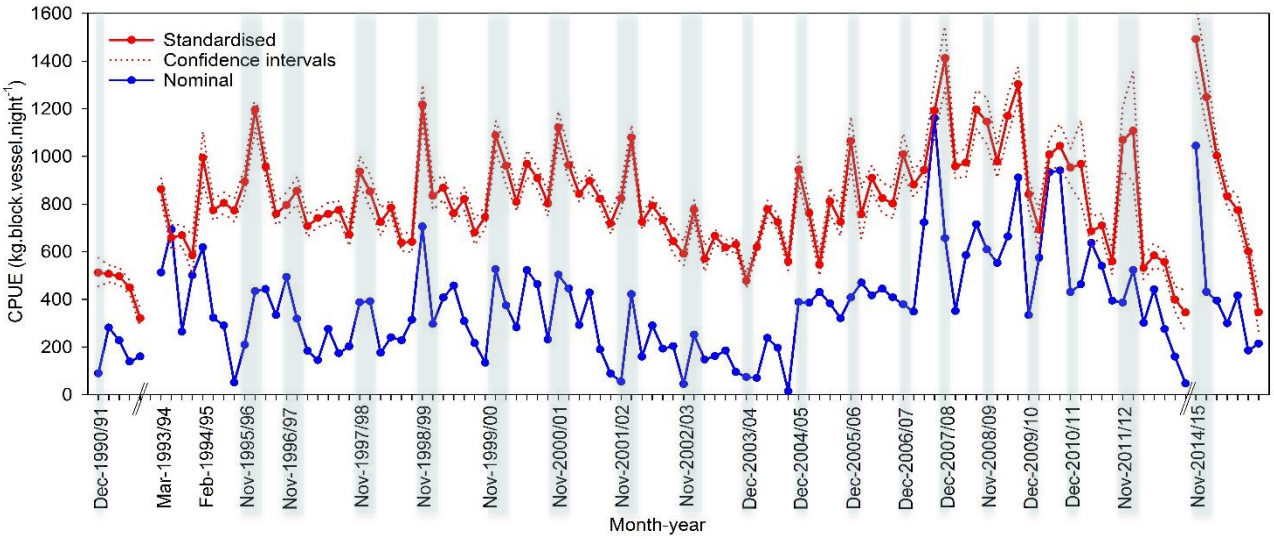

Figure 3.7 Comparison of model-predicted mean commercial catch (kg.block.vessel.night^{-1}) in the GSVPF with raw data from December 1990/91– July 2014/15 (excluding 1991/92-93 and 2012/13-201/14 when the fishery was closed). Pre-Christmas (November–December) period is highlighted.

4. SUMMARY

The GSVPF was closed during 2012/13 and 2013/14 at the request of all ten license holders following declines in catch rates of adult prawns and poor economic performance during the 2011/12 season. The fishery was re-opened in November 2014.

Fishery-independent and fishery-dependent data show that adult biomass increased during the closure, indicated by:

1) ‘Adult’ catch rates from the FIS in May 2014 and 2015 were substantially higher than in May 2012.

2) The annual nominal commercial catch rate in 2014/15 was the highest observed since 2009/10 and standardised catch rates were at, or among, the highest on record in November 2014, December 2014 and March 2015.

3) The total commercial catch of 249.4 t in 2014/15 was almost double that in 2011/12 (125.0 t) and among the highest in recent years.

The recruitment index from the May 2015 survey, while above the lower limit reference point prescribed in the Management Plan (250 recruits.h^{-1}), reached a historical low of 306 recruits.h^{-1}. The survey catch rate of ‘new recruits’ was also the lowest recorded since 2006. These results suggest that future recruitment into the harvestable biomass may be limited.

In summary, the commercial and survey catch rates demonstrate that adult biomass increased following the closure from 2012/13–13/14. However, the low catch rates of recruits in May 2015 suggest that future recruitment to the harvestable biomass may be limited. Using a ‘weight-of-evidence’ approach and the national framework for stock status reporting, the GSVPF is classified as '**transitional-depleting’**. Under the framework, this definition states ‘fishing pressure is too high and moving the stock in the direction of becoming recruitment overfished’ (Flood et al. 2014).

There are several key uncertainties associated with this assessment of stock status. These include:

1) The effects on catch rates for the ‘reduced’ May 2014 survey, caused by extending the survey over the dark phase of the moon (when catch rates are high), are not well understood.

2) The effects on the size composition of the commercial catch resulting from use of T90 gear (with an exclusion grid), which facilitates the escapement of small prawns (Dixon *et al*. 2013), and other recent changes to net configuration (e.g. increasing the number of standard meshes from 10 to 33), since March 2012 are not well understood.
3) The effects on survey catch rates of operating T90 gear alongside the diamond net during surveys conducted since 2011/12 are not well understood.
4) The effects on recruitment measures of reducing the number of stock assessment surveys from four to two in 2011/12 (April and May on the dark of the moon) and to one in 2013/14 (May) are unknown.
5) The effects of changes to management arrangements on fisher behaviour and the interpretation of fishery-dependent data are not well understood.

The current Management Plan and harvest strategy for the fishery is being reviewed and this is due for completion in 2016. This review will develop PIs for assigning stock status, including identifying when the stock is overfished, transitional or sustainable. The revised harvest strategy will also include decision rules for setting effort and/or catch quotas which are reflective of the fishery's stock status. Economic PIs may also be considered to allow the resource to be exploited for maximum economic value within the framework of sustainable exploitation. The bio-economic model of Noell *et al.* (2015) could be further developed as a tool for assessing stock status relative to model-estimated reference points and determining how the stock may respond to specific management actions.

5. REFERENCES

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6. APPENDIX

Table A 1. Output from R of the GLM used to standardise survey CPUE, and model coefficients.

```
##
## Call:
## glm2(formula = CATCHcbrt ~ YEARSURV + REGION + VESSEL, family = gaussian(l
ink = "identity"),
##     data = d.gsv, offset = EFFORT)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -3.0514  -0.5718   0.0202   0.5918   3.3642
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)            2.19939    0.10402  21.143  < 2e-16 ***
## YEARSURV2004/05_SURV2  0.08214    0.12590   0.652 0.514189
## YEARSURV2004/05_SURV3  0.13589    0.12723   1.068 0.285564
## YEARSURV2004/05_SURV4  0.21665    0.13245   1.636 0.101990
## YEARSURV2005/06_SURV1 -0.30232    0.12537  -2.411 0.015943 *
## YEARSURV2005/06_SURV2  0.18654    0.12525   1.489 0.136491
## YEARSURV2005/06_SURV3  0.23400    0.12514   1.870 0.061584 .
## YEARSURV2005/06_SURV4  0.25641    0.13084   1.960 0.050110 .
## YEARSURV2006/07_SURV1 -0.16057    0.12611  -1.273 0.203029
## YEARSURV2006/07_SURV2  0.33606    0.12548   2.678 0.007440 **
## YEARSURV2006/07_SURV3  0.62036    0.12592   4.927 8.78e-07 ***
## YEARSURV2006/07_SURV4  0.70008    0.12775   5.480 4.57e-08 ***
## YEARSURV2007/08_SURV1  0.15638    0.12536   1.248 0.212297
## YEARSURV2007/08_SURV2  0.47186    0.12590   3.748 0.000181 ***
## YEARSURV2007/08_SURV3  0.70111    0.12555   5.584 2.53e-08 ***
## YEARSURV2007/08_SURV4  0.68873    0.12828   5.369 8.46e-08 ***
## YEARSURV2008/09_SURV1  0.37974    0.12674   2.996 0.002753 **
## YEARSURV2008/09_SURV2  0.61413    0.12593   4.877 1.13e-06 ***
## YEARSURV2008/09_SURV3  0.67654    0.12534   5.398 7.23e-08 ***
## YEARSURV2008/09_SURV4  0.63014    0.12532   5.028 5.22e-07 ***
## YEARSURV2009/10_SURV1  0.30746    0.12674   2.426 0.015326 *
## YEARSURV2009/10_SURV2  0.42920    0.12647   3.394 0.000698 ***
## YEARSURV2009/10_SURV3  0.56241    0.12559   4.478 7.78e-06 ***
## YEARSURV2009/10_SURV4  0.57177    0.12687   4.507 6.82e-06 ***
## YEARSURV2010/11_SURV1  0.27721    0.12710   2.181 0.029254 *
## YEARSURV2010/11_SURV2  0.19268    0.12690   1.518 0.129031
## YEARSURV2010/11_SURV3  0.43718    0.12868   3.397 0.000688 ***
## YEARSURV2010/11_SURV4  0.20706    0.12652   1.637 0.101824
## YEARSURV2011/12_SURV3 -0.05174    0.12916  -0.401 0.688744
## YEARSURV2011/12_SURV4  0.05827    0.12755   0.457 0.647788
## YEARSURV2013/14_SURV4  1.08094    0.16250   6.652 3.37e-11 ***
## YEARSURV2014/15_SURV4  0.49434    0.13991   3.533 0.000416 ***
## REGIONINV             -0.48947    0.05344  -9.159  < 2e-16 ***
## REGIONRG1             -0.49573    0.06221  -7.969 2.19e-15 ***
## REGIONRG2             -0.02948    0.06045  -0.488 0.625781
## REGIONRG3             -0.17591    0.06403  -2.747 0.006045 **
## REGIONRG4             -0.54340    0.06679  -8.136 5.74e-16 ***
## REGIONRG5             -0.20005    0.06241  -3.205 0.001362 **
## REGIONRG6             -0.27120    0.07411  -3.659 0.000257 ***
## VESSELA                0.17122    0.05401   3.170 0.001537 **
## VESSELB               -0.04185    0.05824  -0.719 0.472428
## VESSELC               -0.80474    0.20678  -3.892 0.000101 ***
```

```
## VESSELD                0.13897    0.15481   0.898 0.369421
## VESSELE                0.03320    0.05403   0.614 0.539008
## VESSELF               -0.16496    0.05955  -2.770 0.005631 **
## VESSELG                0.14183    0.21767   0.652 0.514718
## VESSELH               -0.07115    0.08013  -0.888 0.374610
## VESSELI               -0.18178    0.17539  -1.036 0.300072
## VESSELJ               -0.33291    0.11941  -2.788 0.005335 **
## VESSELK                0.20745    0.15931   1.302 0.192933
## VESSELL                0.59590    0.29377   2.028 0.042595 *
## VESSELM                0.09563    0.09365   1.021 0.307254
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.8067096)
##
##     Null deviance: 3115.6  on 3338  degrees of freedom
## Residual deviance: 2651.7  on 3287  degrees of freedom
## AIC: 8812.1
##
## Number of Fisher Scoring iterations: 2
```

Table A 2. Output from R of the GLM used to standardise commerical CPUE, and model coefficients.

```
## Call:
## glm2(formula = CATCHcbrt ~ FYEAR_MONTH + REG_ID + LUM + LUMLAG7 +
##     CLOUD + EFFORT + LIC_NO, family = gaussian(link = "identity"),
##     data = d.gsv)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -4.5933  -0.7922  -0.0018   0.7897   5.3038
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)            1.448292   0.168601   8.590  < 2e-16 ***
## FYEAR_MONTH1990/91_3  -0.028294   0.188537  -0.150 0.880709
## FYEAR_MONTH1990/91_4  -0.083356   0.189768  -0.439 0.660483
## FYEAR_MONTH1990/91_5  -0.346160   0.182905  -1.893 0.058434 .
## FYEAR_MONTH1990/91_6  -1.181793   0.214264  -5.516 3.53e-08 ***
## FYEAR_MONTH1993/94_3   1.546219   0.183573   8.423  < 2e-16 ***
## FYEAR_MONTH1993/94_4   0.718356   0.201831   3.559 0.000373 ***
## FYEAR_MONTH1993/94_5   0.758657   0.189468   4.004 6.25e-05 ***
## FYEAR_MONTH1993/94_6   0.367597   0.259077   1.419 0.155956
## FYEAR_MONTH1994/95_2   2.014952   0.244175   8.252  < 2e-16 ***
## FYEAR_MONTH1994/95_3   1.206347   0.184154   6.551 5.90e-11 ***
## FYEAR_MONTH1994/95_4   1.325872   0.184093   7.202 6.19e-13 ***
## FYEAR_MONTH1994/95_5   1.202159   0.188433   6.380 1.82e-10 ***
## FYEAR_MONTH1995/96_11  1.662360   0.188766   8.806  < 2e-16 ***
## FYEAR_MONTH1995/96_12  2.656231   0.200141  13.272  < 2e-16 ***
## FYEAR_MONTH1995/96_3   1.890924   0.188789  10.016  < 2e-16 ***
## FYEAR_MONTH1995/96_4   1.140802   0.190357   5.993 2.11e-09 ***
## FYEAR_MONTH1995/96_5   1.293369   0.190660   6.784 1.21e-11 ***
## FYEAR_MONTH1996/97_11  1.520458   0.195055   7.795 6.84e-15 ***
## FYEAR_MONTH1996/97_12  0.928515   0.190894   4.864 1.16e-06 ***
## FYEAR_MONTH1996/97_3   1.071466   0.178615   5.999 2.03e-09 ***
## FYEAR_MONTH1996/97_4   1.142036   0.188125   6.071 1.30e-09 ***
## FYEAR_MONTH1996/97_5   1.207772   0.178367   6.771 1.32e-11 ***
## FYEAR_MONTH1996/97_6   0.772723   0.194149   3.980 6.92e-05 ***
## FYEAR_MONTH1997/98_11  1.815356   0.197251   9.203  < 2e-16 ***
## FYEAR_MONTH1997/98_12  1.509644   0.208336   7.246 4.49e-13 ***
## FYEAR_MONTH1997/98_2   0.999766   0.203829   4.905 9.44e-07 ***
## FYEAR_MONTH1997/98_3   1.246888   0.174922   7.128 1.06e-12 ***
## FYEAR_MONTH1997/98_4   0.619214   0.179488   3.450 0.000562 ***
## FYEAR_MONTH1997/98_5   0.635894   0.193106   3.293 0.000993 ***
## FYEAR_MONTH1998/99_11  2.721489   0.200608  13.566  < 2e-16 ***
## FYEAR_MONTH1998/99_12  1.440270   0.198646   7.250 4.35e-13 ***
## FYEAR_MONTH1998/99_3   1.568104   0.186922   8.389  < 2e-16 ***
## FYEAR_MONTH1998/99_4   1.153402   0.181274   6.363 2.04e-10 ***
## FYEAR_MONTH1998/99_5   1.387402   0.187158   7.413 1.30e-13 ***
## FYEAR_MONTH1998/99_6   0.811715   0.199341   4.072 4.68e-05 ***
## FYEAR_MONTH1999/00_11  1.087637   0.189624   5.736 9.89e-09 ***
## FYEAR_MONTH1999/00_12  2.325042   0.187380  12.408  < 2e-16 ***
## FYEAR_MONTH1999/00_2   1.899077   0.213247   8.906  < 2e-16 ***
## FYEAR_MONTH1999/00_3   1.344099   0.178403   7.534 5.19e-14 ***
## FYEAR_MONTH1999/00_4   1.928519   0.190104  10.145  < 2e-16 ***
## FYEAR_MONTH1999/00_5   1.716978   0.182479   9.409  < 2e-16 ***
## FYEAR_MONTH1999/00_6   1.315424   0.191323   6.875 6.41e-12 ***
## FYEAR_MONTH2000/01_11  2.429086   0.192808  12.598  < 2e-16 ***
## FYEAR_MONTH2000/01_12  1.910280   0.193101   9.893  < 2e-16 ***
## FYEAR_MONTH2000/01_3   1.474653   0.176130   8.373  < 2e-16 ***
```

```
## FYEAR_MONTH2000/01_4   1.672843   0.181947   9.194  < 2e-16 ***
## FYEAR_MONTH2000/01_5   1.389479   0.172718   8.045 9.25e-16 ***
## FYEAR_MONTH2000/01_6   0.978220   0.187367   5.221 1.80e-07 ***
## FYEAR_MONTH2001/02_11  1.399431   0.187438   7.466 8.69e-14 ***
## FYEAR_MONTH2001/02_12  2.296212   0.181234  12.670  < 2e-16 ***
## FYEAR_MONTH2001/02_3   1.004323   0.174202   5.765 8.31e-09 ***
## FYEAR_MONTH2001/02_4   1.281103   0.177246   7.228 5.13e-13 ***
## FYEAR_MONTH2001/02_5   1.039725   0.174737   5.950 2.73e-09 ***
## FYEAR_MONTH2001/02_6   0.651034   0.205348   3.170 0.001525 **
## FYEAR_MONTH2002/03_11  0.400503   0.205724   1.947 0.051577 .
## FYEAR_MONTH2002/03_12  1.213009   0.182529   6.646 3.12e-11 ***
## FYEAR_MONTH2002/03_2   0.294959   0.210943   1.398 0.162046
## FYEAR_MONTH2002/03_3   0.750480   0.171097   4.386 1.16e-05 ***
## FYEAR_MONTH2002/03_4   0.525247   0.178521   2.942 0.003263 **
## FYEAR_MONTH2002/03_5   0.585621   0.172370   3.397 0.000682 ***
## FYEAR_MONTH2003/04_12 -0.183732   0.185818  -0.989 0.322788
## FYEAR_MONTH2003/04_3   0.533961   0.172025   3.104 0.001913 **
## FYEAR_MONTH2003/04_4   1.222079   0.177599   6.881 6.16e-12 ***
## FYEAR_MONTH2003/04_5   0.997207   0.176182   5.660 1.54e-08 ***
## FYEAR_MONTH2003/04_6   0.235513   0.184660   1.275 0.202191
## FYEAR_MONTH2004/05_12  1.841785   0.196044   9.395  < 2e-16 ***
## FYEAR_MONTH2004/05_3   1.153735   0.193458   5.964 2.52e-09 ***
## FYEAR_MONTH2004/05_4   0.177085   0.203393   0.871 0.383957
## FYEAR_MONTH2004/05_5   1.354312   0.194664   6.957 3.61e-12 ***
## FYEAR_MONTH2004/05_6   1.005908   0.206611   4.869 1.13e-06 ***
## FYEAR_MONTH2005/06_12  2.248736   0.229847   9.784  < 2e-16 ***
## FYEAR_MONTH2005/06_3   1.134927   0.272346   4.167 3.10e-05 ***
## FYEAR_MONTH2005/06_4   1.719597   0.189128   9.092  < 2e-16 ***
## FYEAR_MONTH2005/06_5   1.403991   0.204420   6.868 6.75e-12 ***
## FYEAR_MONTH2005/06_6   1.314761   0.207485   6.337 2.41e-10 ***
## FYEAR_MONTH2006/07_12  2.067974   0.213705   9.677  < 2e-16 ***
## FYEAR_MONTH2006/07_3   1.617161   0.189299   8.543  < 2e-16 ***
## FYEAR_MONTH2006/07_4   1.838143   0.194939   9.429  < 2e-16 ***
## FYEAR_MONTH2006/07_5   2.646404   0.249251  10.617  < 2e-16 ***
## FYEAR_MONTH2007/08_12  3.270136   0.237304  13.780  < 2e-16 ***
## FYEAR_MONTH2007/08_3   1.891542   0.184490  10.253  < 2e-16 ***
## FYEAR_MONTH2007/08_4   1.946503   0.195881   9.937  < 2e-16 ***
## FYEAR_MONTH2007/08_5   2.659443   0.203725  13.054  < 2e-16 ***
## FYEAR_MONTH2008/09_11  2.506247   0.221556  11.312  < 2e-16 ***
## FYEAR_MONTH2008/09_3   1.960402   0.200694   9.768  < 2e-16 ***
## FYEAR_MONTH2008/09_4   2.577996   0.209487  12.306  < 2e-16 ***
## FYEAR_MONTH2008/09_5   2.971134   0.190898  15.564  < 2e-16 ***
## FYEAR_MONTH2009/10_12  1.464337   0.202815   7.220 5.43e-13 ***
## FYEAR_MONTH2009/10_3   0.864992   0.242113   3.573 0.000354 ***
## FYEAR_MONTH2009/10_4   2.062893   0.195271  10.564  < 2e-16 ***
## FYEAR_MONTH2009/10_5   2.181169   0.219737   9.926  < 2e-16 ***
## FYEAR_MONTH2010/11_12  1.873493   0.213346   8.781  < 2e-16 ***
## FYEAR_MONTH2010/11_3   1.924878   0.344202   5.592 2.28e-08 ***
## FYEAR_MONTH2010/11_4   0.836062   0.215797   3.874 0.000107 ***
## FYEAR_MONTH2010/11_5   0.936046   0.193049   4.849 1.25e-06 ***
## FYEAR_MONTH2010/11_6   0.244816   0.215558   1.136 0.256086
## FYEAR_MONTH2011/12_11  2.263009   0.275932   8.201 2.56e-16 ***
## FYEAR_MONTH2011/12_12  2.386769   0.405390   5.888 4.00e-09 ***
## FYEAR_MONTH2011/12_3   0.102467   0.207222   0.494 0.620976
## FYEAR_MONTH2011/12_4   0.364416   0.205540   1.773 0.076253 .
## FYEAR_MONTH2011/12_5   0.230390   0.191957   1.200 0.230073
## FYEAR_MONTH2011/12_6  -0.654861   0.230514  -2.841 0.004505 **
## FYEAR_MONTH2011/12_7  -1.015649   0.343395  -2.958 0.003104 **
## FYEAR_MONTH2014/15_11  3.478157   0.249840  13.922  < 2e-16 ***
```

```
## FYEAR_MONTH2014/15_12  2.812445   0.251117  11.200  < 2e-16 ***
## FYEAR_MONTH2014/15_3   2.046535   0.186396  10.980  < 2e-16 ***
## FYEAR_MONTH2014/15_4   1.434315   0.183519   7.816 5.81e-15 ***
## FYEAR_MONTH2014/15_5   1.207500   0.198009   6.098 1.10e-09 ***
## FYEAR_MONTH2014/15_6   0.451086   0.194989   2.313 0.020714 *
## FYEAR_MONTH2014/15_7  -1.005658   0.343800  -2.925 0.003448 **
## REG_IDINV             -0.576222   0.040944 -14.073  < 2e-16 ***
## REG_IDLIH             -0.108850   0.045722  -2.381 0.017292 *
## REG_IDRG1             -0.390762   0.049773  -7.851 4.40e-15 ***
## REG_IDRG2             -0.150238   0.038737  -3.878 0.000106 ***
## REG_IDRG3             -0.073015   0.042664  -1.711 0.087026 .
## REG_IDRG4             -0.479722   0.044030 -10.895  < 2e-16 ***
## REG_IDRG5             -0.283350   0.044514  -6.365 2.00e-10 ***
## REG_IDRG6             -0.230478   0.061968  -3.719 0.000200 ***
## REG_IDSDH             -0.128950   0.053113  -2.428 0.015200 *
## LUM                   -0.241186   0.061154  -3.944 8.05e-05 ***
## LUMLAG7                0.109093   0.034141   3.195 0.001399 **
## CLOUD                  0.130030   0.036194   3.593 0.000328 ***
## EFFORT                 0.700745   0.003016 232.365  < 2e-16 ***
## VESSELA                0.307801   0.040197   7.657 2.01e-14 ***
## VESSELB                0.105722   0.042024   2.516 0.011887 *
## VESSELC                0.240396   0.042480   5.659 1.55e-08 ***
## VESSELD                0.125287   0.041523   3.017 0.002554 **
## VESSELE                0.377097   0.040246   9.370  < 2e-16 ***
## VESSELF                0.255365   0.041383   6.171 6.96e-10 ***
## VESSELG                0.143750   0.041926   3.429 0.000608 ***
## VESSELH                0.262476   0.041709   6.293 3.20e-10 ***
## VESSELI                0.185037   0.044253   4.181 2.91e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 1.369102)
##
##     Null deviance: 139325  on 15845  degrees of freedom
## Residual deviance:  21513  on 15713  degrees of freedom
## AIC: 50082
##
## Number of Fisher Scoring iterations: 2
```