Spencer Gulf Prawn
Penaeus (*Melicertus*) *latisulcatus*
Fishery 2007/08

Fishery Assessment Report to PIRSA Fisheries

August 2009

C.D. Dixon, G.E. Hooper and S.D. Roberts

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EXECUTIVE SUMMARY

1. This report updates the 2006/07 fishery assessment report and is part of SARDI Aquatic Sciences' ongoing assessment program for the Spencer Gulf Prawn Fishery (SGPF). It aims to (1) synthesise and assess the information available for the SGPF, (2) assess the status of the resource and consider uncertainty associated with that assessment, (3) comment on current biological Performance Indicators for the fishery, and (4) identify future research priorities.

2. The SGPF was established in 1968 and catches increased rapidly to reach 2,287 t in 1973/74. Annual catches have since fluctuated between 1,048 and 2,522 t.

3. During 2007/08, total catch (2,028 t) was above the previous 5-year average (1,850 t). Nominal fishing effort was 18,438 hrs which was 40% of the peak effort in 1978/79 (45,786 hrs) and the second lowest recorded in the post-exploratory phase of the fishery. CPUE (110.0 kg/hr) increased for the third consecutive year and was the highest recorded since 2001/02.

4. The average size of prawns harvested in 2007/08 (210 prawns/7 kg) was the equal largest observed since 2002/03. The number of nights when very small prawns (>280 prawns/7 kg) were caught by individual vessels was 12 (of 1,938 vessel nights), which was low in an historical context. However, the number of nights where small prawns (>240 prawns/7 kg) were caught was 290 (of 1,938 vessel nights), which was the highest recorded since 2003/04.

5. Estimates of relative biomass, obtained by comparing consistently surveyed shots over time for November, February and April stock assessment surveys, suggest that the average biomass during the last four years has stabilised. This is consistent with increased stability in recruitment, and is likely a result of the investment in constraining pre-Christmas catch.

6. Sub-optimal size prawns (smaller average size than the target criteria) were caught following harvest strategies that were developed from all three spot surveys conducted during 2007/08. Small prawns were harvested at the scale of fishing block during March, April, May and June. Small prawns were also harvested at the scale of daily fleet average during March, April and May.

7. The key PIs for recruitment, prawn harvest size, commercial catch and CPUE were above reference ranges for 2007/08. PIs for “fishery-independent surveys”, “indices of current and future biomass” and “Committee comply with harvest strategy decision rules” were achieved.

8. Appropriate measures for assessing harvest strategy development and management at sea are required to ensure an objective rather than subjective assessment of the Performance Indicator “Committee comply with harvest strategy decision rules”.

9. Historical reductions in effort, relatively stable catches and increases in prawn size over time suggest that the SGPF is currently being fished within sustainable limits. Over the last four years, fishery performance has been above the long-term averages for total catch and commercial CPUE and stock assessment survey catch rates have stabilised considerably. This may have resulted from conservative harvest of the spawning biomass (prior to Christmas) which has led to improved recruitment. Whilst overall performance of the fishery is sound, there is potential for improvement in harvest strategy development and management at sea, particularly following strategies developed from spot survey results.

1. GENERAL INTRODUCTION

1.1 Overview

This Fishery Assessment Report for the Spencer Gulf Prawn Fishery is the fifth version of a "living" document that is part of SARDI Aquatic Sciences' ongoing assessment programs for South Australian Prawn Fisheries. The report concludes the annual reporting cycle for the fishery, which also comprises 1) survey reports completed within two weeks of the conduct of each of three fishery-independent surveys, and 2) a status report due four months after the end of the fishing-year that provides a brief synopsis of the commercial logbook and survey data collected that year.

The aims of the Fishery Assessment Report are to: (i) synthesise information for the Spencer Gulf Prawn Fishery; (ii) assess the current status of the resource and consider the uncertainty associated with the assessment; (iii) comment on the current biological Performance Indicators and Reference Points; and (iv) identify future research needs for the fishery.

Since 2004, this report has documented the biology and management of the primary harvest species, presented analyses of commercial logbook and fishery-independent survey data, and provided assessment against the Performance Indicators of the Management Plan (Dixon and Sloan 2007). More recent reports have also provided detailed spatial and temporal assessments of the fishing year to link harvest strategy development (based on survey results) with subsequent commercial catch. These analyses provide critical information for the assessment and improvement of the "Real Time Management" system that is the cornerstone of Spencer Gulf Prawn Fishery's success.

These and other analyses, such as the importance of pre-Christmas harvest on recruitment to the fishery, have provided important information for fishery management and the Management Plan. The increased focus on determining auditable assessment measures for fishery performance and harvest strategy development is in line with the Government and industry goal of fostering greater co-management responsibility to the Spencer Gulf prawn fishing industry (i.e. Spencer Gulf and West Coast Prawn Fisherman's Association).

1.2 Description of the Fishery

1.2.1 Fishery location

There are three commercial prawn *Penaeus* (*Melicertus*) *latisulcatus* fisheries in South Australia: Spencer Gulf, Gulf St. Vincent (GSV) and the West Coast (Figure 1.1). The Spencer Gulf Prawn Fishery is the largest of these in terms of total area, production, and number of licence holders.

Fishing is permitted in all waters north of the geodesic joining Cape Catastrophe (Latitude 34º 35.4'S, Longitude 136º 36.0'E) on Eyre Peninsula and Cape Spencer (Latitude 34º 9.6'S, Longitude 135º 31.2'E) on Yorke Peninsula, with the exception of several permanently closed areas. Spencer Gulf is divided into 125 prawn fishing blocks aggregated into regions reflective of the main trawl grounds of the fishery (Figure 1.2).

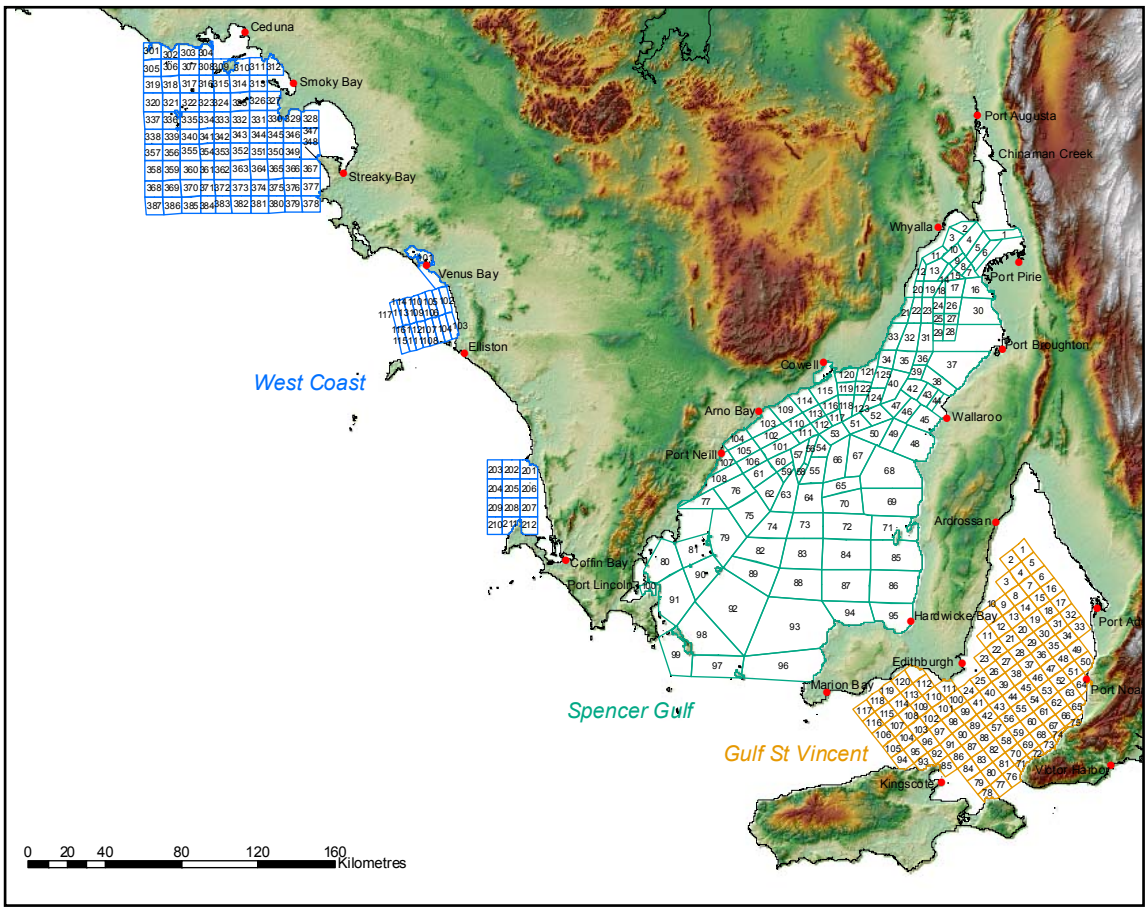

Figure 1.1 Location of South Australia's three commercial prawn fisheries.

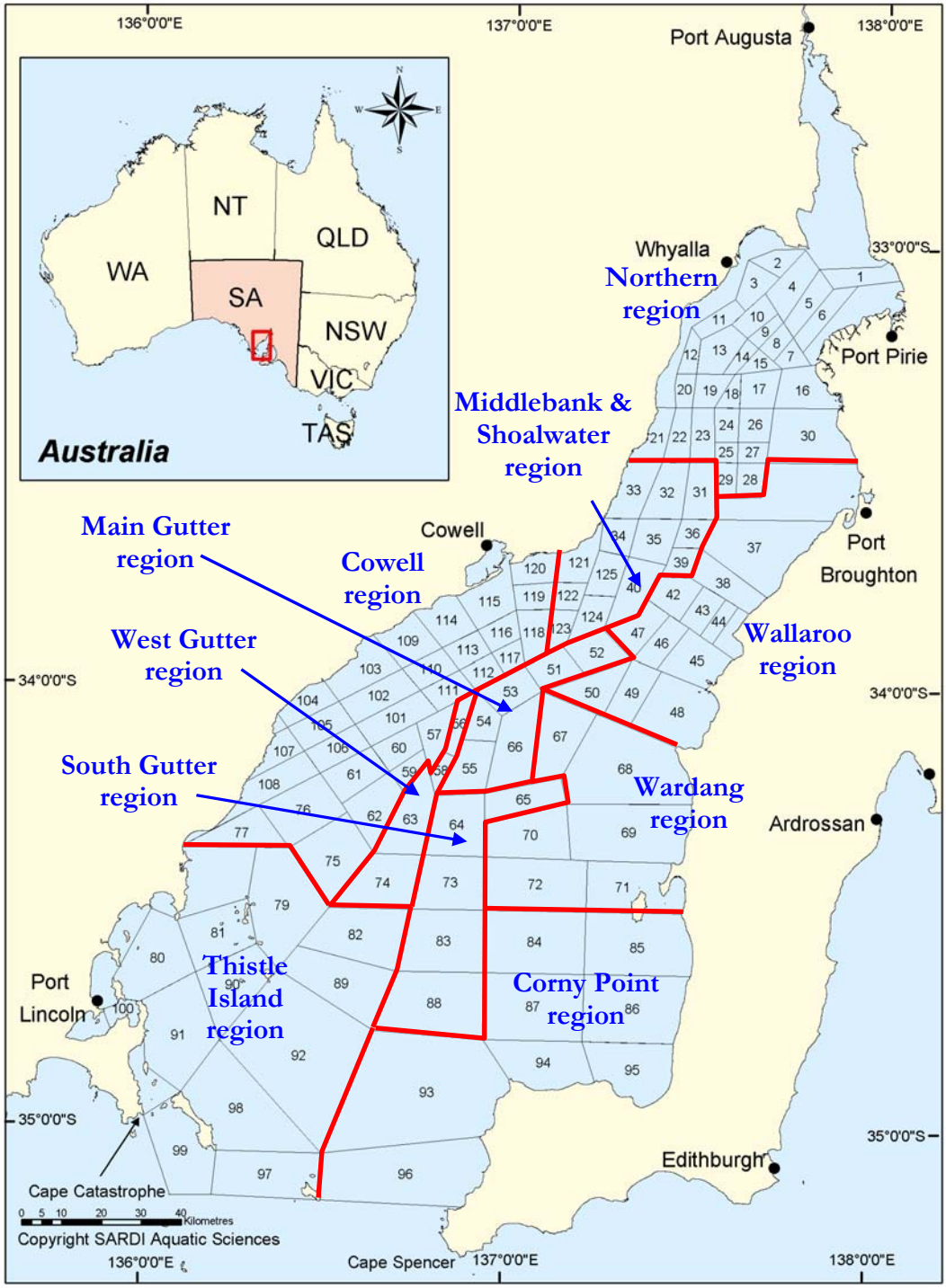

Figure 1.2 Fishing blocks and reporting regions of the Spencer Gulf Prawn Fishery.

1.2.2 Commercial fishery

The Spencer Gulf Prawn Fishery is a single species fishery that targets the western king prawn. This species was initially classified as *Penaeus latisulcatus* (Kishinouye, 1896), then subsequently reclassified by Perez Farfante and Kensley (1997) to raise the sub-genus *Melicertus* to generic rank (ie. *Melicertus latisulcatus*). Recently, Flegel (2007) revised the taxonomic name to *Penaeus (Melicertus) latisulcatus*. A smaller penaeid, *Metapenaeopsis crassima*, occurs in Spencer Gulf but is of no commercial value.

P. latisulcatus were first trawled in Spencer Gulf in 1909 by the FIS *Endeavour*. The first commercial prawn trawling attempts occurred in 1948 but the first commercial quantity of prawns was not harvested until October 1968 (Carrick 2003). Prawns are harvested at night using demersal, otter-trawl, double-rig gear (Figure 1.3). Considerable technological advancements have been made in the fishery including the use of “crab bags” to exclude mega-fauna by-catch (Figure 1.4), “hoppers” for efficient sorting of the catch and rapid return of by-catch (Figure 1.3), and “graders” to sort the prawns into marketable size categories (Figure 1.3). Many vessels in the prawn fleet are “factory vessels” that process the catch on-board.

Currently, the Spencer Gulf Prawn Fishery ($32.1M) is the third most valuable prawn fishery in Australia behind the Queensland East Coast Prawn Fishery ($90M) and Northern Prawn Fishery ($62.2M; Table 1.1). In terms of value per licence holder, the Spencer Gulf Prawn fishery is ranked second (39 licences, $0.82M per licence) behind the Northern Prawn Fishery (52 licences, $1.20M / licence). The Queensland East Coast Prawn Fishery has 498 licence holders ($0.18M / licence).

South Australia’s prawn fisheries are the only substantial single species prawn fisheries in Australia. However it is not the only fishery to target *P. latisulcatus*, as this species comprises 62% of the Shark Bay prawn catch, 46% of the Broome prawn catch and 43% of the Exmouth Gulf prawn catch (Table 1.1).

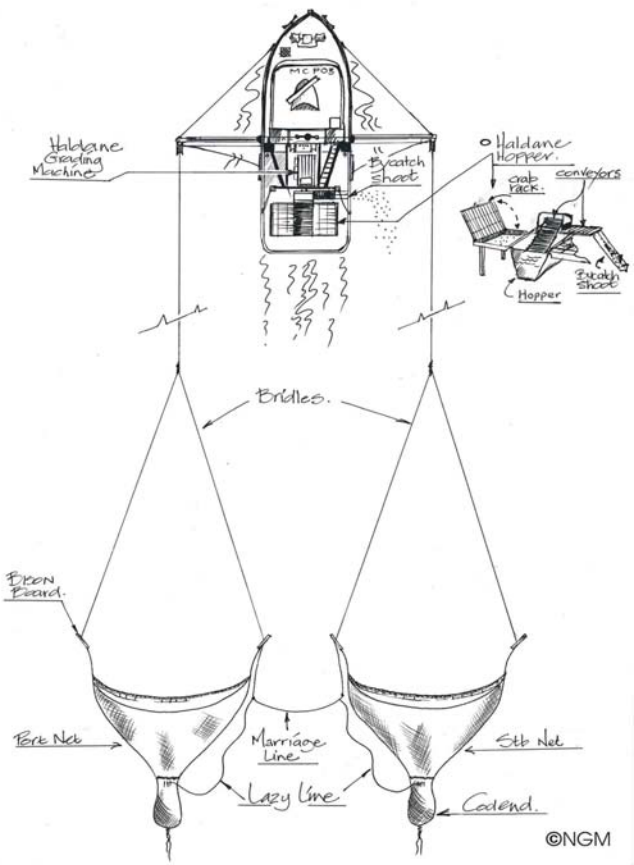

Figure 1.3 Double rig trawl gear and location of hopper sorting and prawn grading systems used in the Spencer Gulf Prawn Fishery. Figure from Carrick (2003).

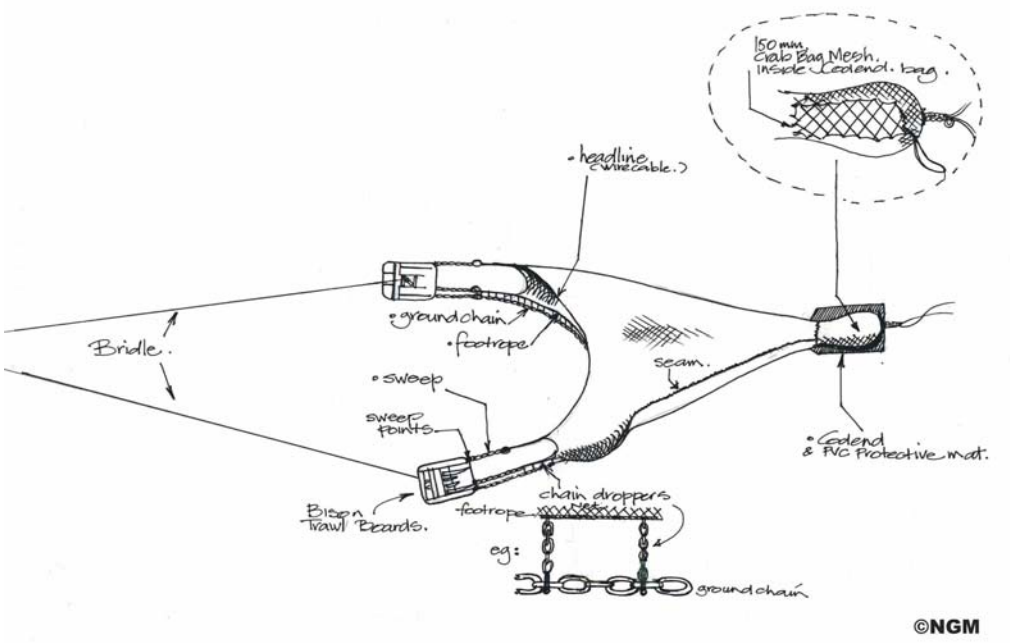

Figure 1.4 Trawl net configuration showing trawl boards, head rope, ground chain and cod end with crab bag. Figure from Carrick (2003).

Table 1.1 Production figures and species harvested in all Australian prawn fisheries. * NSW production and value is calculated from total reported commercial wild harvest (includes by-product). ** only one vessel fished in 2007.

Fishery	Year	Production t (% *King*)	Value $ (million)	Licences	Prawn species harvested
South Australia					
Spencer Gulf [1]	2007/08	2028 (100%)	32.1	39	Western king
GSV[1]	2007/08	229 (100%)	2.9	10	Western king
West Coast[1]	2007/08	60 (100%)	0.8	3	Western king
Commonwealth					
Northern[2]	2007	4310 (0.5%)	62.2	52	Banana, Tiger, Endeavour and King
Torres Strait[3]	2007	1078 (4%)	11	61	Tiger, Endeavour and King
Other States					
NSW–Ocean Trawl[4]*	2006/07	3476 (13%)	21.5	306	Eastern King, School, Royal Red, Brown Tiger
NSW–Estuary General[4]*	2006/07	3657 (1.1%)	20.8	685	Eastern King, School, Brown Tiger, Greentail
NSW–Estuary Trawl[4]*	2006/07	522 (0.4%)	3.9	216	Eastern King, School, Brown Tiger, Greentail
QLD–East Coast[5]	2006	5635 (35%)	90	498	Tiger, Banana, Red Spot King, Endeavour, Eastern King and Bay
QLD–River & Inshore[6]	2007	364 (0%)	4.8	143	Banana, Bay and Tiger
WA–Shark Bay[7]	2007	1250 (62%)	14.3	27	Western King, Brown Tiger, Coral and Endeavour
WA–Exmouth[7]	2007	790 (43%)	9.1	16	Western King, Brown Tiger, Banana and Endeavour
WA–South West[7]	2007	6 (100%)	-	14	Western King
WA–Onslow[7]**	2007	4 (<25%)	-	Up to 31	Western King, Brown Tiger, Banana and Endeavour
WA–Nickol Bay[7]	2007	44 (0.2%)	0.3	14	Western King, Brown Tiger, Banana and Endeavour
WA–Kimberley[7]	2007	271 (0.4%)	2.2	137	Banana, Tiger, Endeavour and Western King
WA–Broome[7]	2007	72 (46%)	0.5	5	Western King and Coral
Victoria[8]	2006/07	56 (82%)	0.675	60	Eastern King and School

Sources: 1. Knight & Tsolos (2009); 2. Ciccosillo (2008); 3. Wallis *et al.* (2009); 4. Scandol *et al.* (2008); 5. Anon (2007); 6. Anon (2008a); 7. Kangas *et al*. (2008); 8. Anon (2008b).

1.2.3 Recreational, indigenous and illegal catch

Significant recreational catches of *P. latisulcatus* are precluded by current fisheries regulations that require recreational prawn catches to be taken from waters >10 m in depth using hand held nets. Levels of indigenous and illegal fishing are considered negligible (Anon 2003).

1.3 Management of the Fishery

The Spencer Gulf Prawn Fishery is managed by Primary Industries and Resources South Australia (PIRSA) under the framework provided by the *Fisheries Management Act 2007*. General regulations for South Australia's prawn fisheries (commercial and recreational) are described in the *Fisheries (General) Regulations 2000*, with specific regulations located in the *Scheme of Management (Prawn Fisheries) Regulations 2006*. These three documents provide the statutory framework for management of the Spencer Gulf Prawn Fishery.

The introduction of the *Fisheries (Management Committees) Regulations 1995* provided a forum for South Australia's fishing industries to participate in the active management of their respective fishery. The introduction of the *Fisheries Management Act 2007* saw the abolishment of FMC's, and establishment of a Fisheries Council. These changes aim to provide well organised, representative fishing bodies, such as the Spencer Gulf and West Coast Prawn Fisherman's Association, greater opportunities to increase responsibility in co-management, and at the same time reduce administrative costs.

1.3.1 Management history

Management arrangements have evolved in the Spencer Gulf Prawn Fishery since its inception in the late 1960's, with key milestones presented in Table 1.2.

Table 1.2 Major management milestones for the Spencer Gulf Prawn Fishery

Date	Management milestone
1968	Licence limitation. Trawling prohibited in waters of <10 metres. Commercial recording of catch and effort introduced
1969	Prawn Resources Regulations established. Spencer Gulf divided into two zones
1971	Spencer Gulf zones removed
1974	Spatial closure north of Point Lowly implemented
1976	Licences capped at 39
1981	Spatial closure adjacent to Port Broughton implemented
1991	Scheme of Management (Prawn Fisheries) Regulations introduced
1995	The *Fisheries (Management Committees) Regulations 1995* are introduced
1998	1st Management Plan implemented
2007	Management Plan reviewed and updated

1.3.2 Current management arrangements

The Spencer Gulf Prawn Fishery is a limited entry fishery with 39 licensed operators. Trawling activities are banned during daylight hours and must be conducted in waters >10m depth. Effort is restricted both spatially and temporally throughout the fishing year by closures. Effective effort (fishing power) is restricted by gear restrictions including vessel size and power, type and number of trawl nets towed, maximum headline length and minimum mesh sizes (Table 1.3).

Table 1.3 Current management arrangements

Prawn fishery management strategy	Specification
Permitted prawn species harvested	*Penaeus (Melicertus) latisulcatus*
Permitted by-product species harvested	*Ibacus* spp., *Sepioteuthis australis*
Limited entry	Yes
Number of licences	39
Corporate ownership of licences	Yes
Licence transferability	Yes
Minimum depth trawled	10 metres
Method of capture	Demersal Otter Trawl
Trawl net configuration	Single or double
Maximum total headline length	29.26 metres
Minimum mesh size	4.5 cm
Maximum length of vessel	22 metres
Maximum engine capacity	272 kW
Catch and effort data	Daily logbook submitted monthly
Catch and disposal records	Daily CDR records
Recreational fishery	Depth >10 metres, hand nets only
Recreational licence	Not required

There are generally 6 fishing periods within each fishing year. Each fishing period lasts a maximum of 18 nights from the last to first quarters of the moon in November, December, March, April, May and June. Harvest strategies for each period are determined on the basis of data collected during fishery-independent and fishery-dependent surveys.

1.3.3 Spencer Gulf Prawn Fishery Management Plan

MacDonald (1998) developed the first Spencer Gulf and West Coast Prawn Fishery Management Plan, documenting the management history, policy framework and Performance Indicators for these two fisheries. Recently, a review of the Management Plan was undertaken and an updated Plan specific to the Spencer Gulf Prawn Fishery was documented (Dixon & Sloan 2007, hereafter referred to as 'the Plan').

The Plan provides an overarching framework for management decision making that is underpinned by four key goals and a series of objectives and strategies. The primary aim for the Spencer Gulf Prawn Fishery for the life of the Plan is to maintain ecologically sustainable stock levels. The Plan also aims to identify an appropriate balance between long-term ecological sustainability and the optimum utilisation and equitable distribution of resources between all stakeholder groups and future generations. The four goals are:

1. Maintain ecologically sustainable stock levels
2. Ensure optimum utilisation and equitable distribution
3. Minimise impacts on the ecosystem
4. Enable effective management with greater industry involvement.

The Plan is the first to contain specific guidelines for the development and assessment of harvest strategies for the fishery. Harvest strategies are the mechanisms for managing fishing effort using spatial and temporal closures. The aim of such closures is for the fleet to target areas of high catch rate of appropriately sized prawns, thereby ensuring biological sustainability and promoting economic efficiency. The Plan provides details on the data required and the decisions rules for harvest strategy determination, both of which can be audited against the Plan.

1.3.4 Performance Indicators

The extent to which the fishery is achieving the range of stated goals and objectives of the Management Plan (Dixon and Sloan 2007) is assessed using a combination of Performance Indicators (PIs). The key biological and management PIs of the Plan that are assessed in this report are presented in Table 1.4. The full suite of PIs is documented in the Management Plan.

Table 1.4 Biological and management Performance Indicators and Limit Reference Points for the Spencer Gulf Fishery (Dixon and Sloan 2007).

Performance Indicator	Limit Reference Point
Fishery independent surveys	3 surveys completed
Recruitment index (juveniles$^{0.5}$.nm^{-1})	>35
Total commercial catch (t)	>1800
Mean commercial CPUE (kg/hr)	>80
% vessel nights with mean size >280prawns/7 kg	<2%
Indices of future and current biomass (defined in the Plan)	Neither index is below lower threshold levels in 2 consecutive surveys
Committee comply with harvest strategy decision rules	Committee develops all harvest strategies based on results of surveys and in accordance with decision rules

The recruitment index is measured as the square root of the number of juvenile prawns (males <33 and females <35 mm CL) captured per nautical mile trawled, following Carrick (2003). Total commercial catch and mean commercial CPUE are calculated from commercial logbook catch and effort data for the fishing season from November to June inclusive. Data on mean prawn size (weighted by catch) are obtained from commercial logbook size grade data. Indices of future and current biomass are based on catch rates obtained during each of the three fishery independent surveys conducted annually. The limit for future biomass is a mean catch rate for the 20+ prawn grade of 10, 50 and 40 kg/hr during November, February and April surveys, respectively. The threshold limit for current biomass is a mean total catch rate of 95, 120 and 160 kg/hr during November, February and April surveys, respectively. Committee compliance with harvest strategy decision rules is assessed by comparing survey results in light of the decision rules of the Plan against the determined harvest strategy.

Limit Reference Points (LRPs) define the minimum acceptable level of performance. If the LRP is not achieved for any PI, measures to improve performance must be developed, following the management responses outlined in the Plan. These responses include detailed assessment of a series of additional performance measures (Table 1.5). Triggering additional performance measures does not evoke a management response.

Table 1.5 Summary of the additional biological and management performance measures and associated limit reference points for the Spencer Gulf Fishery (Dixon and Sloan 2007).

Performance Measure	Limit Reference Point
Recruit index November survey all shots	>12
Recruit index February survey all shots	>19
Recruit index April survey all shots	>15
Egg production (eggs*10^6/ hr trawled)	>500
% of 20+ in the catch – Nov & Dec	<12%
% of 20+ in the catch – March to June	<7%
% of 16–20 in the catch – Nov & Dec	25–35%
% of 16–20 in the catch – March to June	<30%

Additional performance measures include recruitment indices for each stock assessment survey, calculated as with the Recruitment index in Table 1.5, but for all surveyed sites throughout Spencer Gulf. Egg production is calculated following section 3.6 of this report. The percentage of 20+ and 16–20 grade prawns in the catch is calculated from commercial logbook data following Section 2.4 of this report.

1.4 The Spencer Gulf environment

1.4.1 Bathymetry and water temperature

Spencer Gulf is a shallow embayment <40 metres depth in northern areas and up to 60 metres depth in southern areas (Figure 1.5). Sediments are predominately sand and mud, and seagrass habitats are common at depths <10 metres. Due to minimal freshwater input and high summer evaporation rates, it is an inverse estuary, with salinity increasing towards the head of the gulf (Nunes & Lennon 1986).

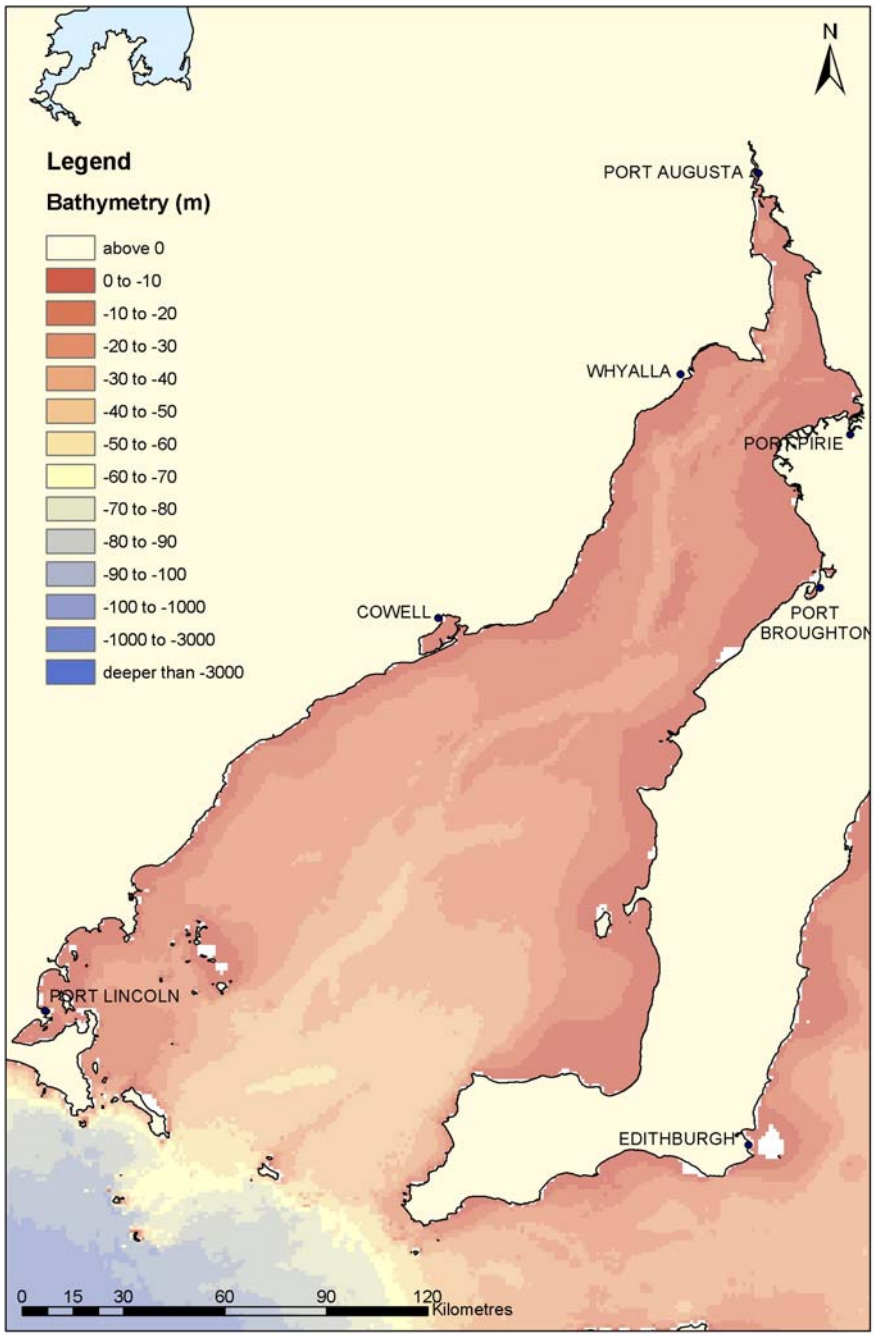

Figure 1.5 The bathymetry of Spencer Gulf

Sea Surface Temperatures (SSTs) in South Australia are lower and more variable than in other northern fisheries that target *P. latisulcatus* (eg. Broome and Shark Bay, Figure 1.6). Figure 1.7 illustrates the warmer SSTs in the north of both gulfs in South Australia, the cooler surface waters in the south of Spencer Gulf, and the considerably lower temperatures in the surrounding open ocean.

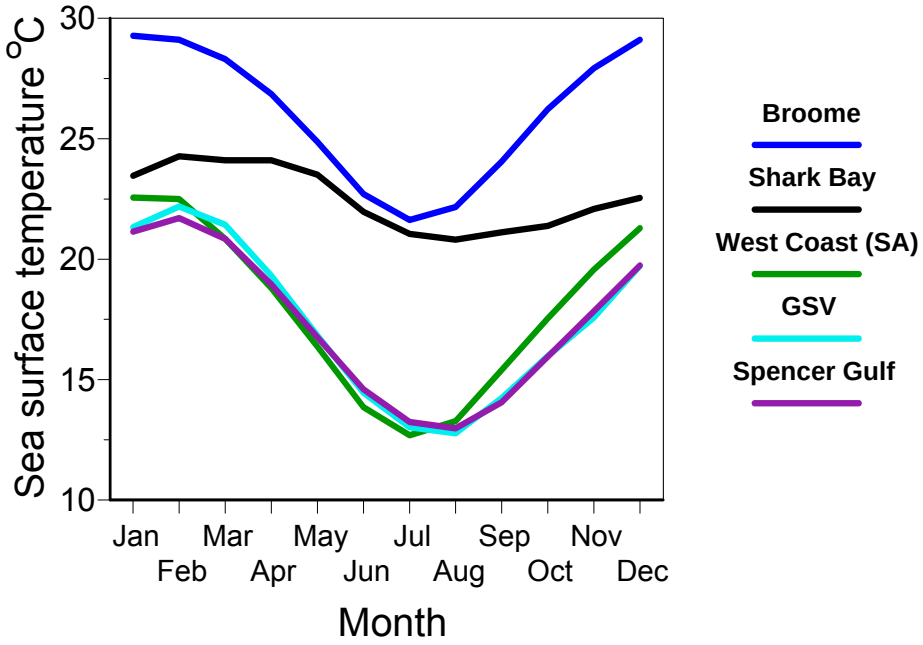

Figure 1.6 Comparison of mean monthly sea surface temperature (SST, ºC) for the Australian prawn fisheries that target *P. latisulcatus*. Figure reproduced from Carrick 2003.

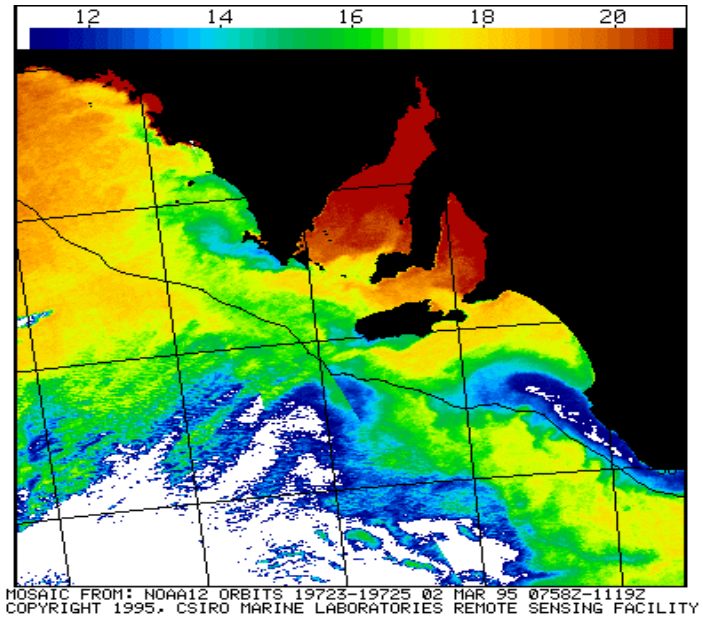

Figure 1.7 Sea-surface temperatures over the continental shelf of South Australia during late summer/early autumn, 1995. A colour-coded key in degree Celsius is situated at the top of the map. Figure from Linnane *et al* (2005), sourced from CSIRO.

1.4.2 Juvenile habitats

In South Australia, juvenile *P. latisulcatus* occur predominately on intertidal sand- and mud-flats, generally located between shallow subtidal / intertidal seagrass beds and mangroves higher on the shoreline (Kangas and Jackson 1998; Tanner and Deakin 2001). In Spencer Gulf, juvenile abundance was significantly greater in the mid intertidal zone compared to lower and upper zones (Roberts *et al.* 2005) while in GSV abundance was similar within intertidal zones (Kangas and Jackson 1998).

Following Bryars (2003), the Spencer Gulf coastline was divided into a number of Fisheries Habitat Areas (FHA 20, 23, 25–37 - Thorny Passage to Formby Bay). Each FHA has a comprehensive description, including colour-coded maps of up to 12 habitat types. Of these, the habitat types 'tidal flats' and 'mangrove forests' were determined as appropriate juvenile prawn habitat. 'Tidal flats' included mud flats, sand flats and intertidal unvegetated soft bottoms. It was noted that tidal flats were often associated with adjacent mangrove forests. However, 'tidal flat' habitat also included intertidal seagrass meadows and intertidal macroalgal environments, which are unsuitable habitat for juvenile prawn settlement (and therefore these are a potential source of error in calculations). 'Mangrove forest' were characterised by a soft sediment substrate in the upper intertidal zone dominated by grey mangrove (*Avicennia marina*). Mangrove forest always overlapped with tidal flat habitat (see Figure 1.8) and was thus labelled mangrove forest (+ tidal flat) for this report. The proportion of the coastline for each FHA containing tidal flat only and mangrove forest (+ tidal flat) was estimated to the nearest 10% from the maps (Bryars 2003). This enabled estimation of the percent length of coast for each habitat type. The total length of coastline was calculated from satellite imagery (http://earth.google.com). Table 1.6 provides summary estimates for each South Australian Prawn Fishery (see also Dixon et al 2006a, 2006b).

Table 1.6 The number of Fishery Habitat Area's (Bryars 2003) and the estimated proportion and distance of coastline of tidal flat (TF) only and mangrove forest (+ TF) for each of South Australia's three prawn fisheries.

Fishery	# FHA's	Coastline (km)	Tidal flat (TF) only		Mangrove (+ TF)	
			%	km	%	km
Spencer Gulf	15	992	51	508	25	245
GSV	11	551	41	225	14	79
West Coast	16	1310	24	310	3	45

The Spencer Gulf coastline was approximated at 992 km, with 753 km (76%) of tidal flat only and 245 km (25%) of mangrove forest (+ tidal flat) (Table 1.6). Areas with the greatest juvenile prawn nursery habitat were the Far Northern Spencer Gulf (~201 km of tidal flat only and 67 km of mangrove forests (+ tidal flat)), Germein Bay (~95 km of tidal flat only and 57 km of mangrove forests (+ tidal flat)) and False Bay (~63 km of tidal flat only and 49 km of mangrove forests (+ tidal flat)) (Figure 1.8). These areas of identified nursery habitat correspond well with sites in Spencer Gulf previously found to contain the greatest abundances of juvenile prawns. Juvenile abundance was significantly greater in the north, with False Bay found to have the greatest abundance (Roberts *et al.* 2005).

The extent of available juvenile habitat appears to correlate well with production from each fishery (Table 1.1), particularly with respect to mangrove habitat (Table 1.6). Of note, the importance of mangrove habitat for prawn recruitment has long been debated (see Lee 2004).

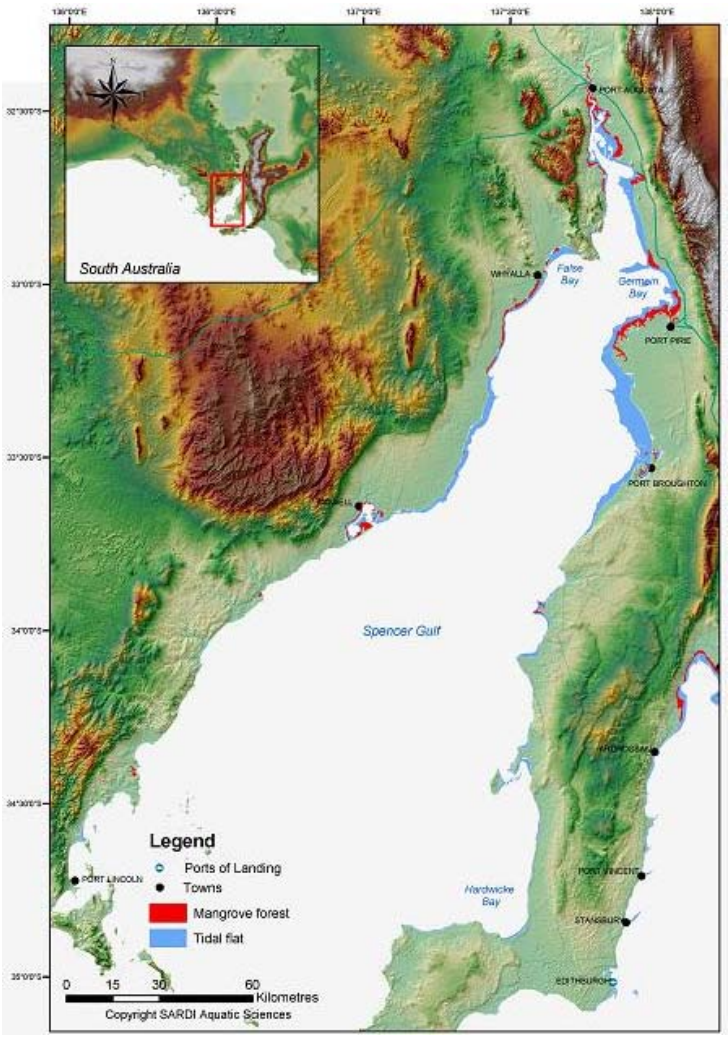

Figure 1.8 Important juvenile nursery habitat, mangrove forest and tidal flats, around coastal Spencer Gulf. Reproduced from Bryars (2003).

1.5 Biology of the Western King Prawn

1.5.1 Distribution and taxonomy

P. latisulcatus, is distributed throughout the Indo-west Pacific (Grey *et al*. 1983). Its distribution in South Australia is unique, as it is at its lowest temperature range, restricted to waters of Spencer Gulf and GSV and along the west coast including the commercially fished areas of Ceduna, Venus Bay and Coffin Bay. King (1977), Sluczanowski (1980) and Carrick (1982, 1996) provide detailed accounts of the distribution of western king prawn in Spencer Gulf.

The western king prawn is a benthic species that prefers sandy areas to seagrass or vegetated habitats (Tanner & Deakin 2001). Both juvenile and adult prawns show a strong diel behavioural pattern of daytime burial and nocturnal activity (Rasheed & Bull 1992; Primavera & Lebata 2000). Strong lunar and seasonal differences in activity are also exhibited, where prawn activity (and catchability) is greater during the dark phase of the lunar cycle and during warmer months.

The distribution and abundance of *P. latisulcatus* within gulfs and estuaries is affected by salinity and the presence of sandy substrate (Potter *et al*. 1991). Higher abundances are associated with salinities above 30 ‰ (Potter *et al*. 1991). In physiological studies on *P. latisulcatus*, optimal salinity ranged from 22 to 34 ‰, and 100% mortality occurred at salinities below 10 ‰ (Sang & Fotedar 2004). Juvenile *P. latisulcatus* are more efficient osmoregulators than adults, tolerating greater variation in salinity. Important nursery areas in Western Australia and South Australia are characterised as being hyper-saline (35–55 ‰) (Carrick 1982; Penn *et al*. 1988).

1.5.2 Reproductive biology

In the Spencer Gulf Prawn Fishery adult prawns aggregate, mature, mate and spawn in deep water (>10 metres) between October and April, with the main spawning period between November and February (Figure 1.9; Carrick, 1996). During mating the male transfers a sperm capsule (spermatophore) to the female reproductive organ (thelycum). The success of this insemination depends on the female prawn having recently moulted. Ovary development followed by spawning of fertile eggs occurs during a single intermoult period (Penn 1980), where fertilisation presumably occurs immediately prior to, or on release of, the eggs by the female.

During the peak spawning period, the sex ratio of *P. latisulcatus* caught in West Australia (WA) was shown to significantly change to that of a female-biased catch. This was attributed to higher catchability of females due to increased foraging-feeding activity necessitated by food requirements during ovary development (Penn 1976; Penn 1980). Similarly during November and December, female-biased populations of *P. latisulcatus* were documented in GSV (Svane 2003; Svane & Roberts 2005).

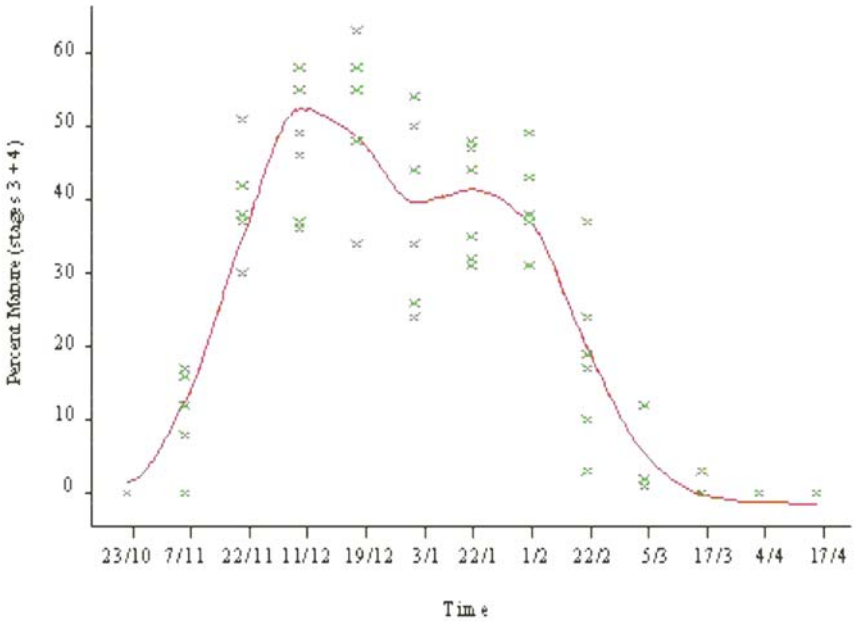

Figure 1.9 Female prawn reproductive maturation trends based on the percentage of ripe (Stage 3 & 4) prawns. Figure from Carrick (2003).

Spawning and fecundity are affected by water temperature, with the minimum for spawning being 17°C for *P. latisulcatus* in WA (Penn 1980). The peak reproductive period in Queensland (QLD) populations of *P. latisulcatus* was between June and July when water temperature dropped below 25°C (Courtney & Dredge 1988). Thus, the ideal temperature range for spawning in *P. latisulcatus* appears to be 17–25°C.

The proportion of reproductively mature female *P. latisulcatus* increases with size. In Spencer Gulf, Carrick (2003) defined the relationship between maturity and size with the logistic equation:

$$\text{Proportion mature} \quad = 8.3\times10^{-6} + \left[\frac{1}{1+e^{-(0.277(CL-36.45))}}\right]$$

While females can mature at a small size, differences between tropical and temperate populations seem to be apparent. The smallest ripe female recorded in WA populations was 29 mm carapace length (CL) (Penn 1980). In Spencer Gulf, the smallest ripe female was 24 mm CL (February 2005 fishery-independent survey data,

SARDI). Insemination rate is indicative of fertilization success and also increases with size. Courtney and Dredge (1988) showed that ~50% of females were inseminated at 34 mm CL, while ~95% were inseminated at 42 mm CL in QLD populations of *P. latisulcatus*. There are no data on the fecundity of *P. latisulcatus* in Spencer Gulf. Table 1.7 and Figure 1.10 presents the results of fecundity studies for *P. latisulcatus* in GSV (Kangas unpublished, cited in Carrick 2003), Shark Bay (Penn 1980) and the North East Coast of Queensland (Courtney and Dredge 1988). In all three fisheries, fecundity increases exponentially with carapace length, however this is more pronounced in the cooler waters of GSV (see Figure 1.10). Thus, larger prawns make a greater contribution to total egg production due to both greater insemination rates, as well as greater fecundity (Penn 1980; Courtney & Dredge 1988; Carrick 1996).

Table 1.7 Fecundity relationships for P. latisulcatus in Gulf St. Vincent, Western Australia and Queensland. Fecundity = a × carapace length^ b

Location	*a*	*b*
Gulf St. Vincent, SA	7.94×10^{-6}	3.462
Shark Bay, WA	6.95×10^{-5}	2.916
Nth East Coast, QLD	4.8×10^{-6}	3.52

For the Eastern King prawn (*P. plebejus*) females greater than 50 mm CL contribute little to egg production, with the bulk of the eggs produced by prawns in the middle to upper size ranges of 35–48 mm CL (Courtney *et al.* 1995). Such ovarian senescence in old female *P. latisulcatus* has not been documented.

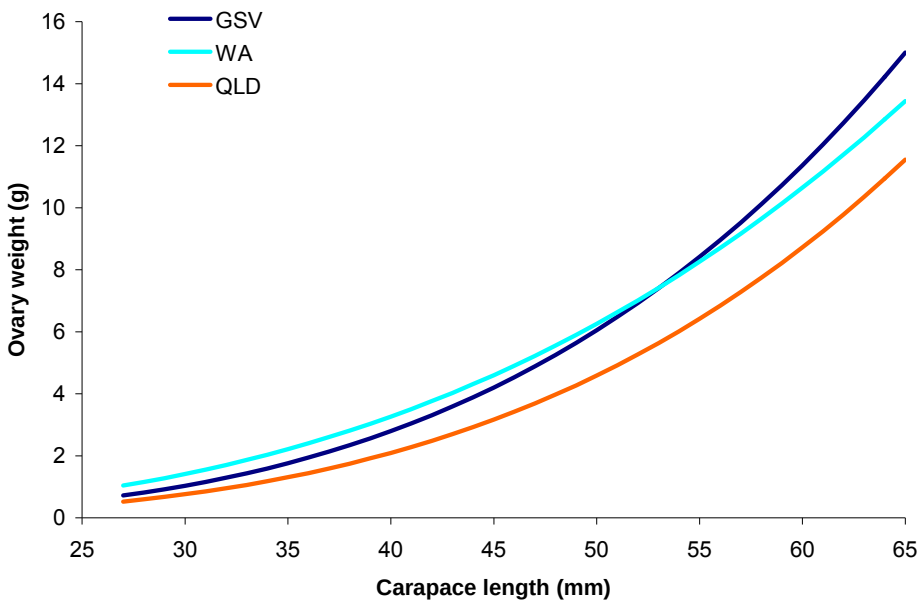

Figure 1.10 The relationship between fecundity (ovary weight) and carapace length (CL) for *P. latisulcatus* in GSV, Western Australia and Queensland.

Spawning frequency for *P. latisulcatus* appears to be related to moulting frequency as no recently moulted female were found with well-developed (Stage 3 or 4) ovaries (Penn 1980; Courtney & Dredge 1988); females generally lose spermatophores with the exuvae at moult (Penn 1980) and; the average interval for both moulting and spawning was the same in tagging experiments (Penn 1980). The average moult interval and hence spawning interval, for mature untagged females in WA populations during the spawning season was estimated at 30–40 days (Penn 1980).

Multiple spawning events can occur in *P. latisulcatus* as spawning frequency is related to moulting frequency. There are three lines of evidence supporting the concept of multiple spawning: (1) spent ovaries are difficult to identify since immediate ovary development meant they were often classified as Stage 2 (Penn 1980; Courtney & Dredge 1988); (2) in an experiment where ripe females were tagged and released, 15 re-captured individuals were found to have spawned and moulted, and had ovaries at an early stage of development during the same season (Penn 1980) and; (3) artificial spawning of *P. orientalis* in aquaria, using eyestalk ablation, provided direct evidence for the multiple spawning capacity of Penaeids (Arnstein & Beard 1975). In addition to multiple spawning within a season, females are likely to spawn for multiple seasons. This was determined by the large proportion of females in different size cohorts being reproductively active during the spawning season (Penn 1980).

Prawn reproduction can also be affected by parasite load and disease status. Courtney *et. al.* (1995) showed that parasitisation by bopyrid isopods affected the reproductive output of *P. plebejus*. Bopyrid isopods have been observed to parasitise individuals of the South Australian population of *P. latisulcatus* (Dr. Shane Roberts, personal observation). In *F. indicus*, it was shown that viral infections affected moulting and reproduction in Penaeid shrimp (Vijayan *et. al.* 2003). In addition, environmental pollution from coastal industries can increase the susceptibility of prawns to disease and reduce reproductive output (Nash *et. al.* 1988). These issues are poorly understood for *P. latisulcatus* in South Australia.

1.5.3 Larval and juvenile phase

P. latisulcatus has an offshore adult life and an inshore juvenile phase (Figure 1.11). Prawn larvae undergo metamorphosis through four main stages: nauplii, zoea, mysis and post-larvae (Figure 1.12). The length of the larval stage depends on water temperature, with faster development in warmer water (Hudinaga 1942). SARDI

unpublished data from FRDC project 2008/011 “Prawn and crab harvest optimisation: a biophysical management tool” demonstrate that the larval period varies from 15 days at 25° C to 34 days at 17° C (Table 1.8). This was determined by spawning wild caught female prawns from Spencer Gulf and raising larvae at different temperature regimes under laboratory conditions. It had previously been suggested that the larval period of *P. latisulcatus* in Spencer Gulf could exceed 40 days, where water temperatures over the main spawning and larval period range from 19–25° C (after Shokita 1984, cited in Carrick 2003).

Table 1.8 Prawn, P. latisulcatus, larval duration reared at four different water temperatures (SARDI unpublished data).

Temperature	17°C	20°C	22.5°C	25°C
Larval duration	34 days	22 days	17 days	15 days

Prawn larvae are generally dispersed by wind-driven and tidal currents (Carrick 2003). Larval sampling in Spencer Gulf has shown that larvae are broadly distributed (Figure 1.13), but highest densities were found north of Cowell (Carrick 1996). Latitude, water temperature and salinity all influenced the distribution and abundance of larvae (Carrick 2003). Larval densities varied significantly among years, probably due to differences in environmental conditions and spawning stock status.

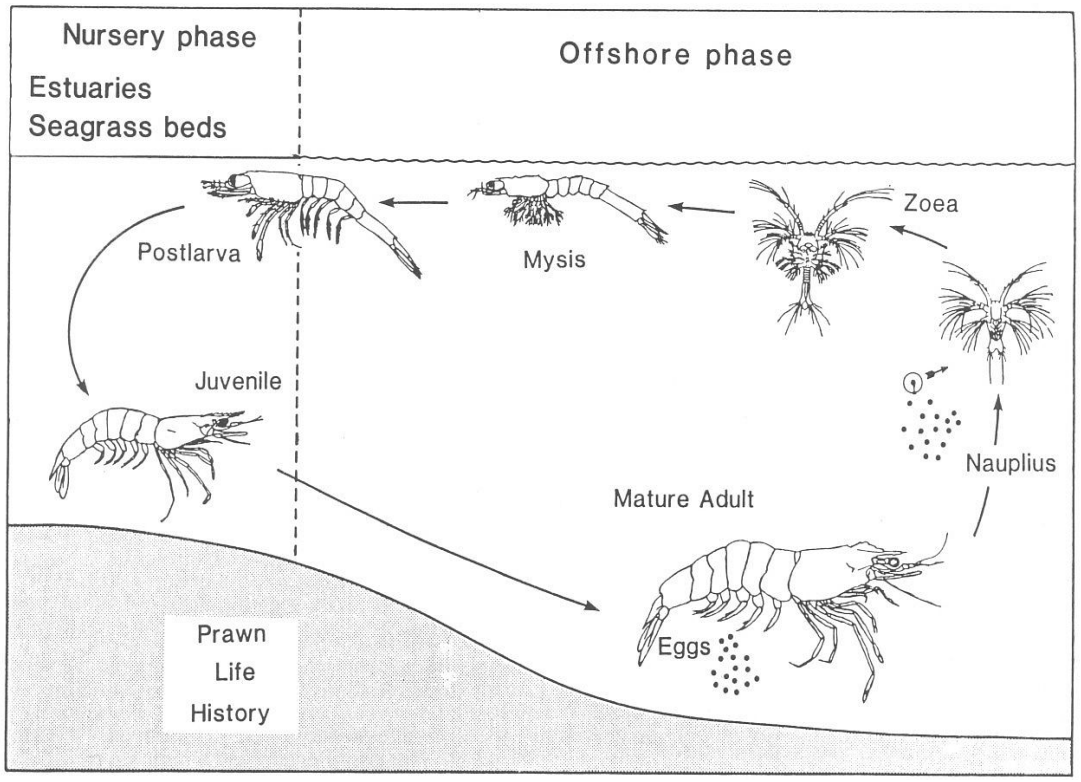

Figure 1.11 Life cycle of *P. latisulcatus* (Carrick 2003).

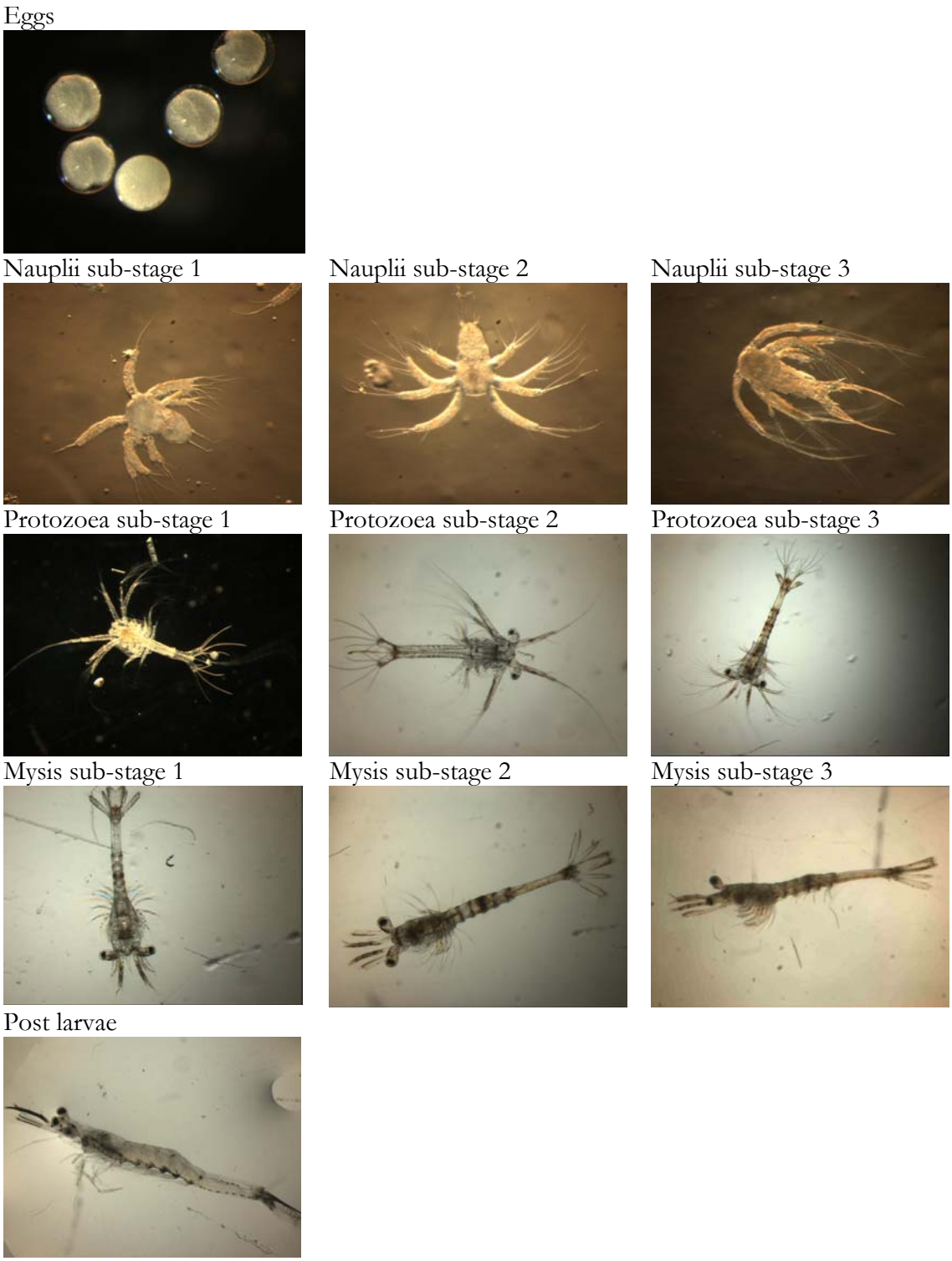

Figure 1.12 Western king prawn, *P. latisulcatus*, larval stages (egg to post larvae) (SARDI unpublished data).

Post-larvae settle in inshore nursery areas when 2-3 mm CL and can remain there for up to 10 months, depending on the time of settlement (Carrick *et al*. 1996). The post-larvae produced from early spawning events settle in nursery areas during December or January where they grow rapidly before emigrating to deeper water in May or June. Alternatively, post-larvae produced from spawning after January settle

in nurseries from March and then grow slowly. They "over-winter" in the nursery areas before recruiting to the trawl grounds in February of the following year (Carrick 2003). The effect of over-wintering on adult growth and survival are unquantified.

Over-wintering mortalities in nurseries ranged from 0.2–16.5% (mean = 7.9%) per week, with evidence of density dependent mortality (Kangas 1999). The mean natural mortality in Spencer Gulf nurseries during winter was estimated at 5% per week (Carrick 2003). These estimates of natural mortality for juvenile *P. latisulcatus* are considerably lower than for other prawn species (Carrick 1996).

In Spencer Gulf, spatial and temporal differences in juvenile prawn abundances were evident (Roberts *et al.* 2005). Even so, inter-annual patterns were generally consistent across sites. Abundances were greatest between February and May, with key nursery sites identified as False Bay, Shoalwater Pt, Plank Pt, Mt Young, 5th Creek and Port Pirie, all in the north of the gulf (Carrick 1996; Roberts *et al.* 2005).

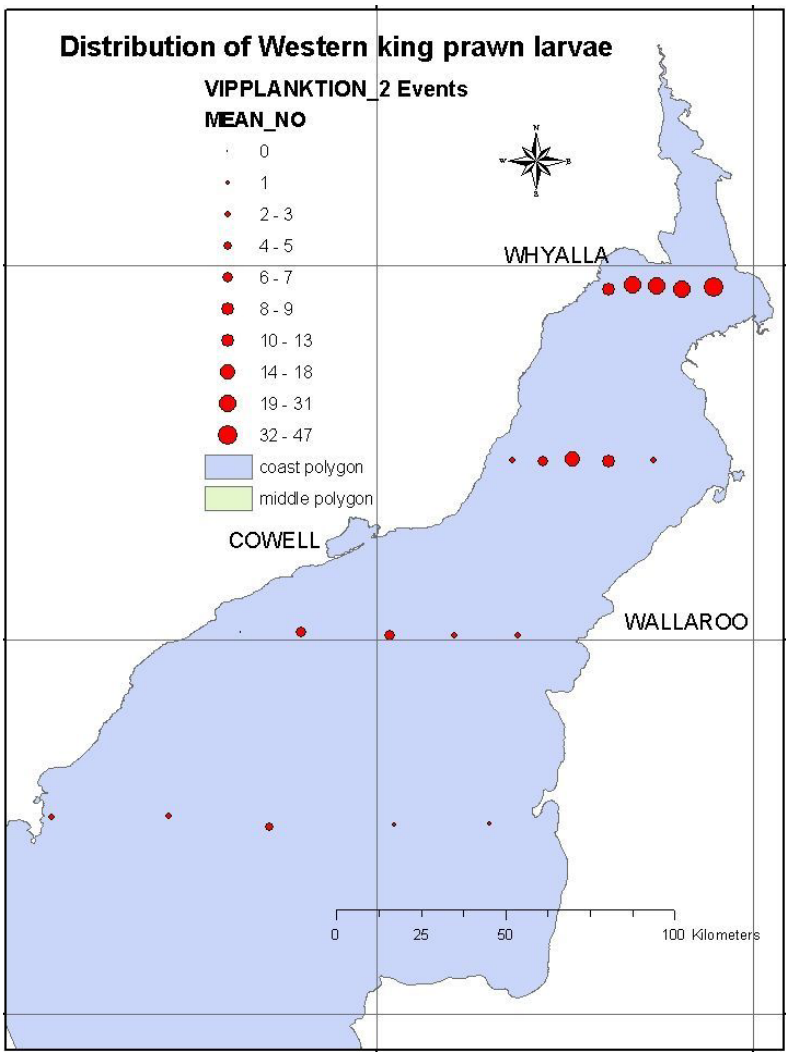

Figure 1.13 Mean larval density (√no./100 m^3) in Spencer Gulf during 1993 and 1994. Figure from Carrick (2003).

1.5.4 Stock structure

Analyses using r-DNA have shown significant genetic differences in haplotype distribution of *P. latisulcatus* between South Australia and Western Australia (South Australian Museum/SARDI cited in Carrick 2003). However, an analysis of the genetic structure of *P. latisulcatus* within South Australia using electrophoresis suggested a homogenous stock (Richardson, 1982 cited in Carrick 2003).

1.5.5 Growth

Prawns undergo a series of moults to increase their size incrementally. The shedding of hard body parts during moulting means that the age of individuals cannot be reliably determined as is possible for teleost and cartilaginous fishes, through the examination of otoliths and vertebrae. The inability to directly age prawns has increased the reliance on tag-recapture and cohort analysis for the determination of growth rate.

Uncertainties associated with each method of growth estimation include:

- growth suppression by the tagging process (Penn 1975; Menz & Blake 1980),
- short time at liberty for tag-recaptures influenced by seasonal growth,
- bias in size at release and time at liberty during tag-recapture experiments,
- inability to distinguish cohorts, effect of catchability, and net migration on cohort analysis,
- measurement error (both methods).

Between 1984 and 1991 >150,000 prawns were individually tagged with streamer tags in Spencer Gulf. The carapace length of each prawn was measured and the tag and location details recorded prior to release. Some 9,000 tagged prawns were recaptured between 1985 and 1992. Sex-specific growth parameters, derived using a modified von Bertalanffy growth model (Carrick 2003), showed that male prawns grew slower and attained a smaller maximum size than females (Table 1.9). Maximum growth rates occurred during late summer and autumn, and growth was negligible from July to December (Carrick 2003). Growth was strongly seasonal because winter water temperatures in Spencer Gulf are at the lower limits of their preferred temperature range (Wu 1990). The von Bertalanffy limited growth model is $dL/dt = k(L_\infty - L)$, where k is a function of temperature. The formula for growth is usually re-written as $L(t) = L_\infty (1-e^{r}(t-t_0))$, where r is the specific growth rate, t is time,

and k=r. The constant r is species (and gender) dependent and determines the rate of growth.

Growth estimates from Spencer Gulf are compared to those estimated from GSV and the West Coast Fishery in Table 1.9 and Figure 1.14. Kangas & Jackson (1997) estimated growth rates from 464 tag-recaptures in GSV while in the West Coast Prawn Fishery growth was estimated from 510 tag-recaptures as well as from length-frequency cohort analyses (Wallner 1985).

Seasonal growth and differences between genders were evident in each fishery. Prawns in Spencer Gulf attained a similar size to GSV prawns, although a slower growth rate was evident for male prawns in GSV (Figure 1.14). Also, prawns in both gulfs attain a greater size and growth rate than their West Coast counterparts. Whilst this may be an artefact of the uncertainty associated with West Coast prawn growth estimates (see Dixon & Roberts 2006), growth may be slower due to the cooler summer water temperatures of the West Coast's oceanic environment.

Table 1.9 Sex-specific growth parameters for P. latisulcatus estimated from tag-recapture and cohort analysis in the West Coast (Wallner 1985) and from tag-recapture in Spencer Gulf (Carrick 2003) and Gulf St Vincent (Kangas & Jackson 1997).

Fishery	Method	Sex	Growth parameters	
			K (yr^{-1})	L_∞ (mm)
West Coast	Cohort	Male	0.73	44.1
		Female	0.88	53.9
West Coast	Tag	Male	0.83	39.4
		Female	0.36	60.4
Spencer Gulf	Tag	Male	0.86	46.1
		Female	0.61	64.0
GSV	Tag	Male	0.62	47.2
		Female	0.54	65.3

1.5.6 Length weight relationship

The relationship between prawn carapace length (CL, mm) and weight (g) was determined from a sample of over 2000 prawns from Spencer Gulf (Carrick 2003). The power relationship described by the equation "Weight = a × carapace length^ b" varies between males (a = 0.00124, b = 2.76) and females (a = 0.00175, b = 2.66). Kangas (1999) determined the length weight relationship for juvenile prawns in GSV (a = 0.00066, b = 2.91, N = 325). The size range of individuals was 2.4–20.4 mm CL, where sexes could not be distinguished at such small sizes.

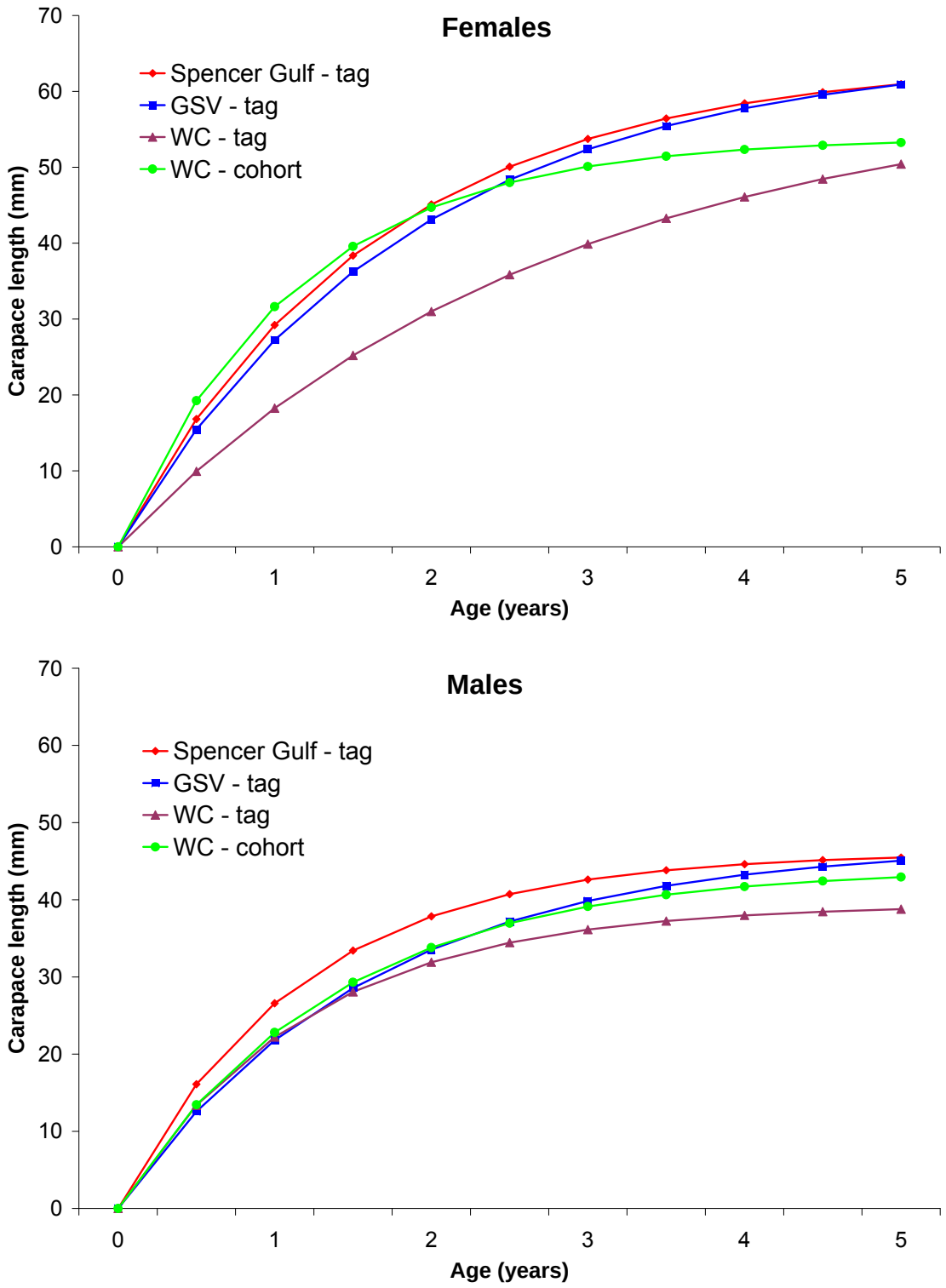

Figure 1.14 Sex-specific growth curves for *P. latisulcatus* estimated from tag-recapture and cohort analysis in the West Coast (Wallner 1985) and from tag-recapture in Spencer Gulf (Carrick 2003) and Gulf St Vincent (Kangas & Jackson 1997).

1.5.7 Movement determined from tagging studies

Tag-recapture data (see 1.5.5) were analysed to determine the movement patterns of prawns in Spencer Gulf (Carrick 2003). The generalised movement patterns were: (1) a net movement from north to south in northern Spencer Gulf, (2) a general east to north-east movement from northern Cowell and the top of the Gutter, (3) south-east movement from southern Cowell and the Gutter towards Corny Pt., and (4) negligible movement from Wallaroo (Figure 1.15, Carrick 2003).

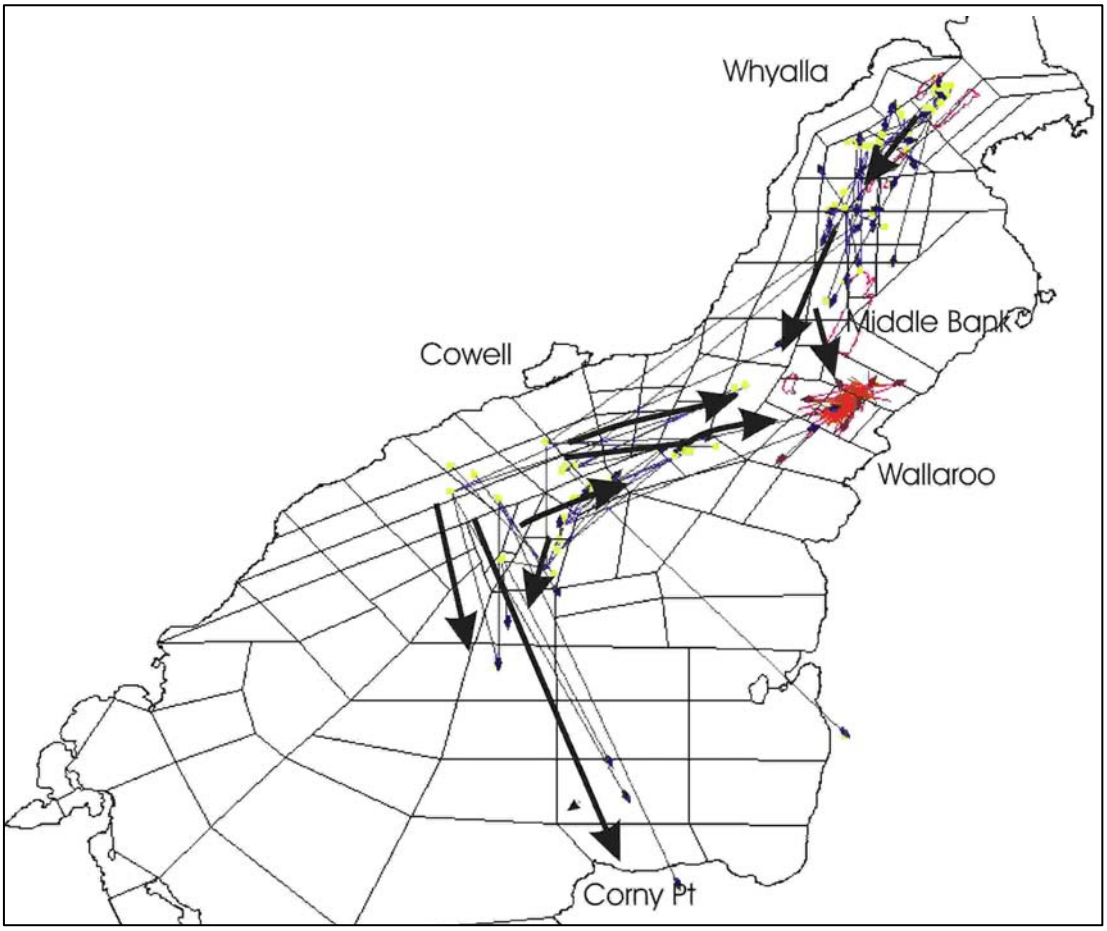

Figure 1.15 Generalised movement patterns of tagged *P. latisulcatus* in Spencer Gulf. Figure from Carrick (2003).

While the use of external tags (as used for prawns in South Australia) has been associated with higher prawn mortality rates (Benzie *et al*. 1995) and suppressed growth rates (Penn 1975; Menz & Blake 1980), particularly for small individuals, it is unclear how these tags affect prawn movement. Potential effects on growth and mortality can be reduced with the use of antibiotic/antifungal ointment on the tag to reduce post-tag mortality from infection (Courtney *et al.* 2001) and selective tag colour to reduce prawn predation (Benzie *et al*. 1995).

1.5.8 Natural mortality

Daily instantaneous rate of natural mortality for *P. latisulcatus* in Spencer Gulf ranges between 0.003 and 0.005.day^{-1} (King 1977). This value was similar to that estimated for *P. latisulcatus* in GSV (0.003.day^{-1}; Kangas & Jackson 1997, Xiao and McShane 2000) the West Coast Prawn Fishery (0.001 to 0.014.day^{-1}; Wallner 1985) and Western Australia (0.002 to 0.005.day^{-1}; Penn 1976).

1.5.9 Prawn health

The health of South Australian populations of *P. latisulcatus* and the potential effects of coastal pollutants, parasites and disease on growth, survival and reproduction is poorly understood. In Spencer Gulf, juvenile habitats appear to have been influenced by oil spills (Roberts *et al.* 2005) and industrial effluent Carrick (2003). In GSV, anecdotal evidence suggests that juvenile prawn abundances at Barker Inlet have significantly declined since the early 1970's, probably due to human factors including increased nutrient loading (Kangas 1999). The disturbance of acid sulfate soils as a result of coastal development were recently identified as a major cause of habitat degradation in GSV, including mangrove dieback at St Kilda and contaminated tidal flats in Barker Inlet (SA Coast Protection Board, 2003). Common marine pollutants in South Australia include heavy metals, high nutrient loads from coastal industries and petroleum (hydrocarbon) discharges (Edyvane 1999). Although these sources of pollution are common, and potentially directly affect juvenile prawn nurseries, little research has been conducted to address these issues.

Parasite load and disease status are limiting factors in marine animal populations, although generally overlooked in fisheries management (Harvell *et. al.* 2004). These factors affect populations through mortality as well as suppression of growth and reproduction, and have yet to be determined for SA prawn populations.

1.6 Stock Assessment

The first stock assessment for the Spencer Gulf Prawn Fishery was completed in 1998 (Carrick and McShane 1998). Subsequent stock assessments in 2000 and 2001 were the first to consider the biological PI's of the fishery (Carrick and Williams 2000, 2001). The 2003 stock assessment report was the first version of a "living" document (Carrick 2003) that constituted a considerable advance on previous stock assessments. This included a description of the life history of prawns and

management of the fishery, detailed spatial and temporal analyses of fishery-dependent and fishery-independent data, assessment of the fishery against the performance indicators defined in the Management Plan, and a review of the biology of *P. latisulcatus*. Subsequent stock assessments have again built considerably on previous reports, to now include a comprehensive assessment of all available fishery-dependent and fishery-independent data, comparisons of survey results and fishing activities at the scale of fishing block and fishing period, development of an egg production model, and information on the extent of suitable juvenile habitats.

1.7 Current Research and Monitoring Program

The current research program conducted by SARDI Aquatic Sciences in support of the Spencer Gulf Prawn Fishery comprises five components. These are: (i) administer a daily logbook program; (ii) collate catch and effort information; (iii) conduct independent stock assessment surveys prior to, during and toward the end of the fishing year, to inform harvest strategies and assess the fishery against the PI's; (iv) manage and analyse by-catch, juvenile sampling and tagging data; and (v) produce an annual report that assesses the status of the Spencer Gulf Prawn Fishery, including assessment of the fishery against the PIs defined in the Management Plan.

1.7.1 Catch and effort research logbook

Licence holders are required to complete a daily and monthly logbook after the completion of fishing in each month. The logbook has undergone several modifications throughout time to improve the information available for assessment. During 1986 the catch and effort reporting blocks were modified to better reflect the fishing grounds and distribution of effort. More recent changes to the logbook include incorporation of the location (GPS position) of at least 3 trawl shots per night, size-grade data of the prawn catch, and reporting of retained by-product.

1.7.2 Stock assessment surveys

The first stock assessment surveys were done in Spencer Gulf in February 1982. Surveys are conducted using industry vessels with independent observers, to assess stock status and to provide data for the development of harvest strategies following the decision rules in the Management Plan (Dixon and Sloan 2007).

1.8 Discussion

Generally, aspects of the biology of *P. latisulcatus*, the environment in which they are distributed and the management of the commercial fisheries that harvest them within South Australia are well documented. However, some key elements of the Spencer Gulf Prawn Fishery are poorly understood, particularly regarding spawning, recruitment success and prawn health.

Currently, there are no data available on the frequency of individual spawning events during the spawning season. Similarly, no data are available on fertilization success of *P. latisulcatus* in temperate South Australian waters. Further, an improved understanding of larval behaviour is needed. The current FRDC project 2008/011 "Prawn and crab harvest optimisation: a biophysical management tool" aims to address many of these issues. The laboratory component of examining the effects of water temperature on the duration and survival of prawn larvae has already been completed and is currently being analysed. The ultimate objective of this project is to develop a model that combines hydrodynamic processes with data on reproduction and larval dispersal to track egg production through to post-larval settlement. This model will 1) provide an improved understanding of the spawner–recruit relationship, 2) enable the determination of environmental conditions that result in favourable recruitment and 3) provide advice on optimal harvest strategies during the spawning season to maximise pre-Christmas catch and minimise the effect on future recruitment to the fishery.

The health status of *P. latisulcatus* in South Australia is also poorly understood. Awareness of the need for understanding the effects of coastal pollutants, parasites and disease on growth, survival and reproduction of prawns in Spencer Gulf has recently increased, due largely to issues regarding the potential risks of disease introduction associated with the use of imported prawns for bait and the proposed development of a desalination plant in northern Spencer Gulf.

2. FISHERY STATISTICS

2.1 Introduction

This section of the report presents summaries and analyses of the catch and effort data for the Spencer Gulf Prawn Fishery. Data were obtained from two sources: annual data from 1968 to 1973 and monthly data from January 1973 to June 1988 were obtained from SAFIC annual reports (1973 to 1988); data from 1988/89 to 2007/08 were obtained from daily logbooks. Daily logbooks provide data for each trawl shot including start/finish times, estimated prawn catch, fishing block, and depth. Average trawl speed and prawn catch by size-grade are provided for each night. Logbook data are available from 1980/81 to 1988/89, however uncertainty in their validity prevents inclusion in this report.

A fishing year is defined as the period from November to October. Fishing is mostly conducted between November and June, during six periods of varying length between the last and first quarter of the moon (over the new moon phase, maximum length 18 days). Estimated prawn catch for each shot was adjusted using validated post-harvest catches reported in monthly logbooks. Results are discussed in terms of the regions defined in Figure 1.2.

2.2 Catch and Effort

2.2.1 Inter-annual trends

Prawns were first harvested commercially from Spencer Gulf in 1968 (Figure 2.1). Catch increased to ~1,000 t over the next four years and to >2,000 t by 1973/74. Thereafter, catch ranged between 1,048 t (1986/87) and 2,522 t (2000/01). During 2002/03, a relatively low catch of 1,479 t was harvested. Since, catches have averaged 1,960 t, which is 51 t greater than the average catch during the previous 30 years (1973/74 to 2002/03: 1,909 t). Catch during 2007/08 was 2,028 t.

Commercial effort increased rapidly from 6,795 hr in 1968 to 45,786 hr during 1978/79 (Figure 2.1), but has declined steadily and significantly in the years since (Linear Regression (LR): $r^2 = 0.92$, df = 28, $P < 0.01$). Effort during 2007/08 was 18,438 hrs, which was 60% lower than the peak in 1978/79 and was the second lowest effort recorded in the post-expansion period of the fishery (since 1973/74).

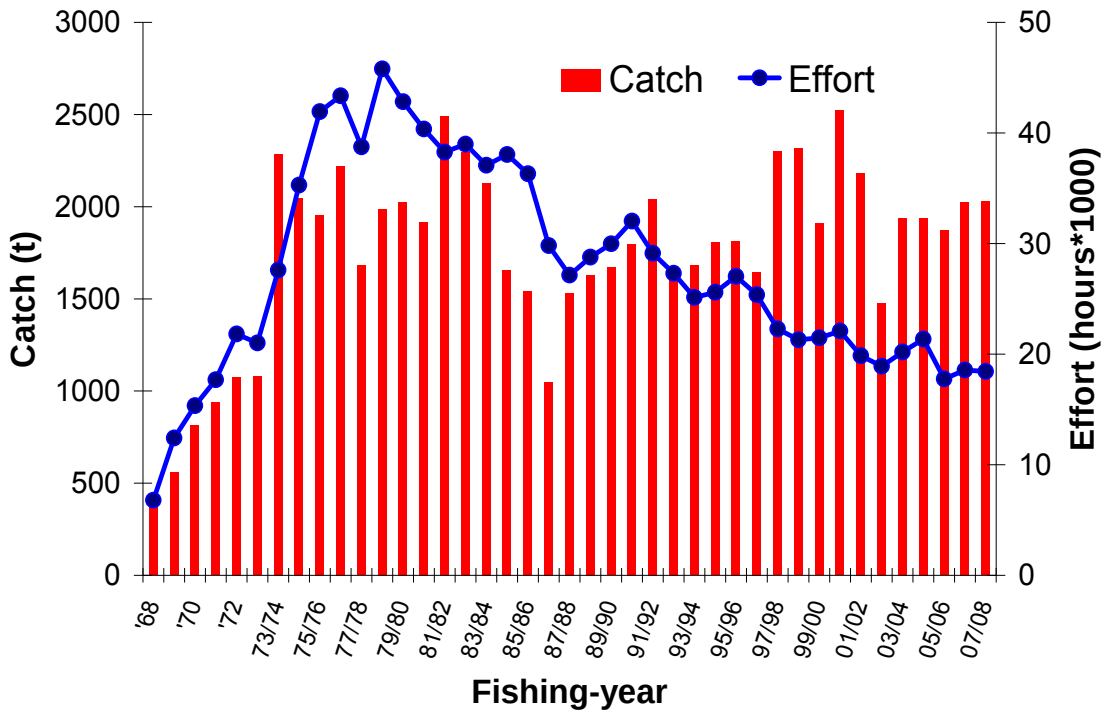

Figure 2.1 Total catch (t) and effort (hrs) for Spencer Gulf from 1968 to 2007/08. Data for 1968–1972 are reported as calendar year. Data for 1972/73 are from January to October 1973. From 1973/74 data are reported in fishing years.

2.2.2 Regional trends

The spatial distribution of catches from Spencer Gulf has changed since 1988/89 (Figure 2.2). The annual catch from the Northern region peaked at 933 t in 1991/92, but has not exceeded 250 t over the last 8 fishing years. Peak catches in the Northern region coincided with the lowest annual catch from the Wallaroo region (206 t). During the past ten fishing years, the Wallaroo, Middlebank/ Shoalwater and Main Gutter regions have produced consistent annual catches, averaging 920, 485 and 169 t, respectively. Other regions have produced variable annual catches. During 2007/08, most of the catch was harvested from the Wallaroo (827 t), Middlebank/ Shoalwater (576 t), Northern (183 t), and Main Gutter (161 t) regions, with smaller catches obtained from the Corny Point (97 t), South Gutter (86 t), Wardang (67 t), Cowell (16 t), Thistle Island (9 t), and West Gutter (4 t) regions. During 2007/08, the catch from the Middlebank/Shoalwater region (576 t) was the highest recorded and the catch from the Northern region (183 t) was highest recorded since 1999/2000 (246 t).

The reduction in fishing effort in the Northern region in the last ten years reflects the management decision to target larger and more valuable prawns, which generally occur further south.

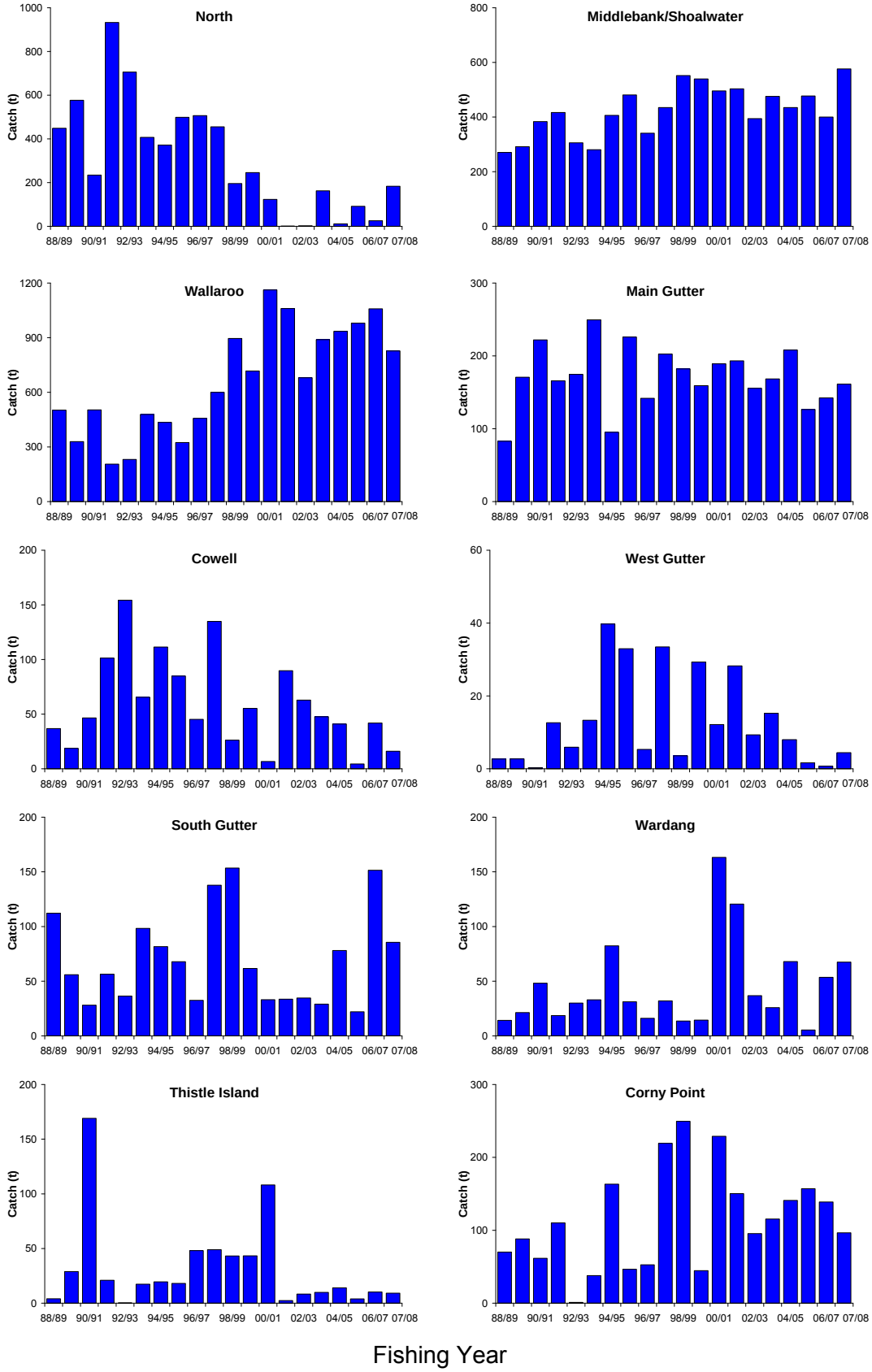

Figure 2.2 Average annual catches from regions of Spencer Gulf from 1988/89 to 2007/08. Note change in Y-axis scales among graphs.

2.2.3 Trends within years

The distribution of monthly catches has changed over the last 34 years (Figure 2.3). Between 1974/75 and 1978/79, prawns were captured in all months. Peak catches were taken during March and the lowest catches were taken from July to September.

Temporal closures were introduced in 1978/79. From 1979/80 to 1983/84, the average catch was highest during April and lowest during January, February and June. No catch was taken from July to September. From 1984/85 to 1988/89, most of the catch was taken during April and May. Further closures were introduced in January and February.

Average catches from the 1989/90 to 1993/94 and 1994/95 to 1998/99 periods were similar. The highest catches were harvested in May, followed by April and March. Similar catches were harvested during November, December and June in each of these periods.

Average catches from 1999/2000 to 2003/04 were highest in April followed by May. Similar catches were harvested from November, December and March, with the lowest catches harvested during June.

The seasonal distribution of annual catches was similar during 2004/05, 2006/07 and 2007/08. The highest catches were harvested during April and May, particularly during 2006/07. Catches ranging from 150 to 300 t were obtained during November, December, March and June in each of these years. In contrast, the catch during March of 2005/06 was similar to that harvested during April and May. Also, the catch during June 2005/06 was low in an historical context.

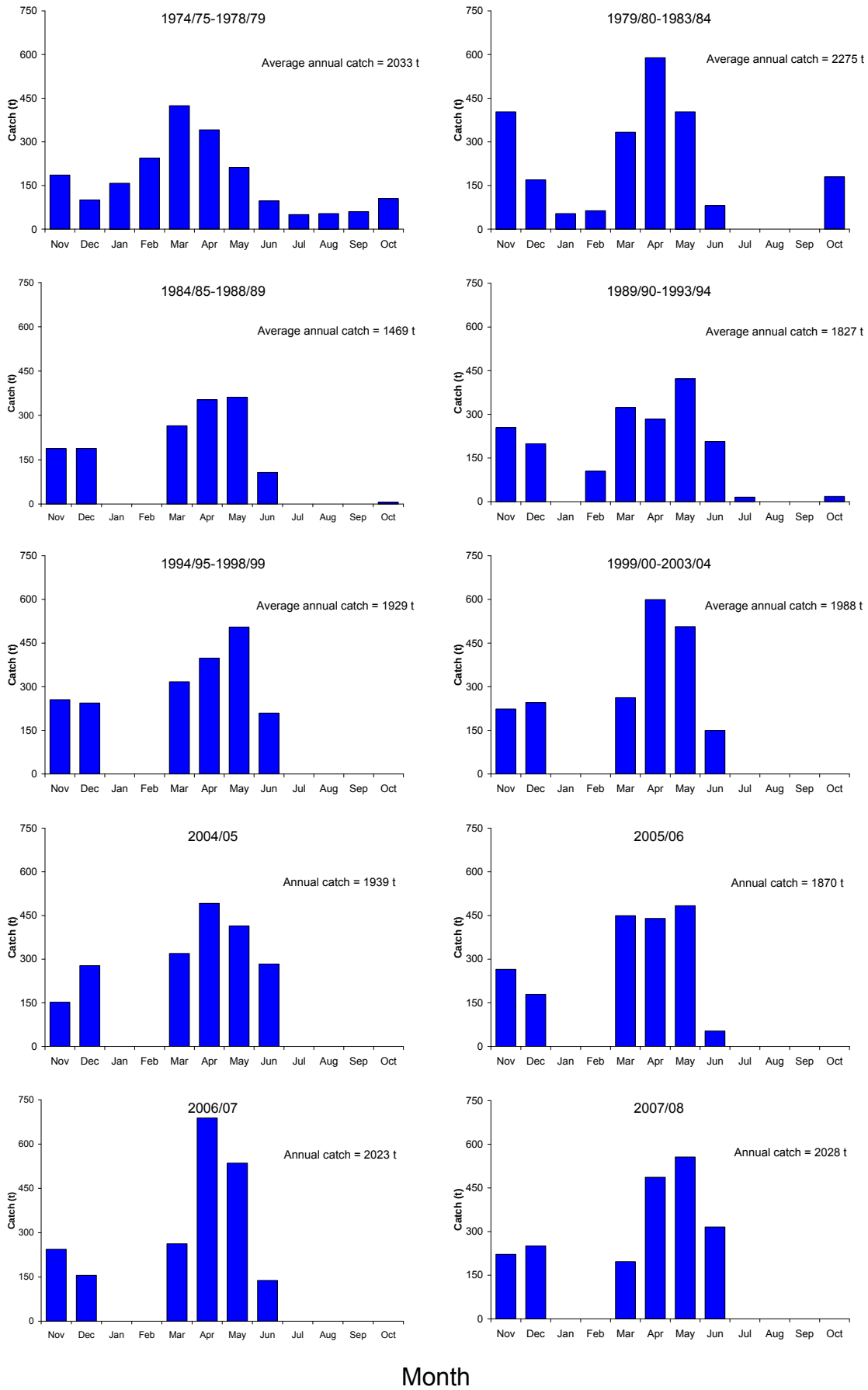

Figure 2.3 Average monthly catches from Spencer Gulf for 5-year periods from 1974/75 to 2003/04 and the four fishing-years 2004/05 and 2007/08.

2.2.4 Catches during the early spawning season

The main spawning period for *P. latisulcatus* in Spencer Gulf extends from November to March. As catch levels during the early spawning period are important for the sustainability of the fishery, levels of catch harvested in November and December, related to total catch, are considered here. Figure 2.4 shows the pre-Christmas (November and December) catch and the total annual catch.

From 1981/82 to 1986/87, the total annual catch declined from 2,491 t to the record low for the established fishery of 1,048 t. This record low catch followed increases in the pre-Christmas catch from 297 in 1979/80 to 833 t in 1983/84. This is the only period in the history of the fishery that pre-Christmas catch has exceeded 500 t in three consecutive years (1981/82, 1982/83, 1983/84). Since 1984/85 catches pre-Christmas have exceeded 500 t on only 4 occasions: 1991/92, 1995/96, 1998/99 and 2001/02. In each case, the total annual catch declined the following year.

During the last five fishing-years, pre-Christmas catches have not exceeded 500 t. It is noteworthy that the stability in pre-Christmas catches coincides with stability in total annual catches. These patterns in pre-Christmas catch and total annual catch, during periods of fluctuating catches and recent stability, add weight to the argument regarding the importance of pre-Christmas harvest on the ongoing sustainability of the Spencer Gulf Prawn Fishery. Pre-Christmas catch during 2007/08 was 472 t.

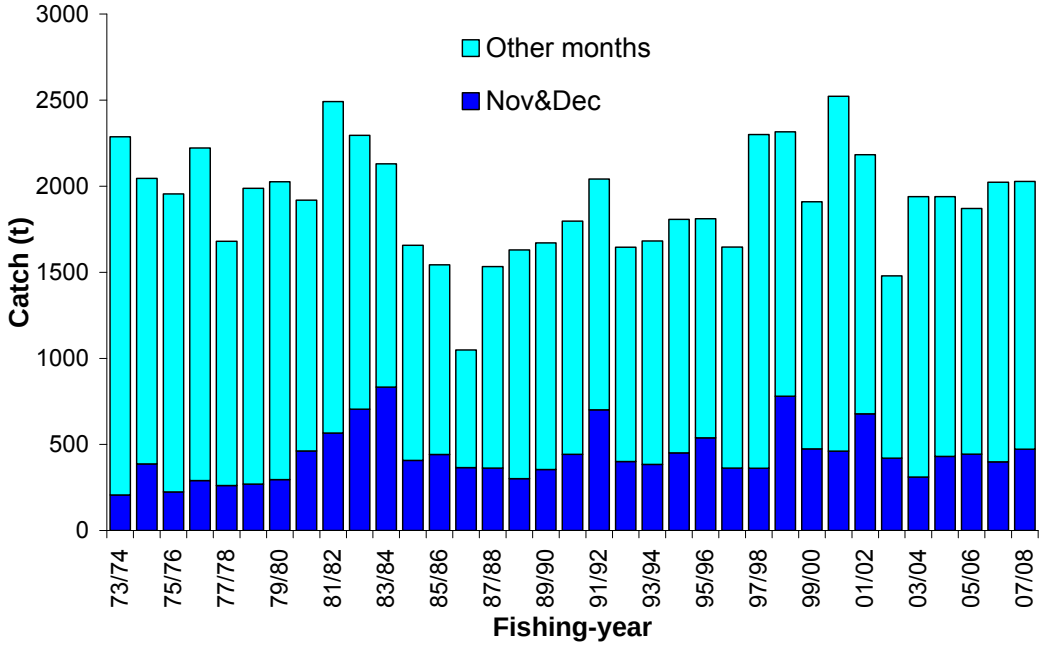

Figure 2.4 Catches from November and December relative to the total annual catch from 1973/74 to 2007/08 in Spencer Gulf.

2.3 Catch-Per-Unit-Effort (CPUE)

2.3.1 Inter-annual trends

Annual (nominal) CPUE has varied substantially since the inception of the fishery (Figure 2.5). Up to 1985/86, CPUE generally fluctuated between 40 and 70 kg/hr, but a peak of 82.9 kg/hr was recorded in 1973/74. The lowest CPUE, 35.2 kg/hr, was recorded in 1986/87. CPUE increased during the late 80s and throughout the 90s and exceeded 100 kg/hr for the first time in 1997/98. CPUE has remained above 80 kg/hr thereafter, except during 2002/03 (78.3 kg/hr). During 2007/08, CPUE was 110.0 kg/hr, the second highest level observed for the fishery (2000/01: 114.2 kg/hr).

The general historical increase in CPUE over time probably reflects increases in the fishing power of the fleet. Decisions to target larger prawns are also likely to affect CPUE. Hence, CPUE does not accurately reflect prawn abundance over the entire history of the fishery. However, changes in CPUE over shorter time periods (e.g. between years) when variations in fishing power are smaller, more reliably reflects changes in prawn biomass (Figure 2.5). Understanding changes in fishing power are important to interpret CPUE trends.

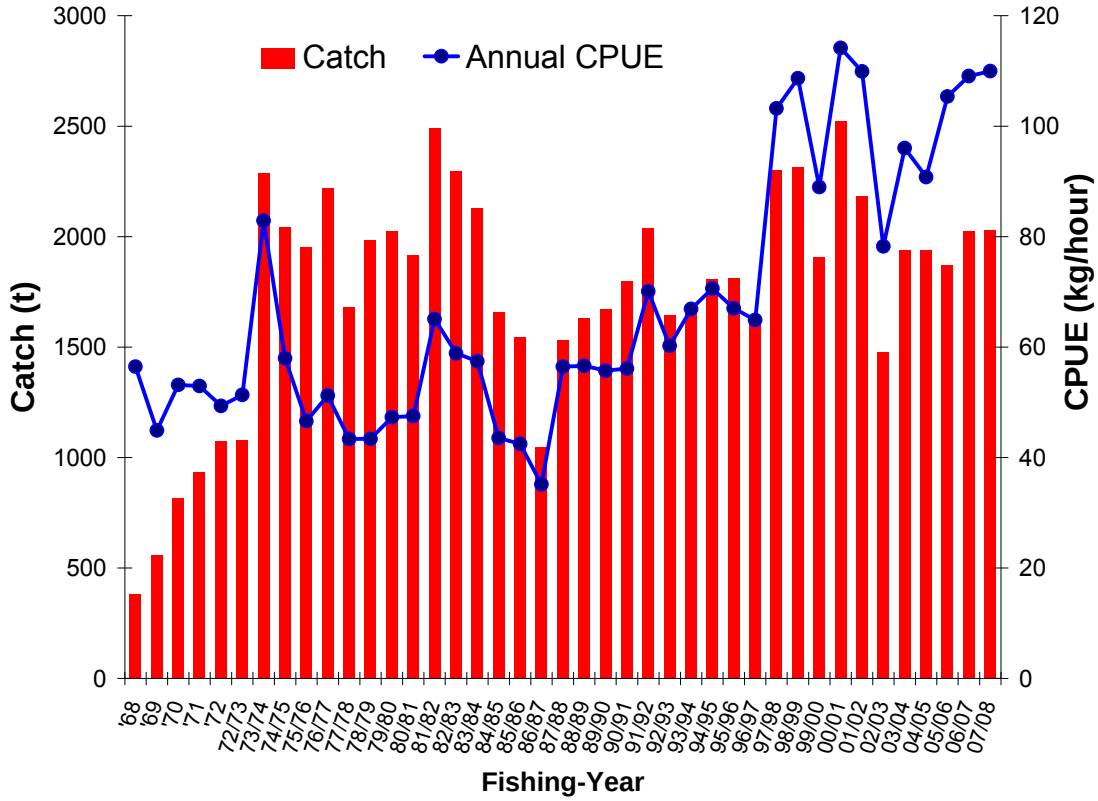

Figure 2.5 Annual catch and catch-per-unit-effort (CPUE) for Spencer Gulf from 1968 to 2007/08. Data for 1968–1972 are reported as calendar year. Data for 1972/73 are from January to October 1973. From 1973/74 data are reported in fishing years.

2.3.2 Trends among regions

Over the past 5 fishing years (2003/04–2007/08) CPUE has varied among regions (Figure 2.6). Generally, CPUE declined with latitude, being higher in the Northern, Shoalwater/Middlebank, Wallaroo and Main Gutter regions than regions further south. Regional differences in CPUE have influenced the long-term CPUE trends for the fishery (Figure 2.5), as the distribution of effort has changed over time.

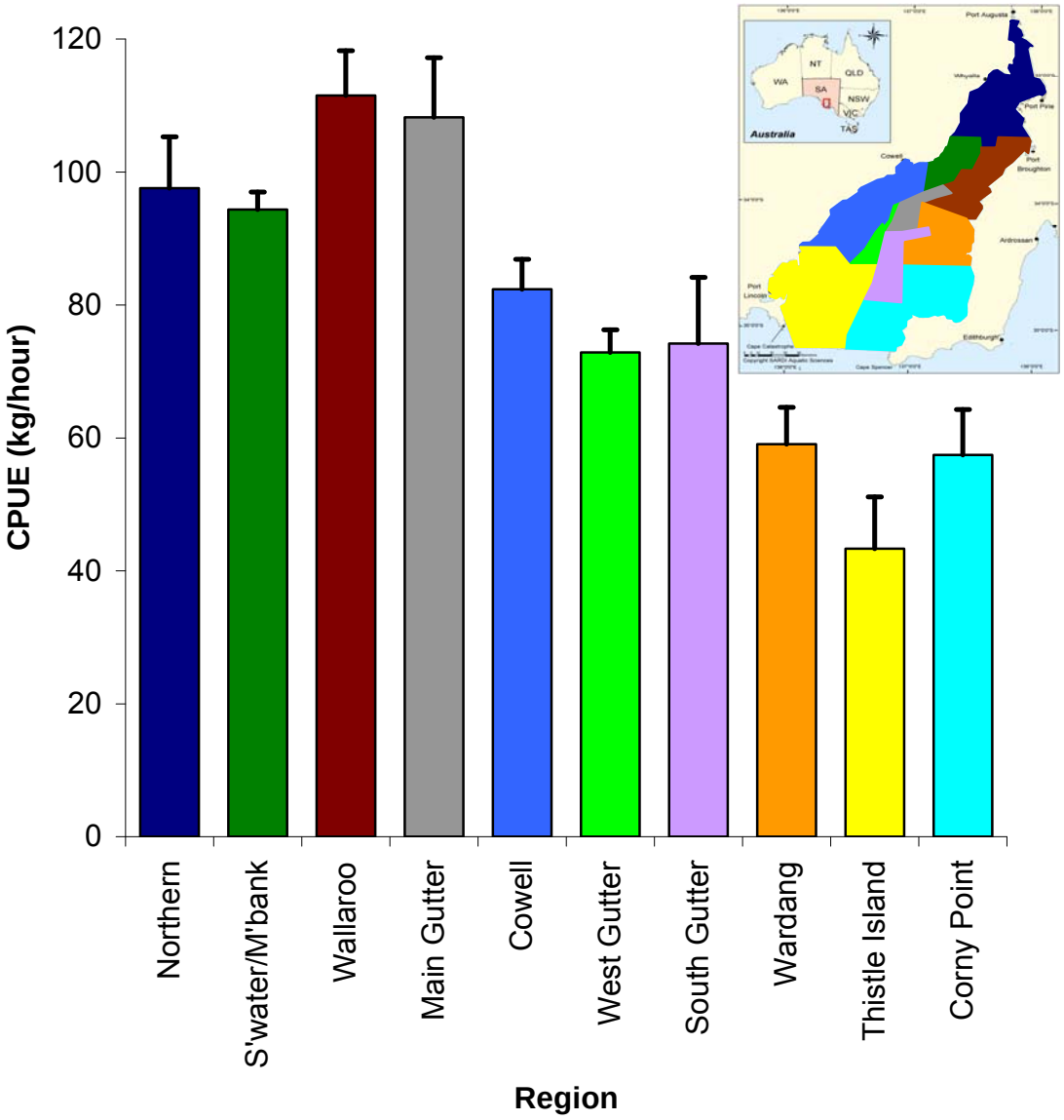

Figure 2.6 Mean (SE) annual catch-per-unit-effort (CPUE, total annual catch/total annual effort) for the 10 fishing regions within Spencer Gulf from 2003/04 to 2007/08. Insert identifies colour coded regions.

2.3.4 Trends in hourly CPUE

During 2007/08, trends in CPUE throughout the night were analysed to assess changes in catch rate relative to sunset and sunrise. CPUE was calculated separately for the first, second, second last and last shots for each fishing night. All other shots throughout the night were combined and are referred to as "middle" shots. Nights when "late starts" occurred were excluded from analyses. Start and finish times were determined from the fishing closure notices produced by PIRSA.

CPUE was lowest close to sunset (first shot) and sunrise (last shot) in all months except March, where CPUE decreased from sunset to sunrise (Figure 2.8). The reason for this pattern in March is unknown. The difference in CPUE throughout the night was highest in April, May and June, and lowest in November and December. Relative CPUE is an important consideration in the start and finish times for fishing, and should be considered for interpretation of stock assessment survey data.

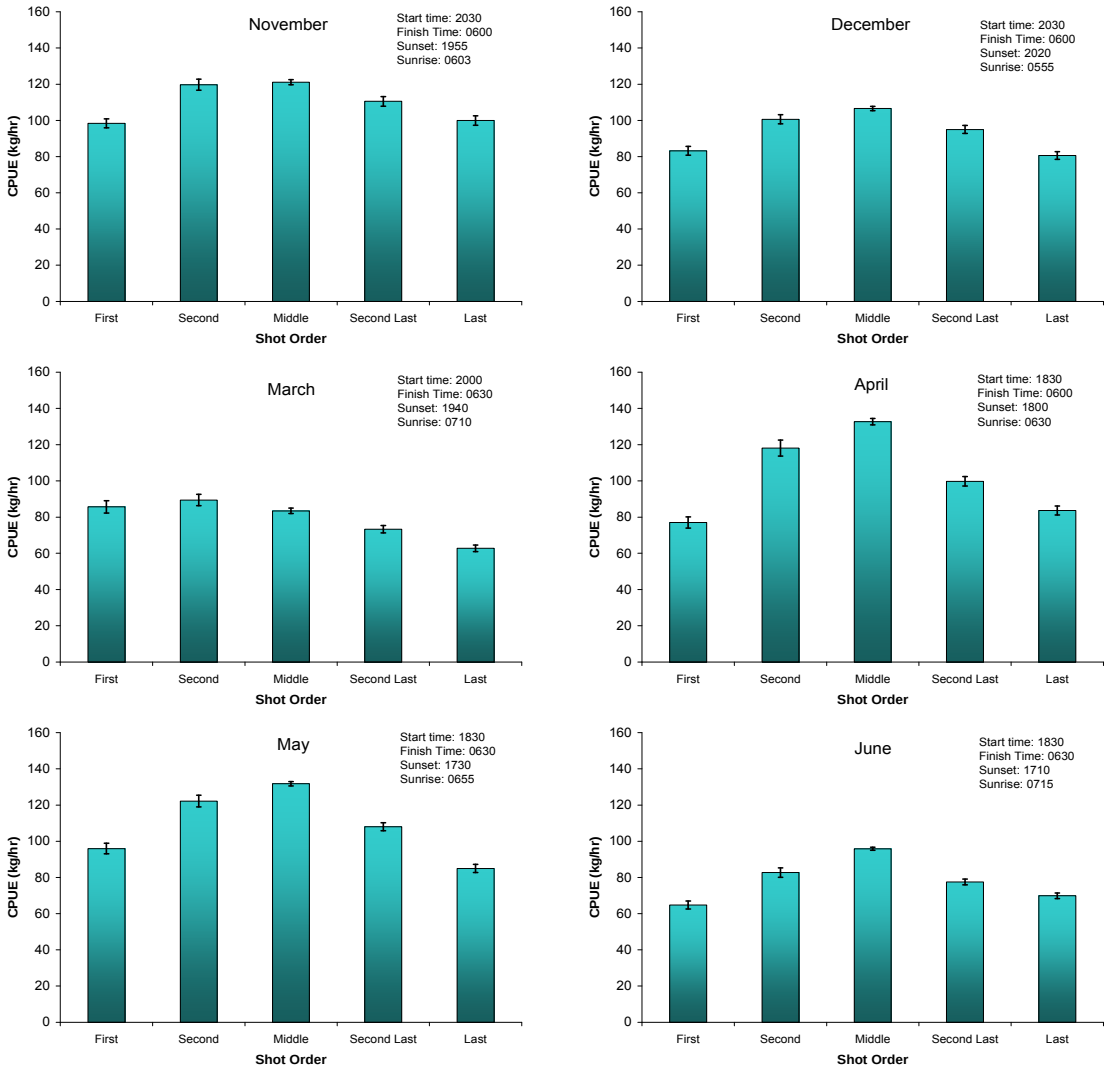

Figure 2.8 Mean (+SE) catch-per-unit-effort (CPUE) during the night for each fishing month during 2007/08.

2.4 Prawn Size

Information on prawn size was obtained from prawn-grade data. These data were only available from 1978/79, 1998/99 and 2002/03 to 2007/08. The grade was determined from the number of prawns to the pound (i.e. U10 = under 10 prawns per pound, etc). In 1978/79 and 1998/99, data were reported as the proportion of the commercial catch that was comprised of four size categories (U10, 10/15, 16/20 and 20+, Carrick 2003). From 2002/03 onward, data were reported as the proportion of the commercial catch occurring in each of 29 size classes (see Table 2.1). To facilitate interpretation of the prawn-grade data among all fishing years, the data from 2002/03 to 2007/08 were converted to four size categories based on the decision rules provided in Table 2.1. For analysis of trends within years, a fifth category, SB (Soft and Broken) was established for prawns that were unable to be graded. In this report, prawns in the U10, 10/15, 16/20, 20+ and Soft and Broken categories are referred to as XL, large, medium, small and SB respectively.

Table 2.1 Analytical categories assigned to reported prawn grades from the commercial logbook data.

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

2.4.1 Inter-annual trends

In 1978/79, small prawns comprised >40% of the catch compared to <7% in the six recent fishing years (Figure 2.9). The proportion of medium prawns was similar in 1978/79 and the six recent fishing years. XL prawns comprised more than twice as much of the catch in recent years compared to 1978/79. The distribution of the catch among size categories was similar in 1998/99 and 2002/03. With the exception of 1978/79, the proportion of small and medium prawns was highest during 2003/04 and the proportion of large and XL was lowest. During 2007/08, the proportion of prawns within each size category was generally similar to the average proportion within each category from the previous five years.

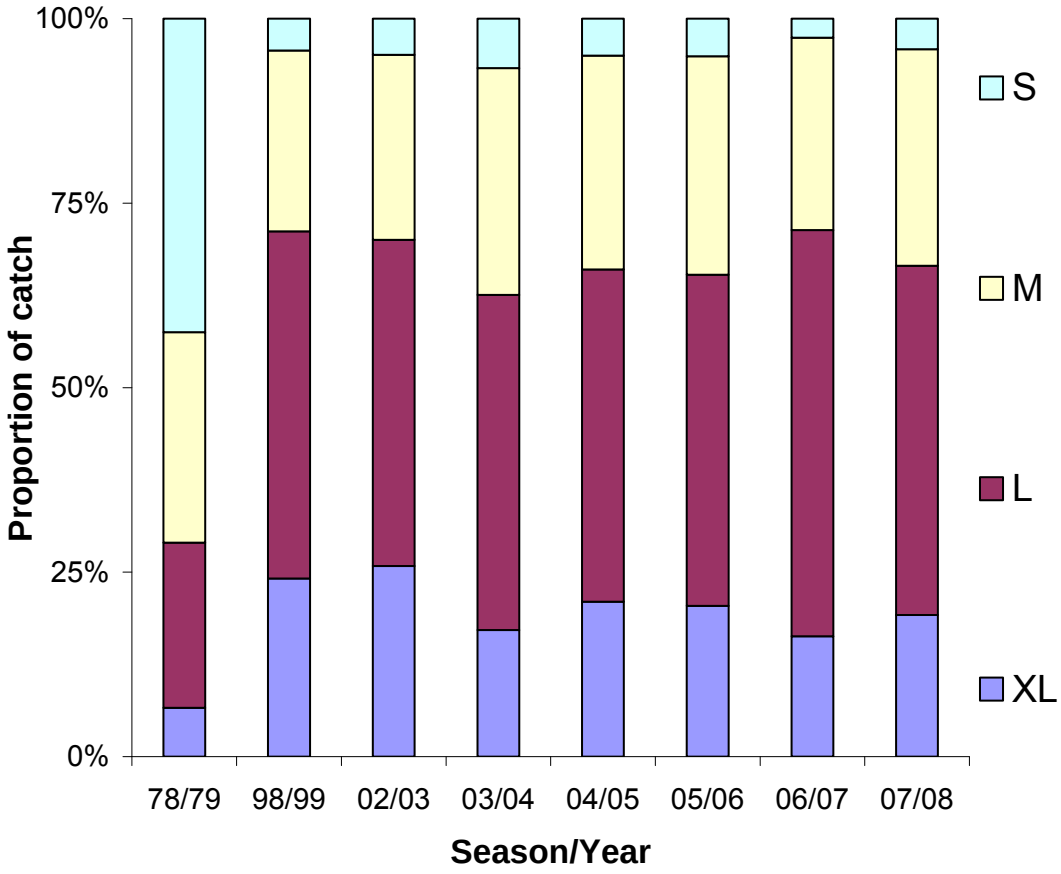

Figure 2.9 Size compositions of prawns in the commercial catch in 1978/79, 1998/99 and 2002/03 to 2007/08.

2.4.2 Trends within years

The size composition of prawns varied among months in all fishing years (Figure 2.10). The proportion of XL prawns in the catch was highest during March of each year except 2005/06 (highest in June) and lowest during May in all years except 2004/05 (lowest in June). Few other consistent seasonal trends were observed among years for other size classes.

During 2007/08, the proportion of XL prawns in the catch was higher than that caught from 2003/04 to 2006/07, ranging from 13% in May to 30% in March. The proportion of large prawns was lowest in March (39%) and highest in November (49%). The proportion of medium prawns was lowest in March (20%) and highest in May (32%). The proportion of small prawns was lowest during November (3%) and highest during March (6%). The proportion of soft and broken (SB) was lowest during November (5%) and highest during December (9%).

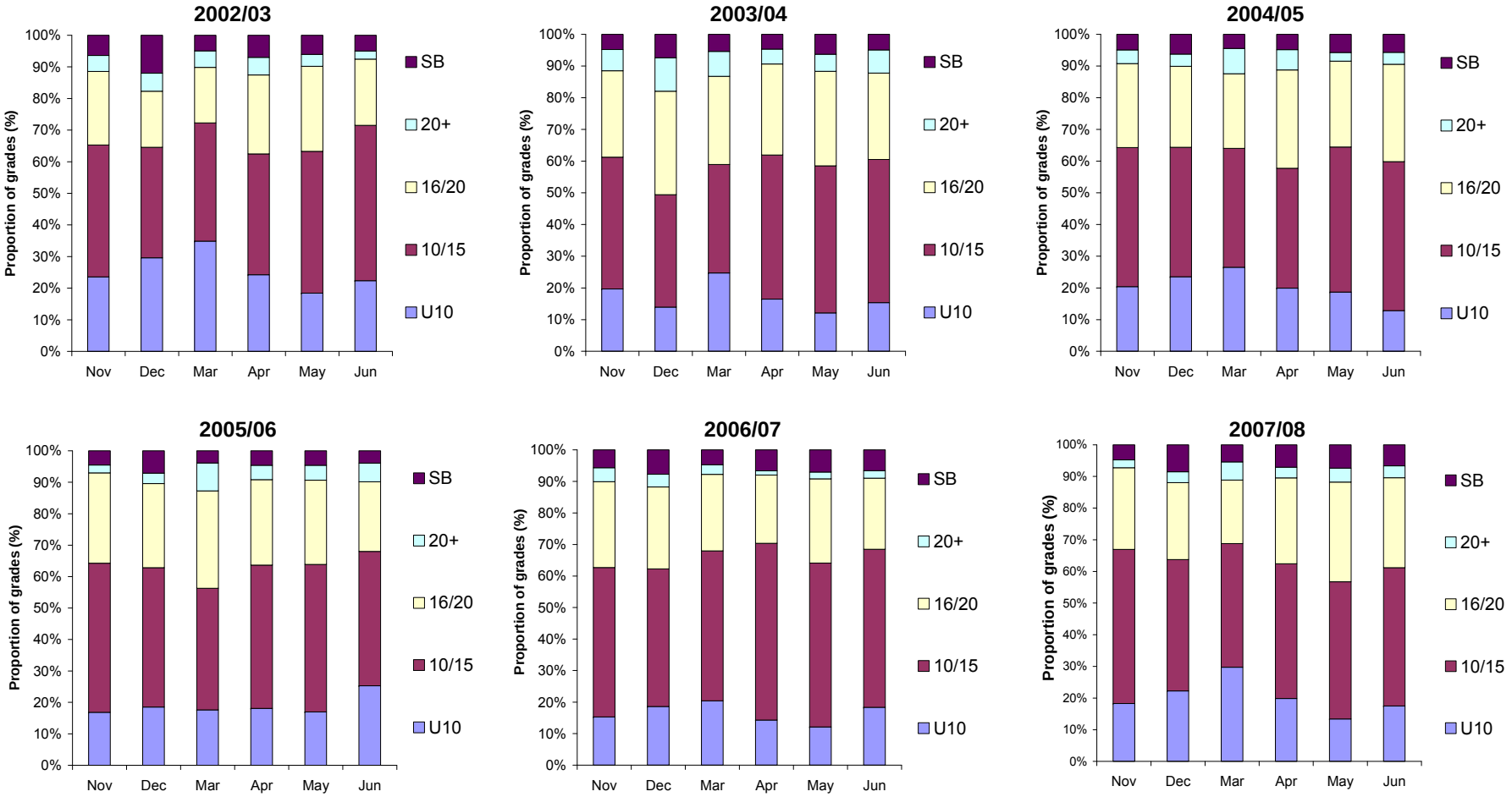

Figure 2.10 Size composition of the commercial catch during each month fished in Spencer Gulf from 2002/03 to 2007/08.

2.4.3 Daily prawn grades

The number of prawns per kilogram for each of the 23 prawn grades was estimated from the prawn grade name (i.e. prawn grade 10–15 was estimated as 12.5 prawns per pound equalling 27.5 prawns per kg) and are presented in Table 2.2.

Table 2.2 The number of prawn per kg estimated for reported prawn grades from the commercial logbook data.

Prawn grade	Prawns per kg	Prawn grade	Prawns per kg	Prawn grade	Prawns per kg
U6	13.2	10/15	27.5	21/25	50.6
U8	15.4	13/15	30.8	S	56.1
XL	15.4	10/20	33.0	20+	56.1
U10	19.8	12/18	33.0	21/30	56.1
L	19.8	M	39.6	26+	61.6
9/12	23.1	16/20	39.6	30+	78.1
U12	24.2	SM	48.4	31/40	78.1
LM	27.5	19/25	48.4		

The average number of prawns per 7 kg (one bucket) for each vessel's daily catch was calculated from the catch by grade data provided in commercial logbooks and the number of prawns per kg for each grade (Table 2.3; Figure 2.11) using the equation:

$$\frac{\sum\left(catch[grade]\times\left(ppkg[grade]\times 7\right)\right)}{\sum\left(catch[grade]\right)}$$

where,

catch is the total daily catch (kg),

ppkg is the number of prawns per kg,

grade is the relevant prawn grade.

Mean annual prawn size (prawns per 7 kg) was determined as the weighted mean prawn size from each daily catch using the equation:

$$\frac{\sum\left(\sum catch\times\sum\left(catch\times pp7kg\right)\right)}{\sum\left(catch\right)}$$

where,

catch is the total daily catch (kg),

pp7kg is the mean daily prawns per 7 kg.

Prawns harvested in 2007/08 were a similar mean size (210 prawns per 7 kg) to 2006/07, and were larger than all years other than 2002/03 (206 prawns per 7 kg, Table 2.3). However, modal size (213 prawns per 7 kg) was the second largest recorded.

The number of nights when very small prawns (>280 prawns per 7 kg) were captured during 2007/08 was again low compared to 2002/03 to 2004/05. These trends reflect improvement in harvest strategy management at sea in recent years. However, it should be noted that the number of nights when small prawns (>240 prawns per 7kg) were caught during 2007/08 was the highest recorded since 2004/05.

Table 2.3 Statistics associated with mean daily prawn size estimated from prawn grade data provided in commercial logbooks.

Year	Mean (pp7kg)	Mode (pp7kg)	Nights measured	Nights >220 pp7kg	Nights >240 pp7kg	Nights >280 pp7kg
2002/03	206	200	1956	542	230	24
2003/04	221	220	2088	919	448	66
2004/05	214	210	2251	767	244	24
2005/06	216	210	1903	624	226	16
2006/07	210	209	1978	558	158	4
2007/08	210	213	1938	702	290	12

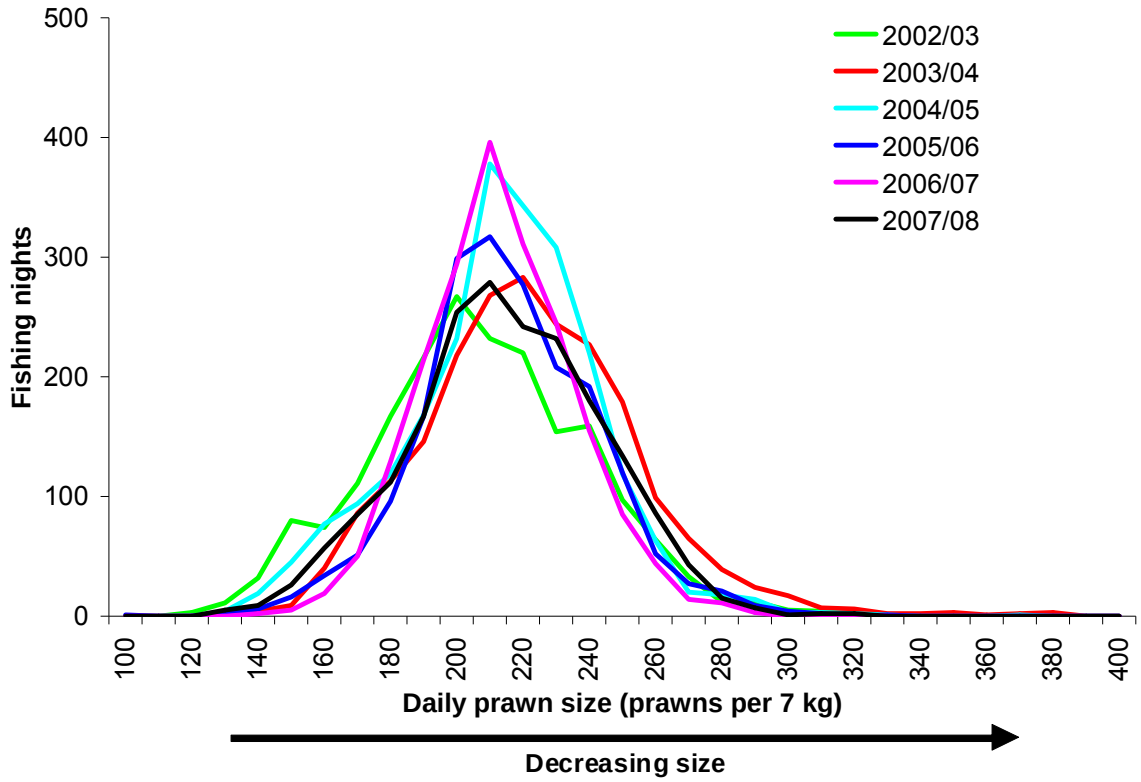

Figure 2.11 Mean daily prawn size estimated from prawn grade data provided in commercial logbooks from 2002/03 to 2007/08.

2.5 Discussion

Annual catch and effort information are available for the entire period since the inception of the fishery in 1968 and validated daily logbook data are available since 1988. Historical data on commercial prawn size are available for 1978/79 and 1998/99. Since November 2002, daily prawn grade data have been reported in commercial logbooks.

Total catch during 2007/08 (2,028 t) was the largest harvested since 2001/02 (2,182 t). In the five years since the very low catch harvested during 2002/03 (1,478 t), annual catch has stabilised, averaging 51 t more than the long-term average of the previous 30 years. The improved stability in total annual catch in recent years has probably been influenced by the policy to maintain stable catches (<450 t) during the pre-Christmas period.

As in most recent years, the majority of the total catch in 2007/08 was harvested from the Wallaroo region (827 t; 41%). Catches in the Middlebank/ Shoalwater region were the highest recorded (576 t, 28%) and the catch in the North region (131 t, 9%) was the highest since 1999/2000.

During 2007/08, total effort (18,438 trawl hours) was the second lowest recorded in the post-expansion phase of the fishery (i.e. since 1973/74) and was only 40% of the peak effort in 1978/79. This reduction in nominal effort, in the context of stable historic catches, represents substantial increases in the efficiency of prawn fishing. Whilst some of this efficiency may have been achieved with improved harvest strategies and knowledge of the fishery, it is most likely that these increases arise predominately from changes in vessel power.

As a result of the stable catches and reductions in trawl effort, commercial CPUE has increased substantially over time. CPUE in 2007/08 (110 kg/hr) was the highest recorded since 2000/01 (114.2 kg/hr). Since the low CPUE observed in 2002/03 (78 kg/hr), CPUE has steadily increased. Commercial CPUE was lowest near to sunset and sunrise during 2007/08. These results have implications for determining the most appropriate start and finish times for fishing, as well as for the interpretation of survey results. Assessment of CPUE data is limited by the inability to determine fishing power and also by temporal variation in catchability.

The mean size of prawns in the daily catch was estimated from commercial prawn grade data for each vessel since 2002/03. The mean size of prawns harvested during 2007/08 across all vessel nights was 210 prawns per 7 kg. This was the same as 2006/07, and was the second largest mean size recorded. The distribution of mean prawn size per vessel night indicates the fleet's ability to avoid high catches of small prawns during harvest strategy management. During 2007/08, the trend of low proportions of very small prawns caught continued, with only 12 of 1938 nights having a mean size >280 prawns per 7 kg. However, during 2007/08 the number of nights when small prawns (>240 prawns per 7 kg) were caught was the second highest recorded (290 of 1938 nights). Uncertainty in the assessment of prawn size data arises from a poor understanding of the variability between commercial grading machines and a lack of available methods to validate commercial catch and effort data on prawn grades.

Trends in fishery-dependent data suggest that the Spencer Gulf Prawn Fishery is being harvested within sustainable limits. Firstly, catches have been relatively stable throughout the fishery's history. Further, effort has reduced to ~40% of peak effort and the size of prawns harvested today is substantially larger than those harvested in 1978/79.

There is also evidence to suggest that the fishery has performed well in recent years, particularly since the low total catch and CPUE observed during 2002/03. Firstly, total annual catch has stabilised and the 2,028 t harvested during 2007/08 was the highest recorded since 2001/02. Secondly, commercial CPUE has successively increased during the past five fishing-years and is now approaching the peak observed during 2000/01. Also, mean harvested prawn size has increased during the last four years, with the mean size observed during 2006/07 being the equal second highest recorded.

3. STOCK ASSESSMENT SURVEYS

3.1 Introduction

Stock assessment surveys, using industry vessels with scientific observers onboard, have been undertaken by SARDI Aquatic Sciences since February 1982. A summary of the number of survey trawl shots conducted within regions (see Figure 1.2) of Spencer Gulf is provided in Table 3.1.

Survey shots were done at semi-fixed sites. Each shot starts at a fixed Global Positioning System (GPS) position and then continues in a particular direction for a specified length of time (usually 30 minutes). The distance trawled depends on trawl speed (generally 3–5 knots), which is influenced by vessel power, tide and weather conditions. The accuracy of distance measurements and starting positions improved when GPS and computer technology were introduced into the fishery. The timing, location and number of surveyed shots have varied considerably over time (Table 3.1). Generally, surveys were conducted in November, February, April or June. Since 1982, a total of 347 different shots have been surveyed, with GPS information available for the start and finish positions of 306 of these shots (Figure 3.1a).

The Management Plan requires that 209 shots (Figure 3.1a) are surveyed each November, February and April. Shots were selected because of their history, location (ensuring a spread of shots throughout the main fishing regions) and survey logistics. The three surveys primarily aim to provide snapshots of the relative prawn biomass throughout the fishing-year to ensure that harvest rates are sustainable. Additionally, data from November and February surveys provide information on egg production, and data from February surveys provide information on recruitment.

The data collected during surveys include total catch, trawl time, trawl distance and water temperature. A length frequency sample was also taken from the catch to provide sex-specific length, sex ratio and mean prawn weight data. During 1994, bucket counts were introduced for rapid estimation of mean prawn weight. Prawns used for the bucket counts were then measured to obtained length-frequency data, and as such the two measures were not independent. GPS data for the start and end of each trawl shot have been collected from November 1998. Length-frequency data are not available for February 1998, April 2003, November 2003, February 2004 and April 2004. Only limited catch rate and prawn size (bucket count) data are available for November 2003, February 2004 and April 2004.

Table 3.1 Number of stock assessment survey shots done in fishing regions of Spencer Gulf from February 1982 to April 2008.

Year	Month	North	M'bank/ S'water	Cowell	Gutter	S. Gutter	Wallaroo	W. Gutter	Corny Pt.	Wardang	Total
1982	Feb	52	3								55
	Mar	52	3	36							91
	Apr	53	6								59
	Nov	13									13
1983	Jun	53	6	38							97
	Oct			36	24						60
	Nov			34							34
1984	Oct	56	6								62
1985	Jun	66	15	39							120
	Oct				27						27
1986	Apr	74	15								89
	Jun	74	14	42							130
	Oct	70	15		18						103
1987	Feb	74	15	40	27	3	18				177
	Jun	75	15	36	27	3					156
	Oct	76	15		27	3	18				139
1988	Feb	77	15	42	27	3	11				175
	Jun	68	15	38							121
	Nov	75	15	32	27		16				165
1989	Feb	75	15	42	27		16				175
	Apr	37	16	17							70
	Jun	59	1	21							81
1990	Jun	68	17								85
1992	Feb	65	16	46	27	3	20				177
1993	Feb	73	16	34	27		20				170
	Apr	3	15								18
	May	19									19
	Jun	68	9								77
1994	Feb	58	12	40	27	3	17				157
	Apr	68	20	30	11		24	4			157
	Jun	82	4	36	16	1					139
	Nov	94	17	35	22		18	4			190
1995	Feb	68	15	36	23		18				160
	Apr	82	18	36	10		3				149
	May	80	7	36							123
	Nov	80	6	37	12		11				146
1996	Feb	75	16				2				93
	Apr	76	18				9				103
	Jun	74	9	52	30						165
	Nov	61	9	50	28		16				164
1997	Feb	69	13	49	26	2	21	10	6		196
	Nov	69	12	48	25	6	21	10	3		194
1998	Feb	74	15	61	29	5	22	10	6		222
	Apr	74	18				22				114
	Nov	78	12	52	25	1	21	10			199
1999	Feb	86	16	41	27	2	22	8	6		208
	Nov	77	16	44	25	4	23	10	6		205
2000	Feb	76	15	11	27	4	22				155
	Oct	62	16	24	27	2	27				158
2001	Feb	76	16	36	30	8	27	10	12		215
	Apr	80	18		7		32				137
	Nov	82	19	35	29	6	38	10			219
2002	Feb	82	17	5	25	2	43				174
	Apr	71	21		7		31				130
	Nov	82	17	36	30	9	43	10	12	6	245
2003	Mar	80	18	36	30	8	42	10	12	7	243
	Apr	77	21				40				138
	Nov	82	16	36	29	6	31	9			209
2004	Feb	81	21	36	27	10	40	2	12	8	237
	Apr	80	22	28	13		40				183
	Nov	78	22	38	23	1	29	10			201
2005	Feb	78	22	42	24	7	29	9	12		223
	Apr	78	22	22	19	5	41	3			190
	Nov	78	22	39	24	1	29	10			203
2006	Feb	78	23	39	26	10	29	10	12		227
	Apr	81	22	22	20	4	36	3		2	190
	Nov	64	21	25	22	8	40	9	12	5	206
2007	Feb	63	21	27	22	8	40	9	12	5	207
	Apr	64	22	27	22	8	40	9	12	5	209
	Nov	64	22	27	22	8	40	9	12	5	209
2008	Feb	63	22	27	21	8	40	9	12	5	207
	Apr	63	22	27	21	8	40	9	12	5	207

3.2 Relative biomass (mean survey catch rate)

The primary aim of stock assessment surveys is to provide an index of relative prawn biomass at regular intervals throughout the fishing-year. Historically, surveys were most consistently conducted during November, February and April. Due to the timing of moon phases, survey months have been occasionally offset e.g. November surveys have been conducted in late October. For the purpose of statistical analyses, surveys conducted under these circumstances have been categorised as November, February or April where appropriate.

Catch rates provide an index of prawn biomass for a given trawl shot, however they are affected by a number of factors that include (but are not limited to) season, water temperature, tide, moon phase and location. The utility of mean catch rate as an index of relative biomass hinges on the assumption that these factors do not adversely bias mean catch rate estimates.

Historically, stock assessment surveys were conducted on or close to the new moon. Also, surveys were generally conducted throughout all hours of the night. This ensured that the influence of moon phase and tide were generally accounted for among surveys. The effects of season, and to a large extent water temperature, can be accounted for by comparing mean catch rates among years for each survey month separately.

Catch rates vary substantially by location in Spencer Gulf with a strong trend of decreasing catch rates with latitude (see Section 2.3.2). Unfortunately, the poor spatial replication of historic survey data creates considerable uncertainty in estimates of relative biomass when including all data from each survey. To address the location bias, we calculated mean catch rate from shots that were consistently surveyed over time. For each of November, February and April surveys, we considered a) only years when consecutive surveys were conducted and b) only shots that had been surveyed on at least 75% of surveyed occasions. We also determined two annual measures of mean catch rate. The first was a combination of consistent sites surveyed in both November and February, and the second a combination of sites consistently surveyed in all months. Figure 3.1 (maps a-f) demonstrates the spatial distribution of consistent survey sites for each of the five measures: November surveys; February surveys; April surveys; annual measure from November and February, and; annual measure from all three surveys.

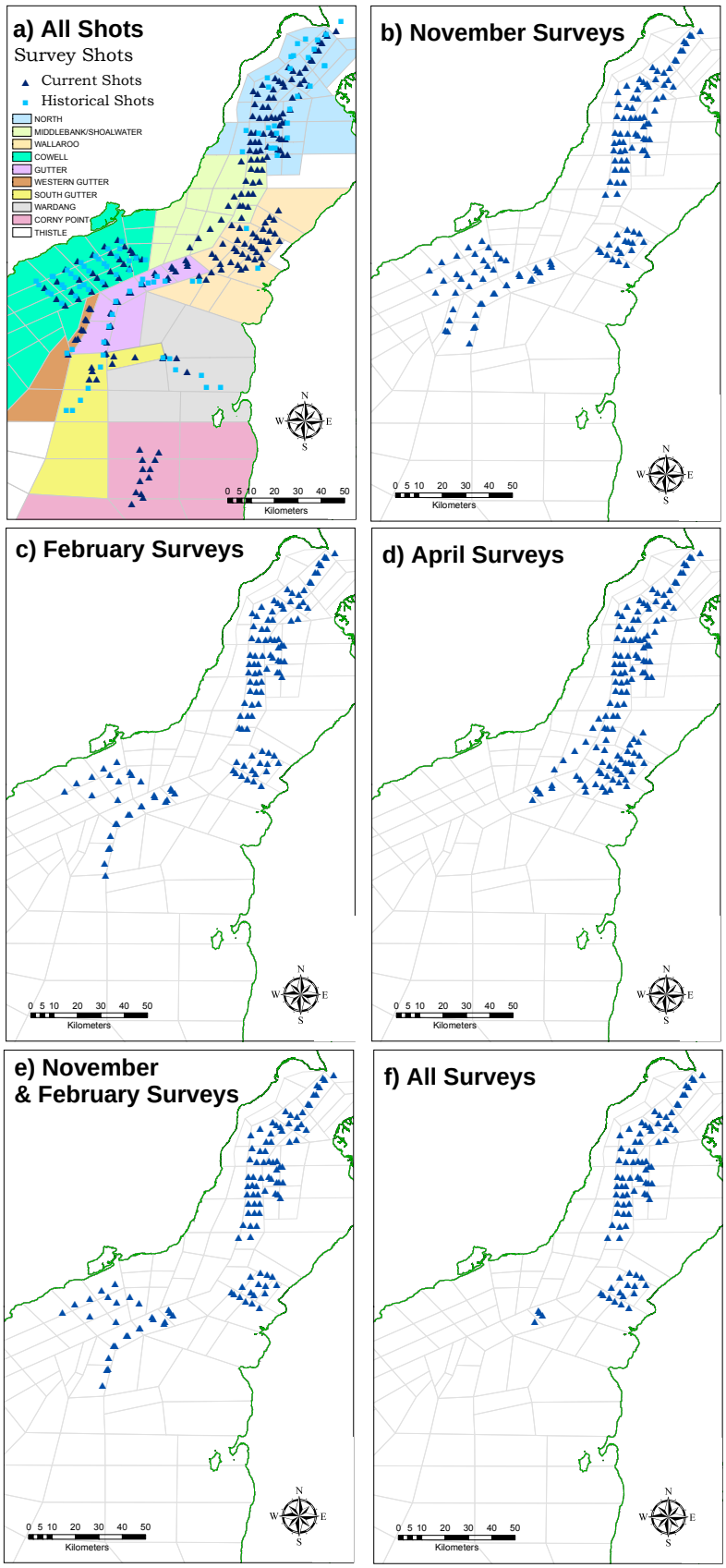

Figure 3.1 Maps showing the distribution of survey shots throughout Spencer Gulf. Map a) shows the distribution of 309 shots surveyed since 1982. Another 41 shots have been surveyed previously, but GPS data were not available. Regions of Spencer Gulf are identified. Maps b) to f) show the distribution of survey shots for measures of relative biomass from b) November, c) February, d) April, e) November and February and f) all three months.

3.2.1 November surveys

November surveys were first conducted in 1982/83 (Figure 3.2). The number of shots surveyed increased from 13 to 165 by 1988/89. November surveys were conducted annually from 1994/95 at up to 245 shots each year. Between 98 and 133 of these were consistently surveyed each year in the North, Middlebank/ Shoalwater, Wallaroo, Cowell, West Gutter and Main Gutter regions (Figure 3.1b).

Due to low sampling intensity, mean catch rates from all shots varied greatly in the first three years. Since 1986/87, mean catch rates from all shots and consistent shots have varied between 67 and 147 kg/hr. Annual variations in mean catch rate were often substantial and may resemble a cyclical pattern. These patterns correlate with observations previously associated with variations in the level of pre-Christmas harvest, particularly prior to 2004/05 (Dixon et. al. 2007). The mean catch rate during 2007/08 was the highest observed since 2001/02. However, it should be noted that possible increases in vessel power are not considered here.

The trends in mean catch rate from consistent shots and all shots since 1994/95 were very similar over time despite the fact that 26–46% less shots was surveyed on each occasion. Whilst the magnitude of the difference was consistently small, the shots not surveyed consistently were generally at lower catch rates and therefore lowered the mean catch rate for all shots.

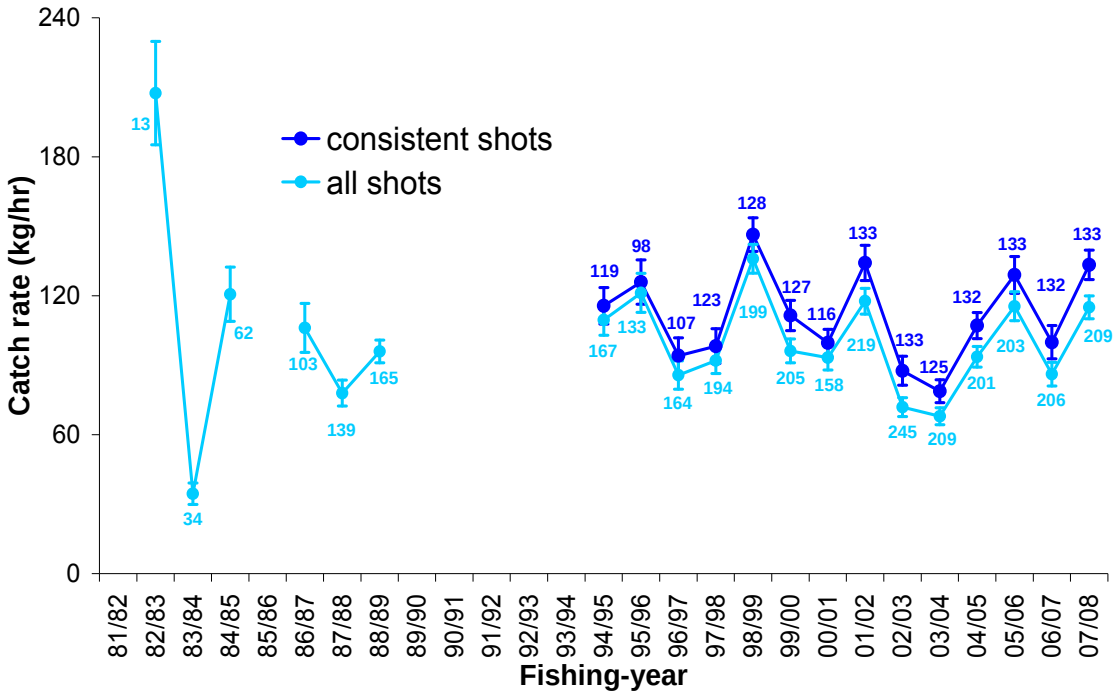

Figure 3.2 Mean catch rate (kg/hr) obtained during November surveys from all shots and consistent shots conducted between 1981/82 and 2007/08. Labels indicate the number of shots surveyed.

3.2.2 February surveys

The first February survey was conducted in 1981/82 with only 55 shots completed (Figure 3.3). They were repeated between 1986/87 and 1988/89, with 175–177 shots surveyed on each occasion. February surveys were conducted annually from 1991/92 at up to 237 shots each year (Figure 3.3). Of the total shots completed, 71–121 of these were consistently surveyed each year in the North, Middlebank/ Shoalwater, Wallaroo, Cowell and Main Gutter regions (Figure 3.1c).

Few trends in mean catch rate could be ascertained from February surveys conducted prior to 1991/92. Mean catch rate varied greatly from 1995/96 to 2004/05, again correlated with the level of pre-Christmas harvest (Dixon et al 2005a, 2007). It is notable, but not unexpected, that stability in February catch rates has been observed since 2004/05, likely the result of implementation of policy on consistent levels of pre-Christmas harvest (Dixon and Sloan 2007).

Trends in mean catch rate for consistent shots and all shots since 1991/92 follow similar patterns of fluctuation over time however the magnitude of difference is highly variable among years, particularly for the 1995/96–2004/05 period. It is likely that this bias is associated with a difference in the proportion of shots that originated in the north region, where the catch rates of newly recruited prawns are very high during February.

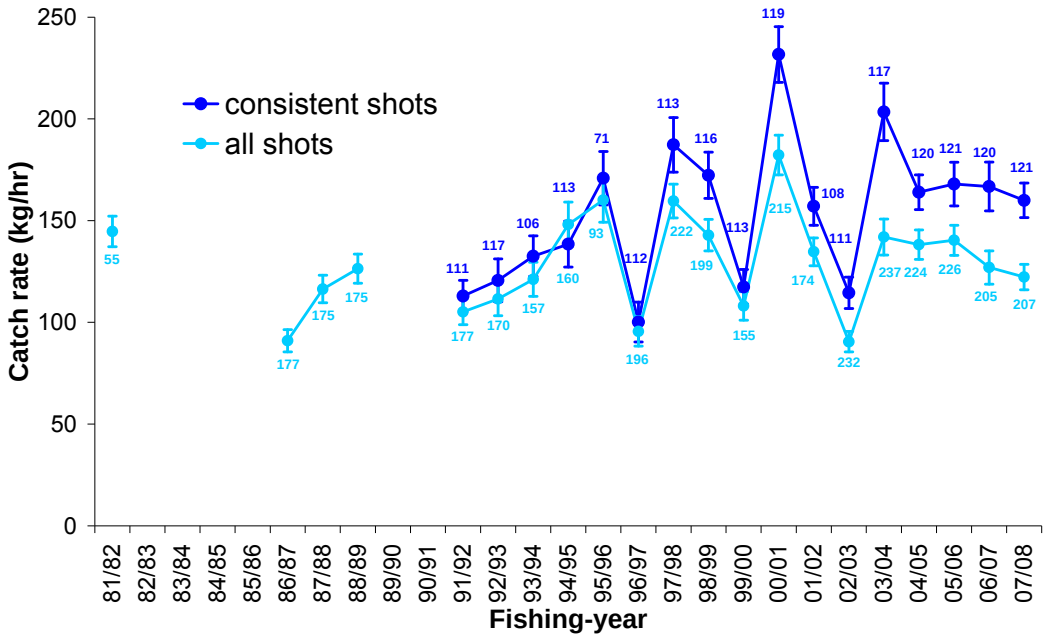

Figure 3.3 Mean catch rate (kg/hr) obtained during February surveys from all shots and consistent shots conducted between 1981/82 and 2007/08. Labels indicate the number of shots surveyed.

3.2.3 April surveys

The first April survey was conducted in 1981/82 with only 59 shots completed (Figure 3.4). They were repeated sporadically until 2000/01, and have been conducted annually since. Until recently, April surveys were generally constrained to less than 150 shots in total (Figure 3.4). Despite this, between 110 and 127 consistent shots were surveyed during the last seven fishing years. Their distribution has been limited to the North, Middlebank/Shoalwater, Wallaroo, and Main Gutter regions (Figure 3.1d).

Few trends in mean catch rate could be ascertained from April surveys conducted prior to 2000/01. Thereafter, mean catch rates varied considerably, ranging from 137–246 kg/hr for consistent shots and 132–245 kg/hr for all shots. Mean catch rate during 2006/07 (237 kg/hr) and 2007/08 (236 kg/hr) were among the highest recorded.

Mean catch rate for consistent shots and for all shots were similar from 2000/01 to 2002/03. Thereafter, mean catch rates from consistent shots were regularly higher, probably the result of the greater number of surveyed shots during this period.

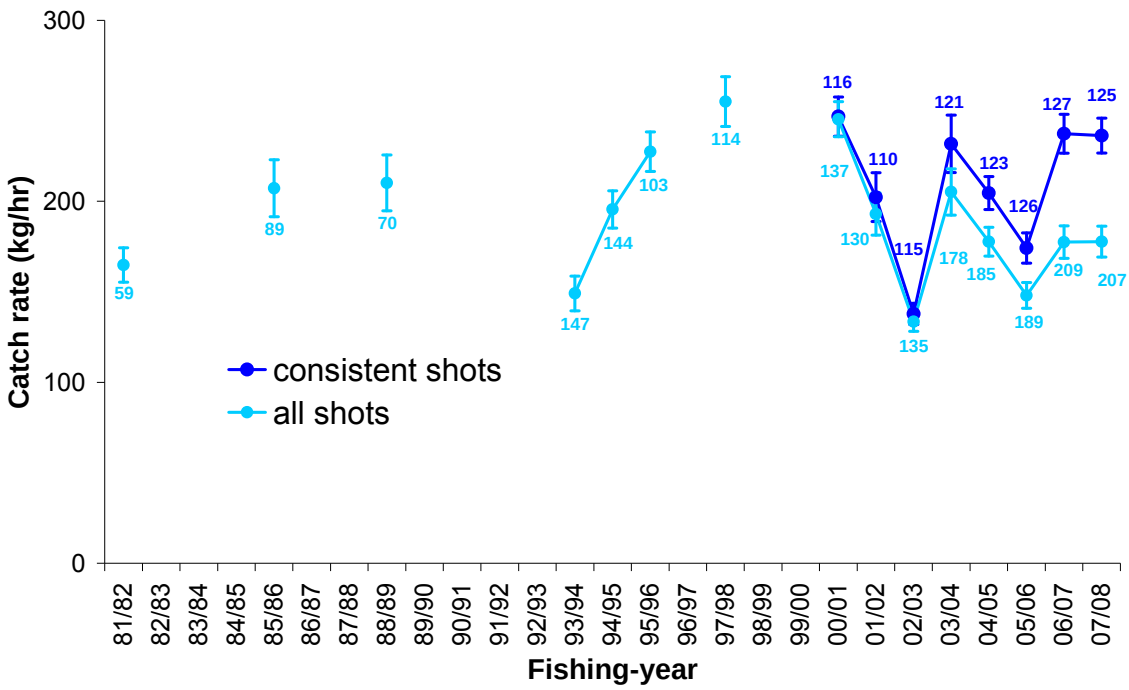

Figure 3.4 Mean catch rate (kg/hr) obtained during April surveys from all shots and consistent shots conducted between 1981/82 and 2007/08. Labels indicate the number of shots surveyed.

3.2.3 Annual measures

Annual measures of relative biomass were obtained by comparing consistent shots surveyed across survey months for each consecutive year. Following the rules applied to November, February and April survey data (see Section 3.2), two different annual measures were obtained: 1) consistent shots surveyed across November and February (1994/95–2006/07), and 2) consistent shots surveyed across November, February and April (2000/01–2006/07). For November/ February (Figure 3.1e) shots were distributed throughout North, Middlebank/Shoalwater, Wallaroo, Cowell and Main Gutter regions. The measure for all months was limited to the North and Wallaroo regions (Figure 3.1f).

The November/February annual measure was obtained from 153–227 shots. Mean catch rate ranged from 101–169 kg/hr and was generally stable, although cyclical trends were evident prior to 2003/04. The annual measure for all months was obtained from 252–270 shots and ranged from 121–212 kg/hr. Mean catch rate has been generally stable in recent years, with an increasing trend over the last 4 fishing-years.

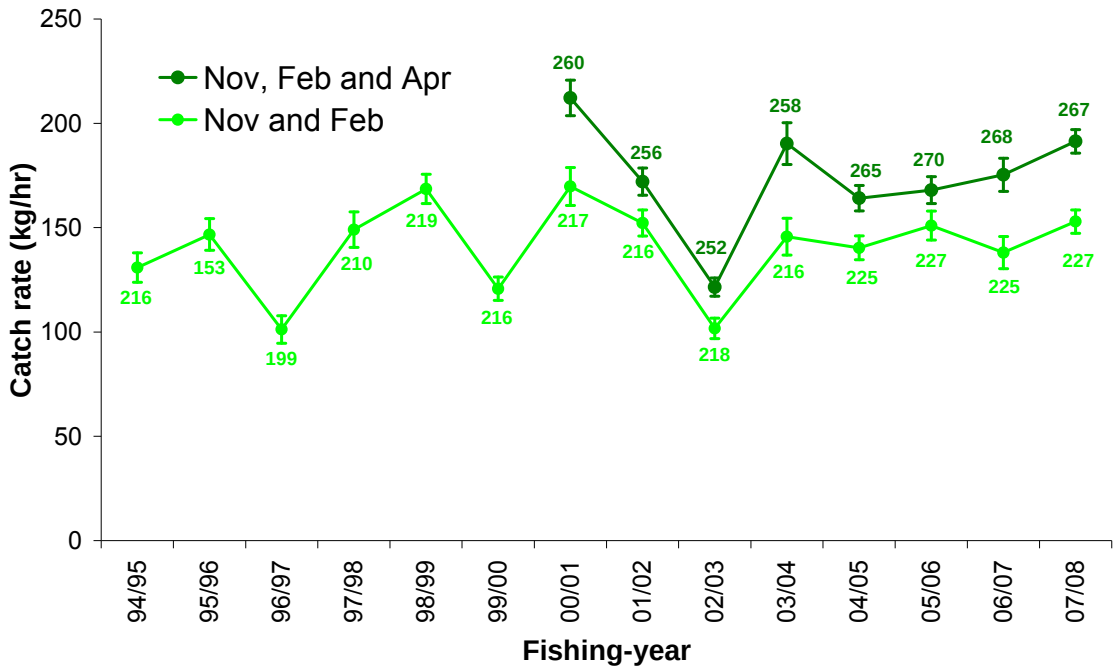

Figure 3.5 Mean catch rate (kg/hr) obtained from consistent shots surveyed in i) November and February, and ii) November, February and April, between 1994/95 and 2007/08. Labels indicate the number of shots surveyed.

3.3 Prawn size

The mean size of male and female prawns (carapace length, mm) was calculated separately for November, February and April surveys (Figure 3.6a-c) and also for two annual measures (Figure 3.7a-b), following the consistent site rules applied for relative prawn biomass (see Section 3.2).

A sub-sample of sex-specific size frequency data was collected for each survey shot and was scaled relative to the weight of the total catch from two nets for a 30 minute trawl. Size frequency data were obtained from at least 90% of consistent shots surveyed in most years, with exceptions in November 1997/98 (87% of shots) and 2004/05 (83%), February 2002/03 (74%) and Nov-Feb 2002/03 (85%). As such, it is considered that estimates of mean size are relatively unbiased representations of the survey catch (i.e. relative biomass) and provide useful comparisons among years.

Female prawns were larger than male prawns in all years and surveys (Figures 3.6 and 3.7) due to differences in growth rate between sexes (see Section 1.5.5). Male and female prawns were largest in November (mean annual size 34.3 and 38.9 mm, CL, respectively) and smallest in February (mean annual size 32.4 and 35.3 mm, CL, respectively; Figure 3.6). These patterns are likely to reflect the timing of low and peak recruitment periods, respectively (Carrick 1996). Generally, the size differences between sexes were consistent among years. However, the magnitude of the difference varied between surveys, being highest in November (mean difference 4.6 mm, CL) and smallest in April (mean difference 2.8 mm, CL).

The mean size of prawns observed on November surveys ranged from 32.7–36.6 mm, CL, for males and 36.7–42.0 mm, CL, for females (Figure 3.6a). Mean size was particularly variable for November surveys between 1995/96 and 1998/99. The mean size of prawns observed on February surveys since 1991/92 ranged from 30.1–33.8 mm, CL, for males and 31.7–37.3 mm, CL, for females (Figure 3.6b). Mean size on February surveys also varied considerably between years which reflects differences in recruitment. It is notable that stability in recruitment in recent years is reflected in stable mean prawn size. The mean size of prawns observed on April surveys since 2000/01 ranged from 32.3–34.3 mm, CL, for males and 34.5–37.8 mm, CL, for females (Figure 3.6c). A paucity of April survey size data prevents informative interpretation of trends among years.

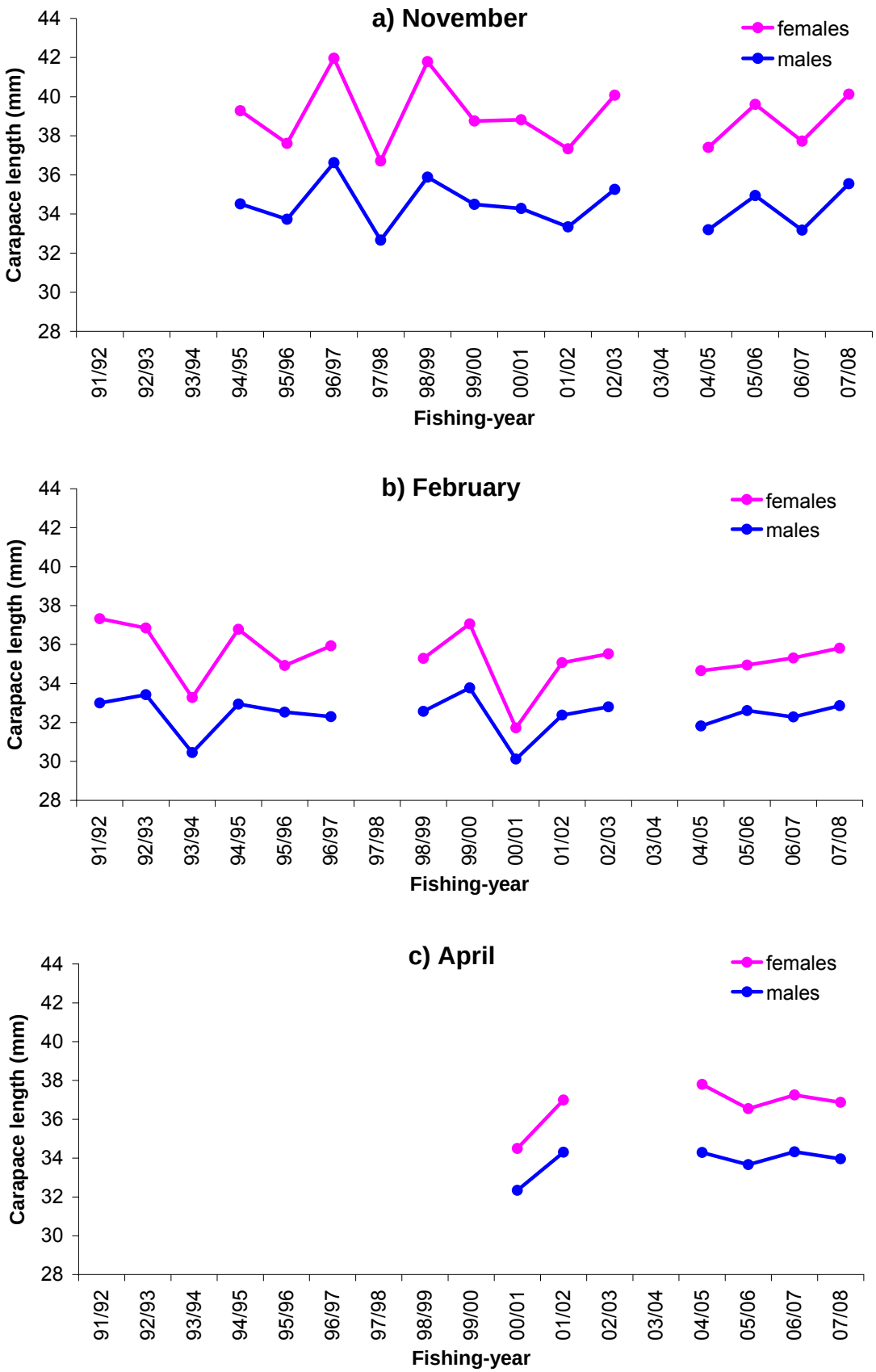

Figure 3.6 Mean sizes (carapace length, mm) for female and male prawns calculated from consistent shots surveyed in a) November, b) February and c) April.

The mean size of prawns observed on November and February surveys combined since 1994/95 ranged from 31.1–34.1 mm, CL, for males and 33.2–38.0 mm, CL, for females (Figure 3.7a). Mean size was notably lowest during 2000/01, which coincides with the year of peak recruit abundance (see Section 3.4). The mean size of prawns observed on November, February and April surveys combined since 2000/01 ranged from 31.3–33.5 mm, CL, for males and 33.3–36.3 mm, CL, for females (Figure 3.7b). Again, the paucity of April survey size data prevents informative interpretation of trends among years but patterns in mean size are similar to those observed for the November and February annual measure.

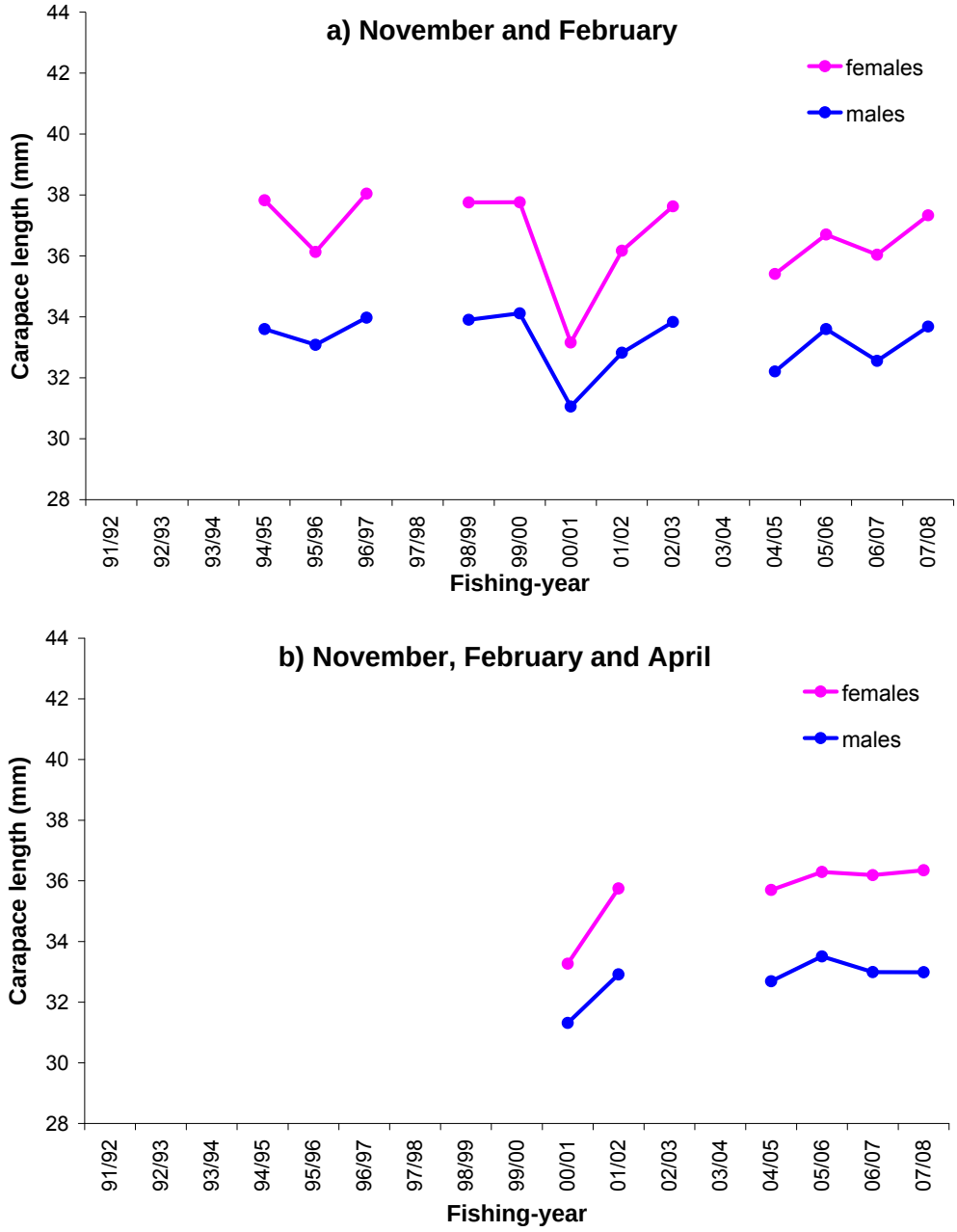

Figure 3.7 Mean sizes (carapace length, mm) for female and male prawns calculated from consistent shots surveyed in a) November and February combined, b) November, February and April combined.

3.4 February recruitment

Recruitment was calculated as the square root transformation of the numbers of prawns (males <33 and females <35 mm carapace length) per nautical mile trawled from up to 39 stations in the north of the gulf during February surveys. Recruitment data were available for 19 February surveys conducted since 1982. During the 1982 surveys, 34 of the 39 recruitment shots were surveyed. Following rationalisation of the survey design, 33 and 34 shots were surveyed during 2007 and 2008, respectively. In all other years at least 36 were completed.

The recruitment index was lowest during 2000 (~30; Figure 3.8) and greatest during 2001 (~60), which equates to a 4-fold difference for the untransformed data. The recruitment index has been above the limit reference level for eight consecutive years and for 17 of the 20 years that February surveys have been conducted since 1982. During 2008, the recruitment index was 44.3.

In recent years, the level of pre-Christmas catch has been capped with the specific aim of ensuring stable recruitment to the fishery. There is evidence to suggest this approach has been successful in the short-term, as the average number of recruits for the last four fishing-years is 17% higher than the previous historic average.

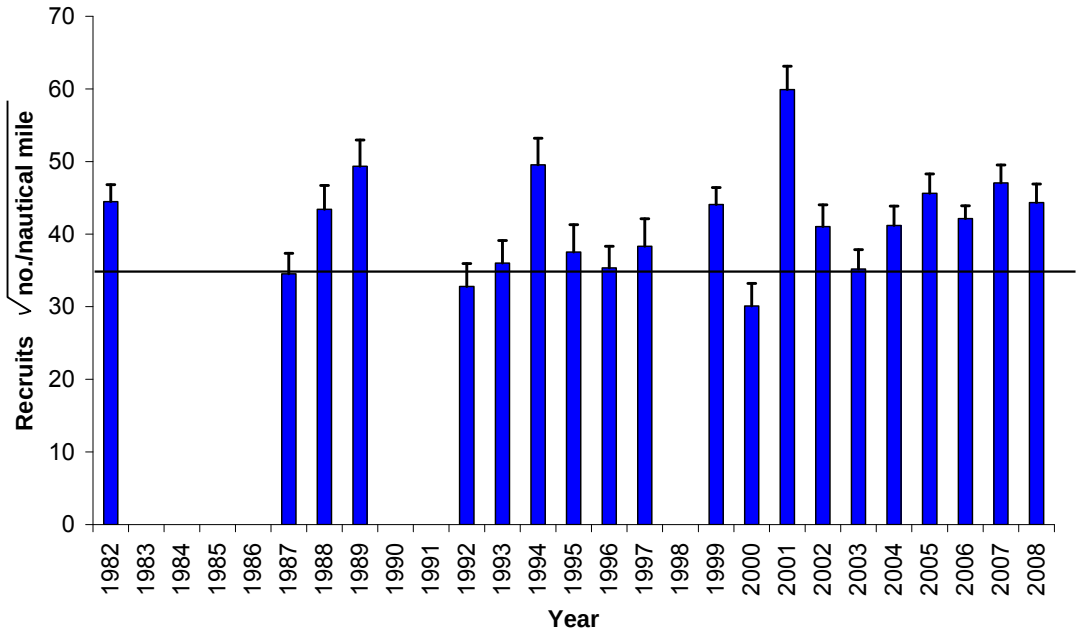

Figure 3.8 Mean (SE) recruitment index for up to 39 stations surveyed in February in the northern region of Spencer Gulf from 1982 to 2008. The line represents the limit reference point (35/nm).

3.5 Recruitment indices, survey catch rates and pre-Christmas catch

Carrick (1996) determined that the seasonal peak in recruitment observed during February was the result of spawning and settlement from the previous summer. To investigate the relationship between environmental variables and prawn recruitment, Charles *et al* (in prep) explored the relationships between prawn recruitment (one summer later) and 1) summer water temperature, 2) summer wind strength and direction, and 3) the level of pre-Christmas catch. The latter variable was assessed following previous observations on the importance of the level of pre-Christmas catch to subsequent catch (Dixon *et al* 2005a, Dixon *et al* 2007). In this report we also explore the relationship between November survey catch rate from consistent sites and recruitment in the next summer. Data were investigated for the period of 1992 to 2005.

No significant effects on recruitment were observed for the environmental variables of water temperature, wind speed and direction (Charles *et al*, in prep.). Of note, water temperature during the summer of 2000/01 was substantially higher (~2ºC) than all other years and in the same year, the highest level of recruitment was observed for the fishery (Figure 3.8). It is hypothesized that the unusually high water temperatures over an extended summer period led to a significant early settlement and recruitment event within the same summer, thus meaning that two cohorts of juveniles recruited to the fishing grounds early in 2001. As a consequence, it was decided to omit the 2001 recruitment event from correlations between recruitment and the previous summer's November survey catch rate (Figure 3.9) and pre-Christmas catch (Figure 3.10).

November survey catch rate was significantly and negatively correlated with recruitment to the fishery in the following summer (LR: df=9, F=5.67, P<0.05; Figure 3.9). This is a counter-intuitive result, as it could be expected that the November spawning biomass would be positively correlated with recruitment rates. i.e. high spawning biomass should result in higher recruitment, especially when no clear environmental drivers of recruitment were evident (Charles *et. al.* in prep.). This unexpected result occurred as a consequence of the harvest strategies applied at the time, which encouraged high levels of pre-Christmas catch when November survey results were favourably high. Figure 3.10 demonstrates that the extent of pre-Christmas catch was a significant and negative influence on subsequent recruitment (LR: df=13, F=10.15, P<0.01).

These results have substantial implications for stock assessment. In particular, they endorse the current strategy of conservative pre-Christmas harvest levels until an improved understanding of the stock recruitment relationship is obtained. An FRDC project is currently underway that aims to improve this understanding by combining a biological and physical (hydrodynamic) model (FRDC project 2008/011).

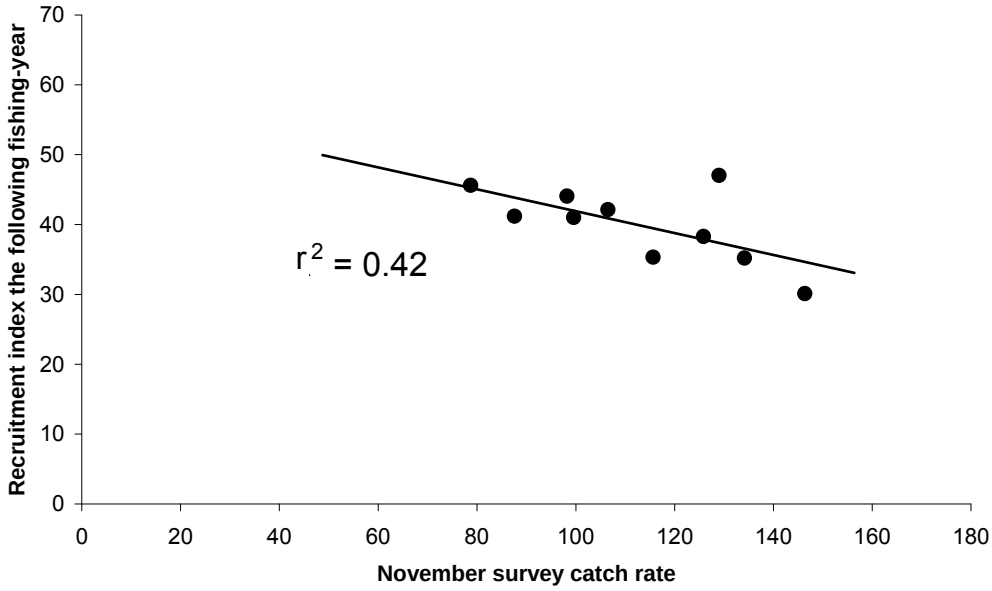

Figure 3.9 Relationship between November survey catch rate (kg/hr) and recruitment index the following fishing-year, from 1992 to 2005.

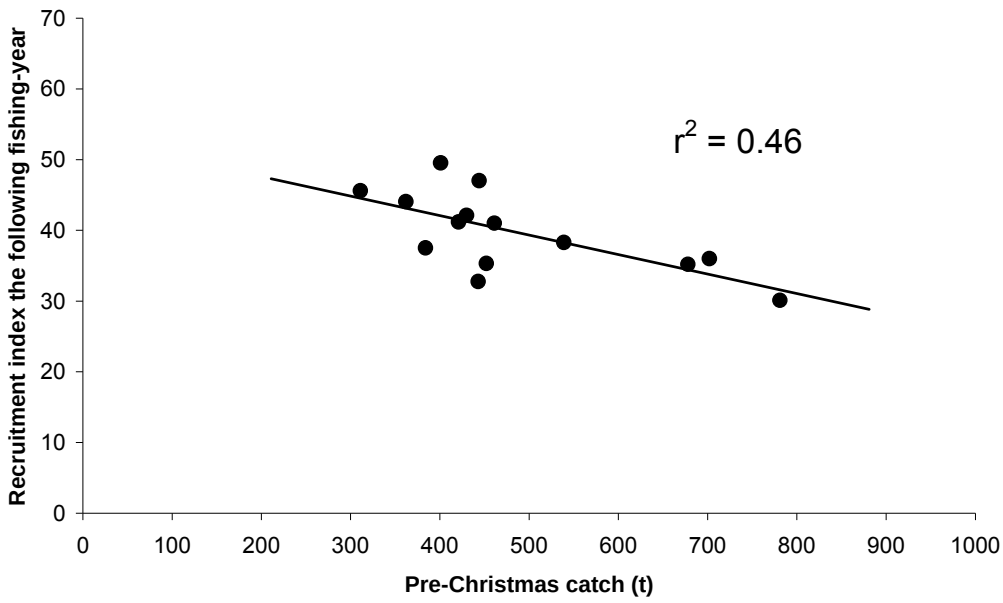

Figure 3.10 Relationship between pre-Christmas catch (t) and recruitment index the following fishing-year, from 1992 to 2005.

3.6 Egg production

Egg production was estimated for surveys conducted from November 2004 to 2007 from survey data that included catch rate, total weight of prawns in each of five grades and the proportion of females in the catch. These estimates reflect the potential egg production of female prawns captured on all survey shots during November only. They are useful to assess the relative contribution toward egg production from female prawns of various size grades. They also provide comparisons of relative egg production between years at this time, however it is uncertain at this time how well they reflect total egg production for the fishery. Detail of the model inputs and assumptions are provided in Appendix 8.1.

Mean egg production per hour trawled during November 2007 (870 million/hr) was higher than that observed for the three previous November surveys (range: 423–710 million/hr). This trend was evident across all three of the largest size classes: U8, U10 and 10/15.

Currently, an FRDC project (2008/011) is underway that will enable development of the biological model for egg production. Potential improvements include: using explicit lengths rather than averages by prawn grade; determining the frequency of spawning; incorporating February survey data; improving the understanding of biological variables such as fecundity and fertilization success.

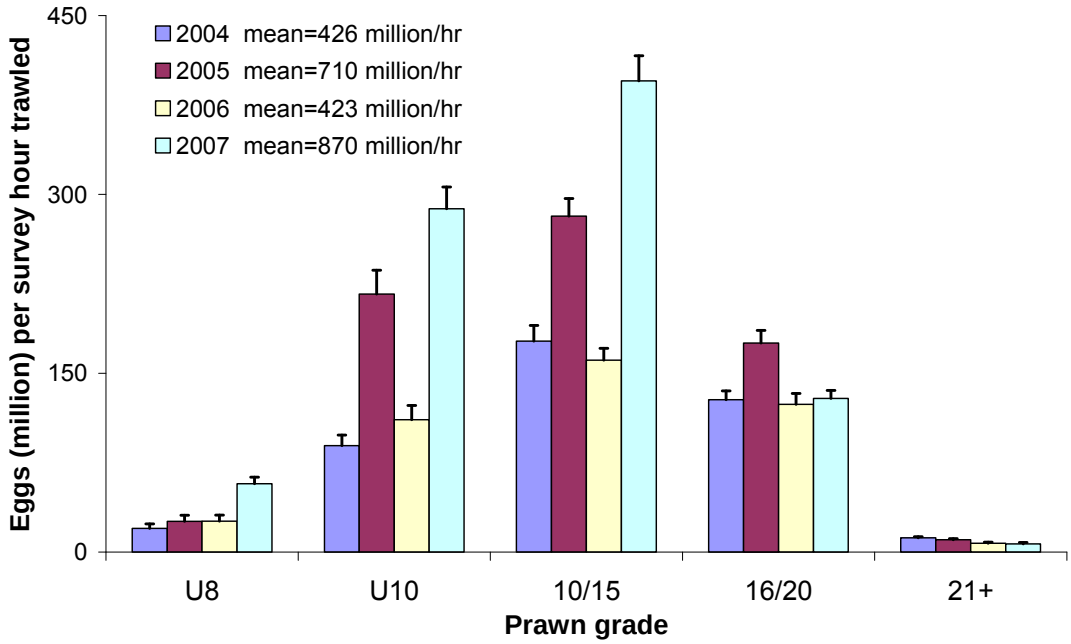

Figure 3.12 Mean (SE) estimated number of fertilized eggs (million/hr) produced by females captured from survey shots during November 2004, 2005, 2006 and 2007.

3.7 Discussion

Fishery-independent surveys have been conducted since February 1982 from up to 347 shots throughout Spencer Gulf, generally during the months of November, February, April and June. Prior to 2004/05, the location of selected shots for any given survey was highly variable, a reflection of the nature of harvest strategy development and the real-time management approach at that time. In recent years, the locations of stock assessment survey shots have been fixed to enable robust comparisons of catch rate (index of relative biomass) and prawn size among years and survey months.

Given the variable nature of the historic survey structure, analyses in this report aim to determine the shots most consistently surveyed, to provide a comparable data set for assessing changes in relative prawn biomass over time. Survey shots were defined as consistently surveyed if they had been completed on at least 75% of survey occasions. Subsets of survey shots were determined for November surveys conducted since 1994 (134 shots), February surveys conducted since 1992 (122 shots) and April surveys conducted since 2001 (127 shots).

Survey data were consistently obtained since November 1994 from shots in the North, Middlebank/ Shoalwater, Wallaroo, Cowell, West Gutter and Main Gutter regions. Prior to 2004/05, catch rates appeared in a three year cycle, likely reflecting a harvest strategy that aimed to increase pre-Christmas catch when November survey results were high, which then negatively impacted on recruitment to the fishery the next two years (Dixon *et. al.* 2005a, 2007). Since 2004/05, the range of catch rates during November surveys has reduced, possibly the result of more stable pre-Christmas catches and recruitment.

February surveys were conducted consistently from 1991/92 from shots in the North, Middlebank/ Shoalwater, Wallaroo, Cowell and Main Gutter regions. From 1995/96 to 2004/05 catch rates were highly variable, ranging from 100–232 kg/hr, likely caused by the effect of fluctuating pre-Christmas catch levels on recruitment which peaks during February. Notably, since pre-Christmas catch has been stabilised, February survey catch rate has been remarkably stable, ranging from 160–168 kg/hr in the last four years. Consistent survey data from April were limited to the last eight years. Catch rate obtained during April 2006/07 and 2007/08 was high in an historical context.

Annual measures of survey catch rate were also determined using the consistent shot rules. Data were obtained from 114 shots surveyed in the North, Middlebank/Shoalwater, Wallaroo, Cowell and Main Gutter regions during November and February from 1994/95 to 2007/08, and from 90 shots surveyed in the North and Wallaroo regions during all three months from 2000/01 to 2007/08. Trends in annual catch rate indicate that biomass has been relatively stable in the last five years. The measure for November and February also suggests that survey catch rates have not changed greatly during the last 14 years. If changes in vessel power have affected survey CPUE during this period, this may indicate long-term decline rather than stable trends in survey CPUE.

Currently, the Management Plan indicates that 209 shots are conducted during each of the three stock assessment surveys; November, February and April. It is envisaged that the collection of these robust data will provide: informative and comparable estimates of biomass over time among months and years; an ability to inform on the reliability of current biomass estimates determined from the subset of consistent shots as documented in this report, and; an ability to determine the most appropriate survey design going forward, ensuring reliable estimates of relative biomass and appropriate measures of performance for stock assessment and harvest strategy decision-making.

Representative estimates of sex-specific mean prawn size (carapace length, mm) were obtained for most years from the subsets of consistent shots determined for November and February surveys. Data for April surveys were insufficient for meaningful interpretation. Female prawns were consistently larger than males in all months and surveys, though the size difference varied between months. These differences reflect different growth rates between sexes. Trends in mean size during February surveys reflected peaks in recruitment indices, although this should be expected as the recruitment index was determined from a subset of 30% of the consistent survey shots. Whilst mean prawn size was occasionally variable among years no long-term temporal trends were apparent.

Recruitment indices were determined from up to 39 shots in the North region that have been surveyed regularly since 1982. Analyses indicate that the large variation observed in the recruitment index since the early 1990's was caused by the level of pre-Christmas catch, which negatively impacted egg production. The recent investment in egg production by stabilising pre-Christmas harvest has seen a short-

term increase in the recruitment index (approximately 25% of recruit abundance) compared to the historic average. This has been achieved with no reduction in the average pre-Christmas catch for the same time period. Whilst these results are notable, it is uncertain if these trends will continue in the long term.

Egg production estimates determined from November 2007 surveys were higher than those obtained from the previous three years. This reflects the size and abundance of females during November surveys. It is currently unclear how well these estimates reflect total egg production. A current FRDC Project (2008/011) will provide substantial improvements in the egg production model in the next two years.

Fishery-independent survey data on catch rate, recruitment index and prawn size suggest that the fishery is currently being harvested in a sustainable manner. All available evidence suggests that the investment in stabilising pre-Christmas catch in recent years has resulted in stabilised recruitment and survey catch rates for all months. Whilst survey catch rates and recruitment were high during 2007/08 in an historic context, it is difficult to determine if the stability in pre-Christmas catch will result in increased trends in the long-term.

4. HARVEST STRATEGY ASSESSMENT 2007/08

4.1 Introduction

Harvest strategies have been a key factor in the success of the Spencer Gulf Prawn Fishery. Harvest strategies aim to maximise economic yield in an ecologically sustainable manner by limiting effort levels spatially and temporally. There are two aspects of the current harvest strategy that require assessment: harvest strategy development and harvest strategy management.

Harvest strategy development is based on data obtained from surveys and involves the establishment of closure lines to exclude fishers from areas where prawn size is sub-optimal from a sustainability and economic viewpoint. The Management Plan provides specific guidelines for the development of harvest strategies based on the data collected during both stock assessment and spot surveys. Harvest strategy management is the tool that makes the Spencer Gulf Prawn Fishery unique. The Committee at-sea refines (in “real time”) the closure lines during the fishing period to maximize the economic performance of the fishery. This report aims to assess both harvest strategy development and management by assessing the fishery against the performance measures of the Management Plan and by providing fine-scale spatial and temporal analyses of both survey data and commercial catch.

4.2 Methods

Eight harvest periods (defined here as consecutive fishing nights) were assessed for the SGPF during 2007/08. Harvest periods were generally preceded by either a “Stock Assessment” or “Spot” survey, with results being used to develop the harvest strategy for the subsequent harvest period. If a survey was not conducted, harvest strategies were developed using the closure lines from the previous harvest period.

These sections comprise two types of figures. One type presents survey information on catch rate and mean size prior to commercial fishing, and the second presents commercial catch and mean size data by fishing block, for each harvest period. Both figures contain the initial harvest strategy closure lines adopted during the subsequent harvest period. Presentation of these data in this manner allows 1) visual assessment of survey data included in the harvest strategy, and 2) assessment of

how the survey data relate to the resultant commercial catch. These analyses are particularly useful in assessing commercial prawn size data.

Fishery-independent "stock assessment" surveys were conducted during November 2007, and February and April 2008 (see Section 3). Fishery-dependent "spot" surveys were conducted during March, May and June 2008 (see Appendix 8.2). Data on catch rate and mean size are presented for each site surveyed prior to each harvest period. The start and end dates of the survey and the number of nights surveyed, are also provided.

Data on commercial catch and mean size were determined from commercial logbooks (see Section 2). Data from fishing blocks with catches from <5 fishers for that harvest period are not presented to ensure compliance with confidentiality requirements. The start and end dates, number of nights fished and total catch for each harvest period are provided. Note that data exists outside the recommended harvest strategy region. This may be due to misreporting of blocks by fishers.

Results are discussed in terms of the regions defined in Figure 1.2. In the following section, catch rates <4 lb/min are referred to as "low", 4–10 lb/min as "medium", and >10 lb/min as "high". The size categories assessed for November and December are defined as "large" when mean size <201 prawns/7 kg, "medium" when 201–250 prawns/7 kg and "small" when >250 prawns/7 kg. From February to June "large" are defined as <220 prawns/7 kg, "medium" as 220–240 prawns/7 kg and "small" as >240 prawns/7 kg. These definitions enable assessment against the size criteria defined in the Management Plan. Commercial catches are reported in ranges that vary with respect to the total catch for that period, with the upper range of each "high" category reflecting the highest catch per block for that period.

Within each map showing commercial catch and mean size by harvest period are daily catch (t) and mean size (prawns/7 kg) graphs. Both of these output controls are used by the "Committee at-sea" to assess the commercial catch on a nightly basis against the "at-sea decision rules" in the Management Plan (Table 4.1).

Table 4.1 At-sea decision rules for the Spencer Gulf Prawn Fishery (Dixon and Sloan 2007).

Harvest Period	Nov & Dec	Mar & Apr	May & June
Minimum catch (kg/vessel night)	350	400	400
Minimum mean size (prawns/7kg)	250	220	240

4.3 Results

4.3.1 Harvest Period 1

A Stock Assessment survey was conducted throughout the gulf prior to the start of the fishing-year. Small prawns at medium and high catch rates were observed in all shots in the northern and western part of the North region (Figure 4.1). Small prawns were also found in the Main Gutter and West Gutter regions. Large and medium size prawns dominated all other regions, with some shots of high catch rates observed in all regions except Corny Point and Wardang. Notably, an aggregation of large prawns at high catch rates was observed in northern Wallaroo and these were excluded from fishing during Harvest Period 1.

During Harvest Period 1, 222 t of prawns were commercially harvested from six fishing nights (Figure 4.2). Commercial catches <10 t were harvested from six fishing blocks and catches from 10–30 t were harvested from four fishing blocks. A catch of 30–70 t was harvested from one fishing block in the Middlebank/ Shoalwater region. Large prawns were harvested from two blocks in the Wallaroo region and medium prawns were harvested from all other blocks. It should be noted that the Management Plan encourages the harvest of medium sized prawns during the November and December harvest periods.

During Harvest Period 1 daily catch (t) ranged from 31 to 43 t per day. The daily mean size ranged from 215 to 208 prawns per 7 kg.

4.3.2 Harvest Period 2

During Harvest Period 2, 251 t of prawns were harvested during nine fishing nights (Figure 4.3). Catches <5 t were harvested from four fishing blocks and catches from 5–10 t were harvested from 11 fishing blocks. Catches of 10–30 t were harvested from two fishing blocks in each of the Wallaroo and Middlebank/ Shoalwater regions. Large prawns were harvested from three blocks of these four high catch fishing blocks, and one medium catch fishing block. Medium prawns were harvested from all other blocks, except for one block in South Gutter where small prawns were caught.

During Harvest Period 2 daily catch (t) ranged from 19 to 41 t per day. Daily mean size ranged from 235 to 192 prawns per 7 kg.

4.3.3 Harvest Period 3

Harvest Period 3 was preceded by a Stock Assessment survey in February and a Spot survey during March. The February Stock Assessment survey was conducted over three nights, with catches of small prawns at high catch rates evident through the North region (Figure 4.4). Some catches of large prawns at medium and high catch rates were observed in the Middlebank/ Shoalwater and Wallaroo regions. High catch rates of prawns of various sizes were found in some areas of the Main Gutter and Cowell regions. Catch rates were generally low in all other regions.

A Spot survey was conducted during March in the Wallaroo, Gutter, Cowell and Corny Point regions. High catch rates were found in the Wallaroo and Main Gutter regions, with a mixture of prawn sizes among survey shots (Figure 4.5).

During Harvest Period 3, 197 t was harvested over six nights (Figure 4.6). Catches <5 t were obtained from two fishing blocks and catches 5–15 t were harvested from six fishing blocks. Catches of 15–40 t were harvested from four fishing blocks in the Wallaroo, Wardang and Corny Point regions. Sub-optimal sized prawns for March (>220 prawns per 7kg) were caught in four blocks, including one of high catch.

During Harvest Period 3 daily catch (t) ranged from 20 to 58 t per day. Daily mean size ranged from 225 to 171 prawns per 7 kg, and was below the target reference on night 1.

4.3.4 Harvest Period 4

During Harvest Period 4, 110 t of prawns were harvested during two fishing nights (Figure 4.7). An initial harvest strategy was established in the southern part of the gulf and catches were low on the first night. Catches of 5–20 t were harvested from two fishing blocks in the South Gutter region, with catches <5 t harvested from three other fishing blocks. Following this, the harvest strategy was amended for night 2 to include the area in Wallaroo and Main Gutter regions that was fished during harvest period 3. Catch increased on night 2, with most (20–45 t) taken from one fishing block in each of the Wallaroo and Main Gutter regions. Sub-optimal size prawns were caught in four of the eight fishing blocks during harvest period 4, including one of high total catch.

During Harvest Period 4 daily catch (t) was 26 and 84 t on days 1 and 2, respectively. Daily mean size was 211 and 223 prawns per 7 kg on days 1 and 2, respectively. Mean size was below the target reference on night 2.

4.3.5 Harvest Period 5

The April Stock Assessment survey was conducted over two nights prior to Harvest Period 5. Small prawns were distributed throughout the North region at high and medium catch rates (Figure 4.8). Small and medium prawns were found throughout the Middlebank/ Shoalwater region at high and medium catch rates. Large prawns were found in some parts of the Wallaroo and Main Gutter regions, as well as the Cowell, Wardang and Corny Point regions. The majority of the Wallaroo, Main Gutter and West Gutter regions had medium and high catch rates of prawns of mixed size.

During Harvest Period 5, 377 t of prawns were harvested from eight fishing nights. Catches <10 t were obtained from seven fishing blocks, mostly in the South Gutter and Corny Point regions and catches 10–20 t were harvested from three fishing blocks in Wallaroo and Wardang regions (Figure 4.9). Catches of 20–55 t were obtained from seven fishing blocks distributed throughout the Wallaroo, Middlebank/ Shoalwater, Main Gutter and Corny Point regions. Large prawns were harvested from all but one fishing block in the north of the Wallaroo region, which notably was an area of only low catch (<10 t).

During Harvest Period 5 daily catch (t) reduced linearly from 75 to 20 t per day. Daily mean size generally increased throughout the period, ranging from 216 to 183 prawns per 7 kg.

4.3.6 Harvest Period 6

The previous harvest strategy was maintained for Harvest Period 6 with 161 t of prawns harvested from three fishing nights. Catches of 20–35 t were obtained from three fishing blocks in the Wallaroo and Middlebank/Shoalwater regions, with catches 5–20 t obtained from five others (Figure 4.10). Large prawns were harvested from all fishing blocks. Of note, during May and June harvest periods the target size is <240 prawns per 7 kg for a standard harvest strategy (i.e. medium size prawns).

During Harvest Period 6 daily catch ranged from 45 to 58 t per day and daily mean size ranged from 205 to 198 prawns per 7 kg.

4.3.7 Harvest Period 7

Prior to Harvest Period 7, a May spot survey was conducted in the North, Middlebank/ Shoalwater and Wallaroo regions. Catches were mixed throughout, with an area of large and medium size prawns at high catch rates observed in the Middlebank/Shoalwater and Wallaroo regions (Figure 4.11). An area of small prawns at moderate catch rates was clustered in the Wallaroo region among areas of large and medium prawns.

During Harvest Period 7, 396 t of prawns was harvested from eight fishing nights. Catches <10 t were harvested from five fishing blocks and catches of 10–30 t were harvested from nine fishing blocks (Figure 4.12). Catches of 30–60 t were obtained from four fishing blocks in the Middlebank/ Shoalwater and Wallaroo regions. Whilst catches of moderate and large prawns were harvested throughout the gulf, the northernmost fished block produced high catches (30–60 t) of sub-optimal, small (<240 prawns per 7 kg) prawns.

During Harvest Period 7, daily catch declined linearly from 77 to 25 t per day. Daily mean size was outside the target range (<240 prawns per 7 kg) for the first two nights (243 and 241 prawns per 7 kg), and ranged from 228 to 206 prawns per 7 kg thereafter.

4.3.8 Harvest Period 8

Prior to Harvest Period 8, a June spot survey was conducted in the North and Middlebank/ Shoalwater regions. Catches were mixed in size and generally of low or medium catch rates (Figure 4.13).

During Harvest Period 8, 316 t of prawns was harvested from nine fishing nights. Catches <10 t were harvested from seven fishing blocks and catches of 10–30 t were harvested from nine fishing blocks (Figure 4.14). Catches of 30–70 t were obtained from on fishing block in the Middlebank/ Shoalwater region. Catches of moderate and large prawns were harvested throughout the Middlebank/ Shoalwater, Wallaroo and Main gutter regions, however the opening in the North region produced catches of predominately sub-optimal, small (<240 prawns per 7 kg) prawns.

During Harvest Period 8 daily catch (t) reduced linearly from 50 to 19 t per day. Daily mean size ranged from 234 to 196 prawns per 7 kg.

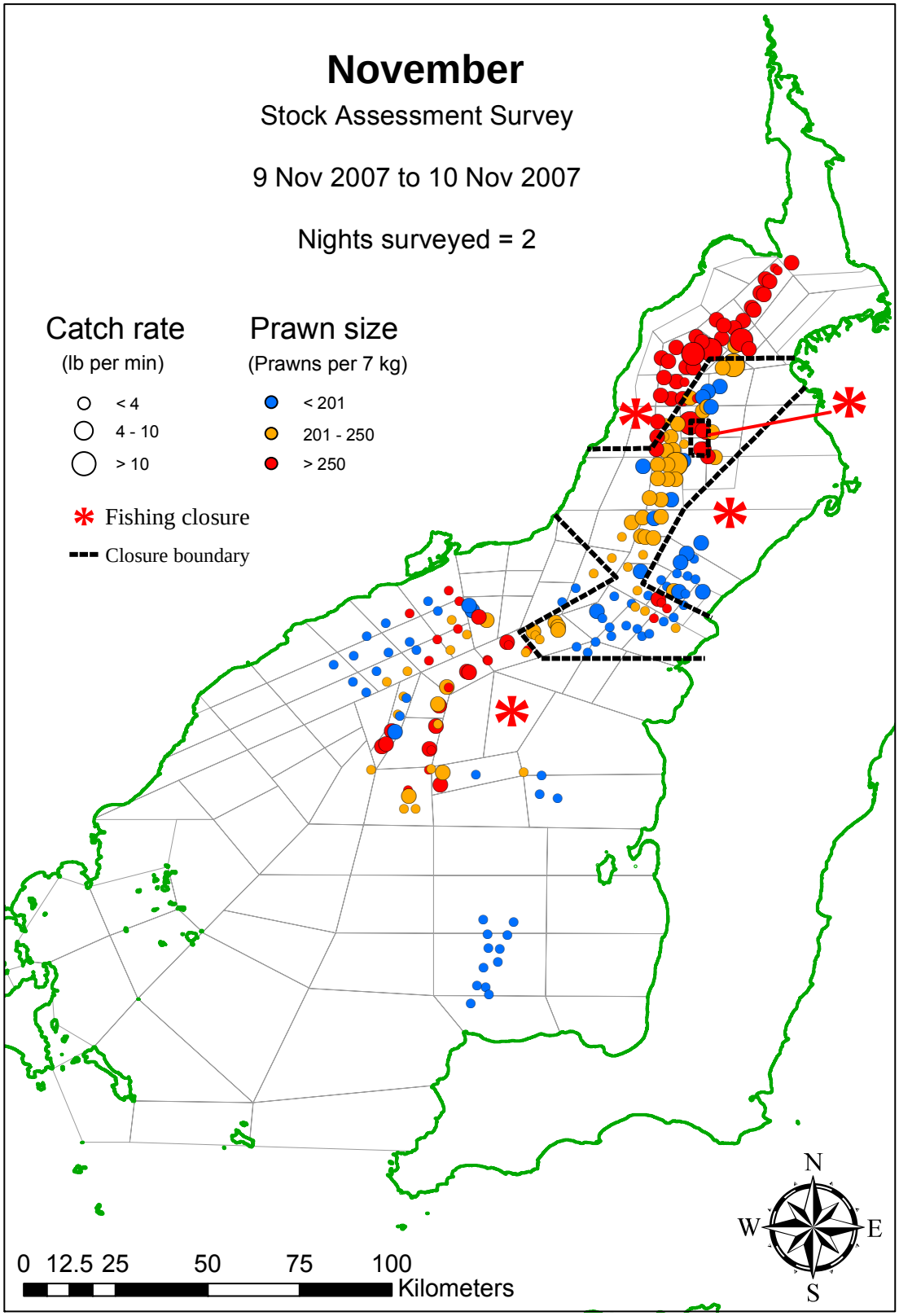

Figure 4.1 Catch rate and mean size during the November 2007 Stock Assessment survey, prior to harvest period 1. Black dotted lines represent harvest strategy closure lines.

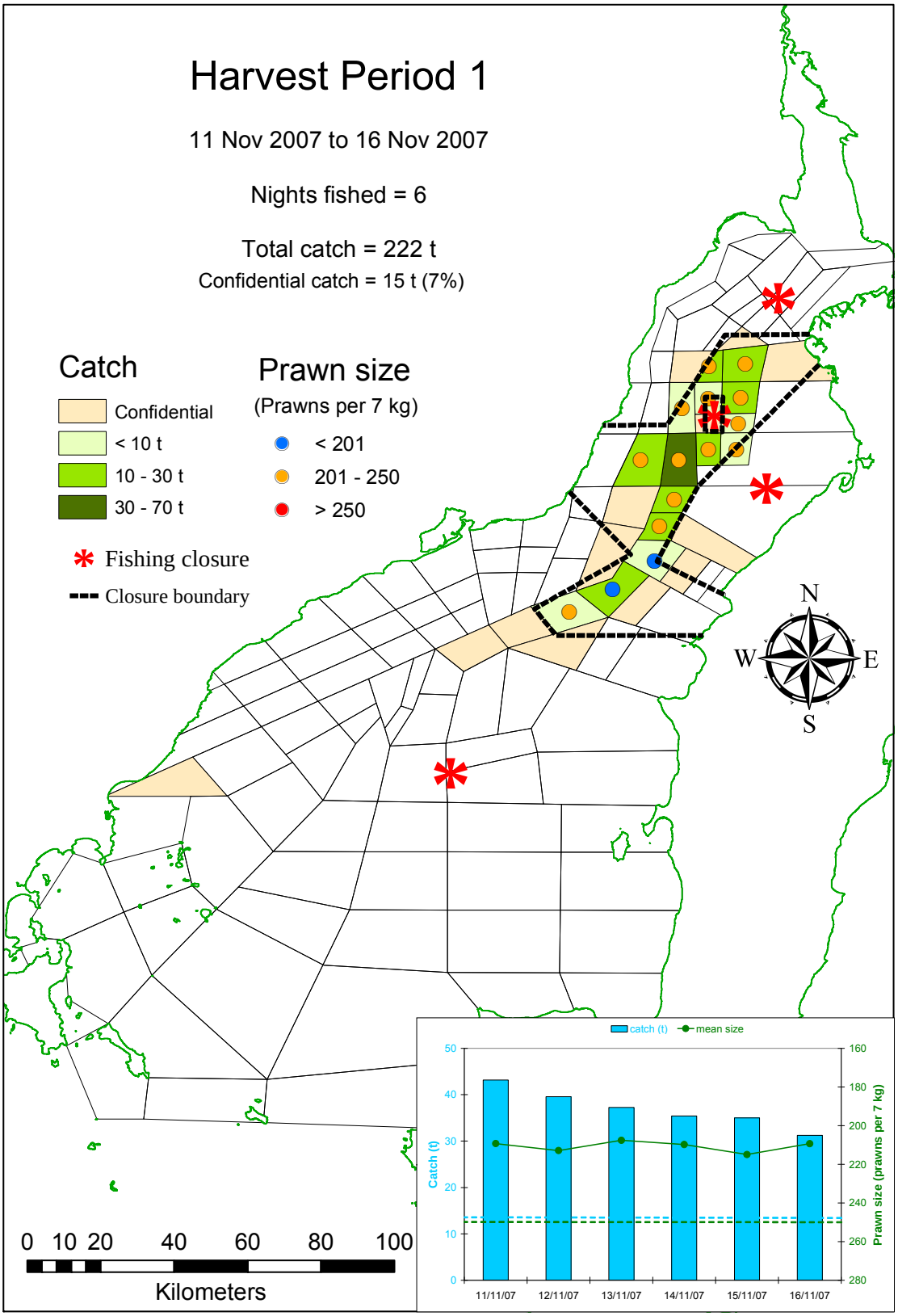

Figure 4.2 Commercial catch and mean size from blocks fished during harvest period 1. Black dotted lines represent harvest strategy closure lines. Inset graphs display daily total catch (blue bars), daily mean prawn size (green line) and at sea decision rules for daily total catch (blue dotted line) and mean daily prawn size (green dotted line).

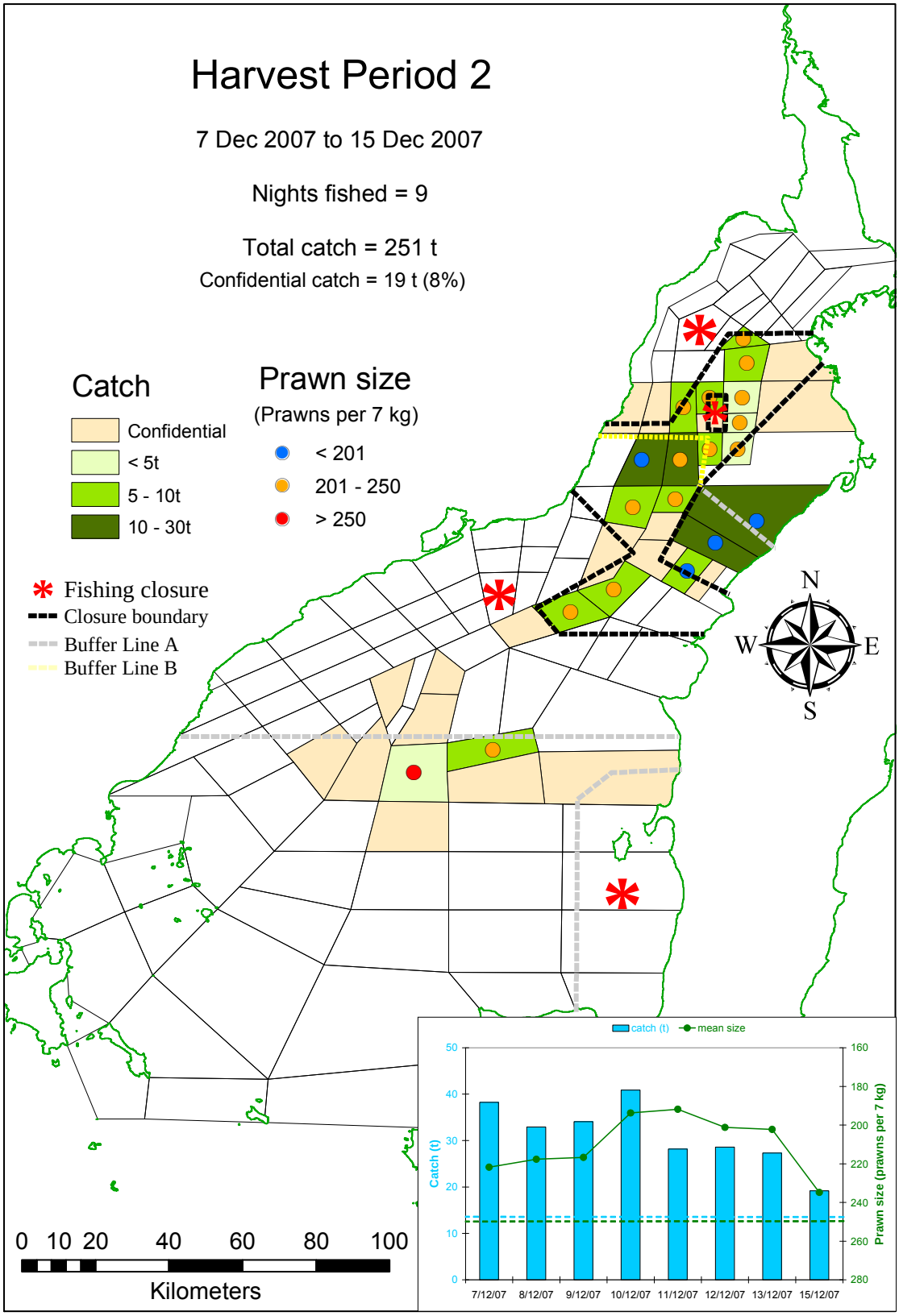

Figure 4.3 Commercial catch and mean size from blocks fished during harvest period 2. Black dotted lines represent harvest strategy closure lines. Grey and yellow dotted lines represent harvest strategy amendments. Inset graphs display daily total catch (blue bars), daily mean prawn size (green line) and at sea decision rules for daily total catch (blue dotted line) and mean daily prawn size (green dotted line).

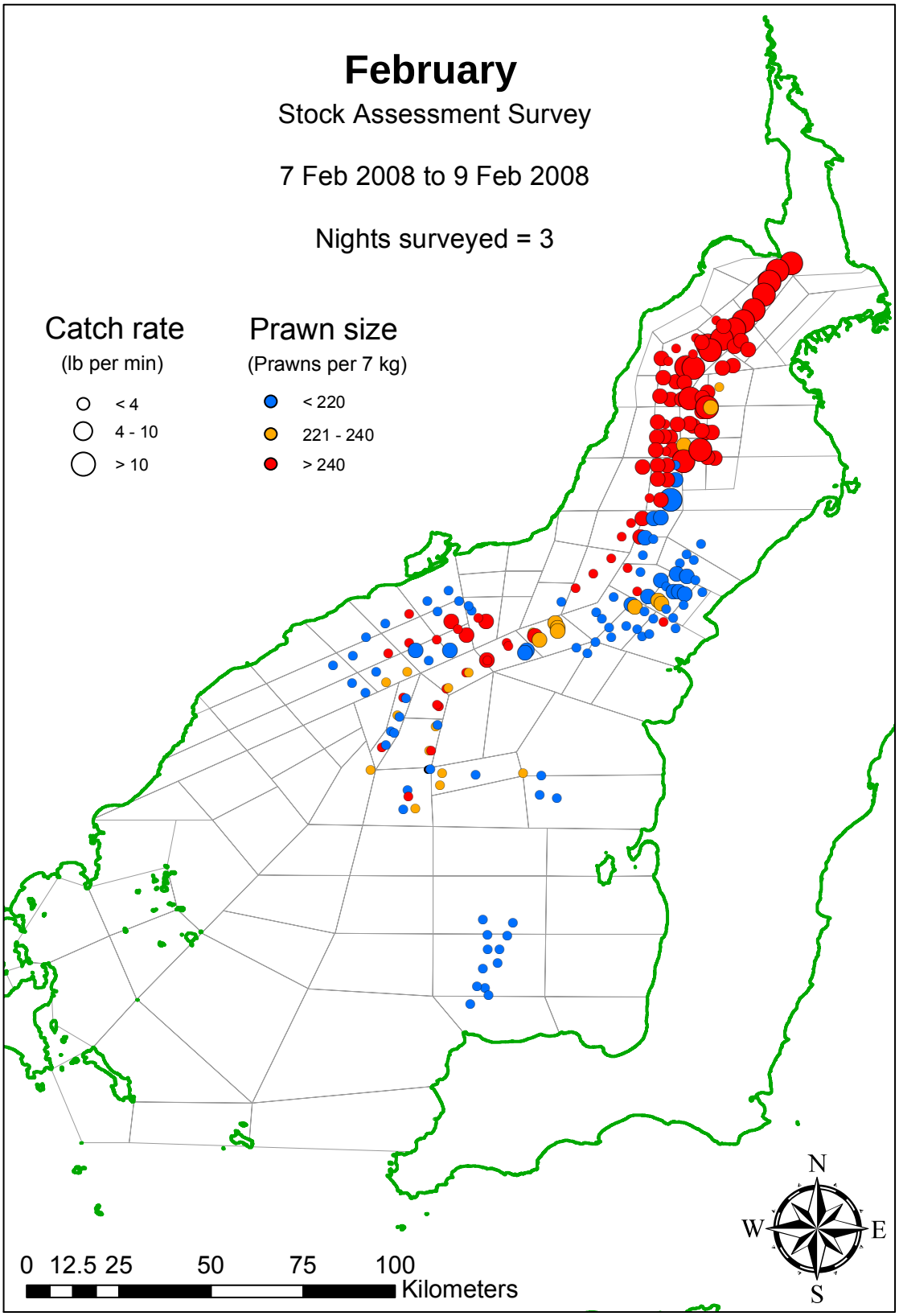

Figure 4.4 Catch rate and mean size during the February 2008 Stock Assessment survey.

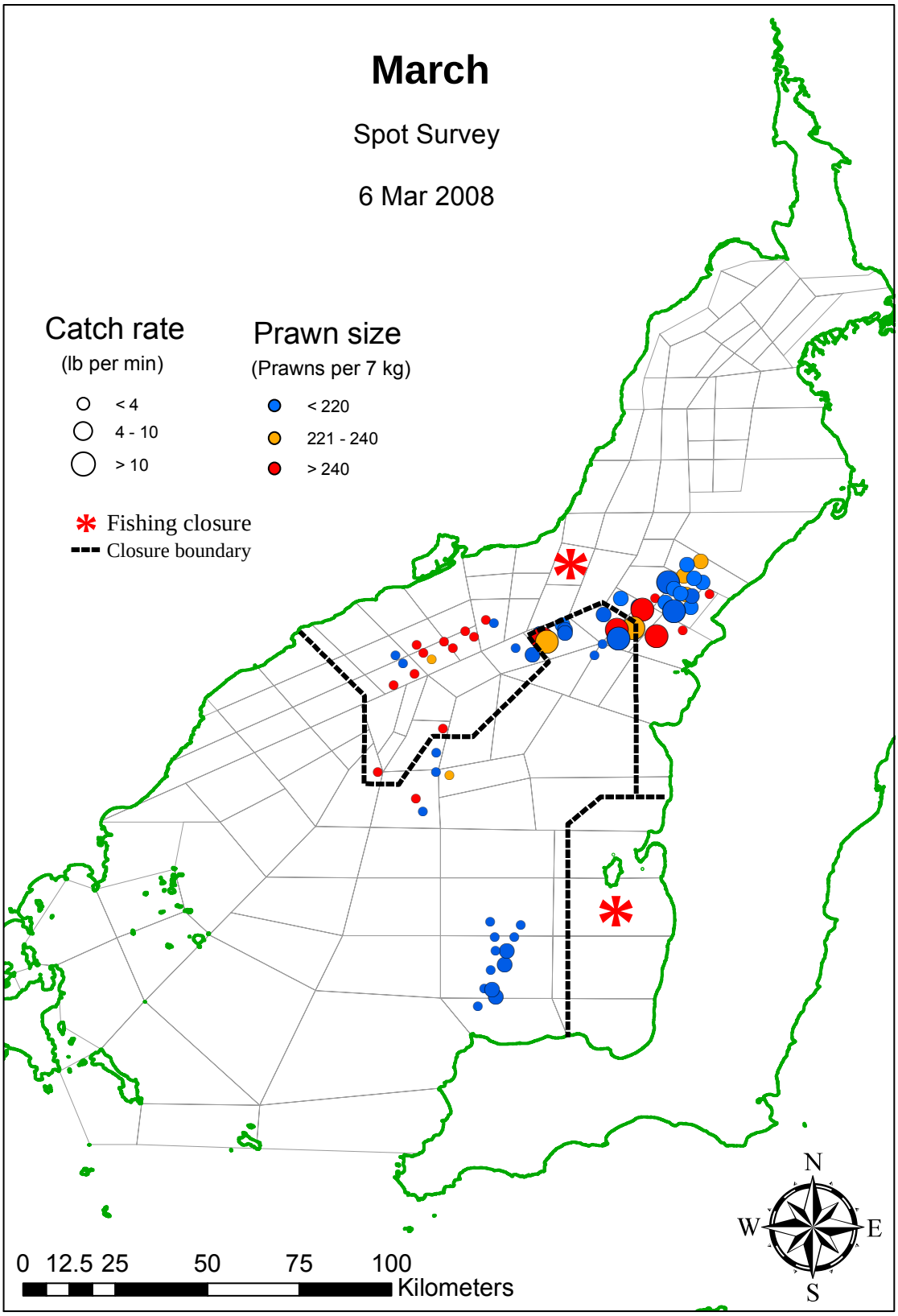

Figure 4.5 Catch rate and mean size during the March 2008 Spot survey, prior to harvest period 3. Black dotted lines represent harvest strategy closure lines.

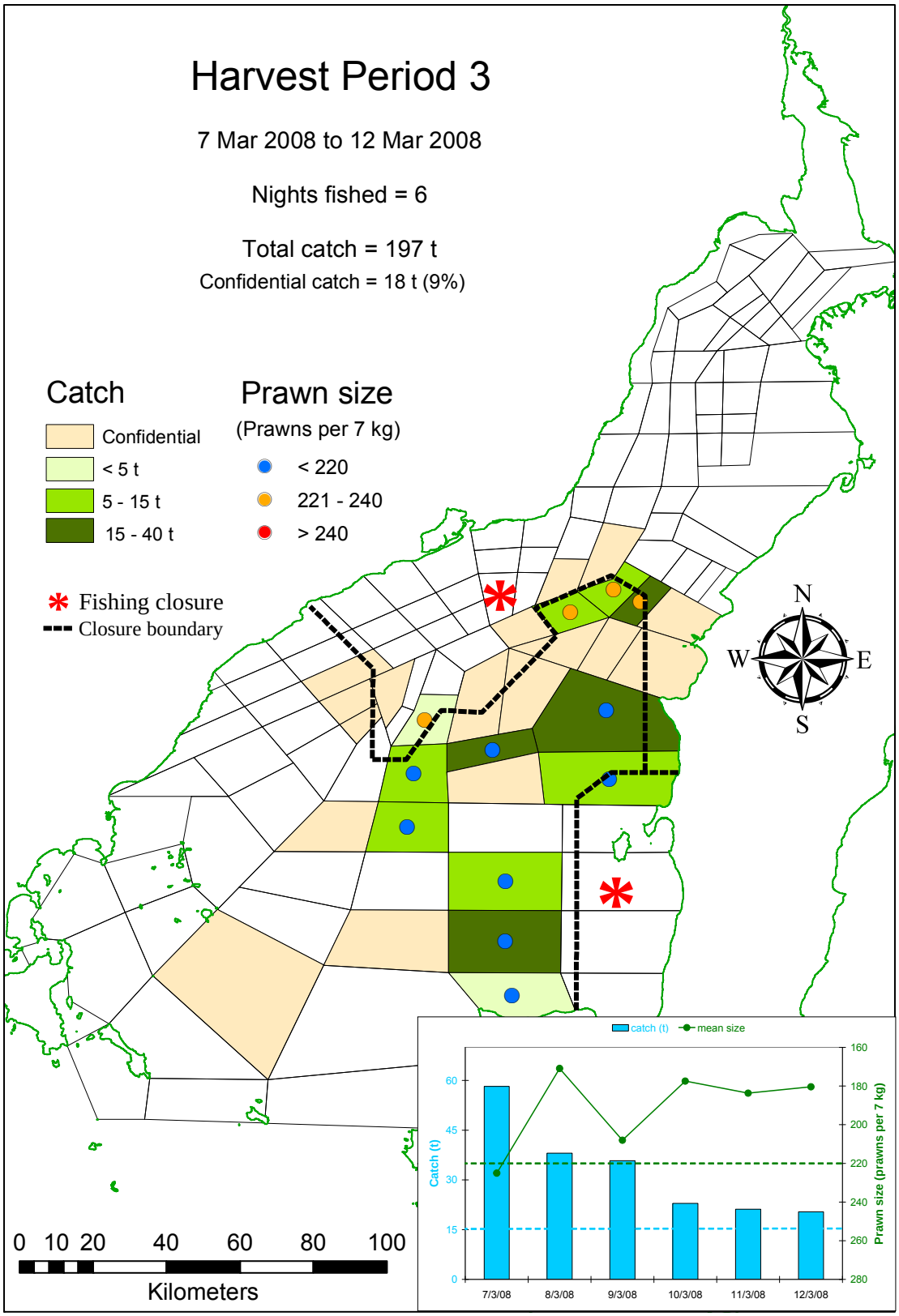

Figure 4.6 Commercial catch and mean size from blocks fished during harvest period 3. Black dotted lines represent harvest strategy closure lines. Inset graphs display daily total catch (blue bars), daily mean prawn size (green line) and at sea decision rules for daily total catch (blue dotted line) and mean daily prawn size (green dotted line).

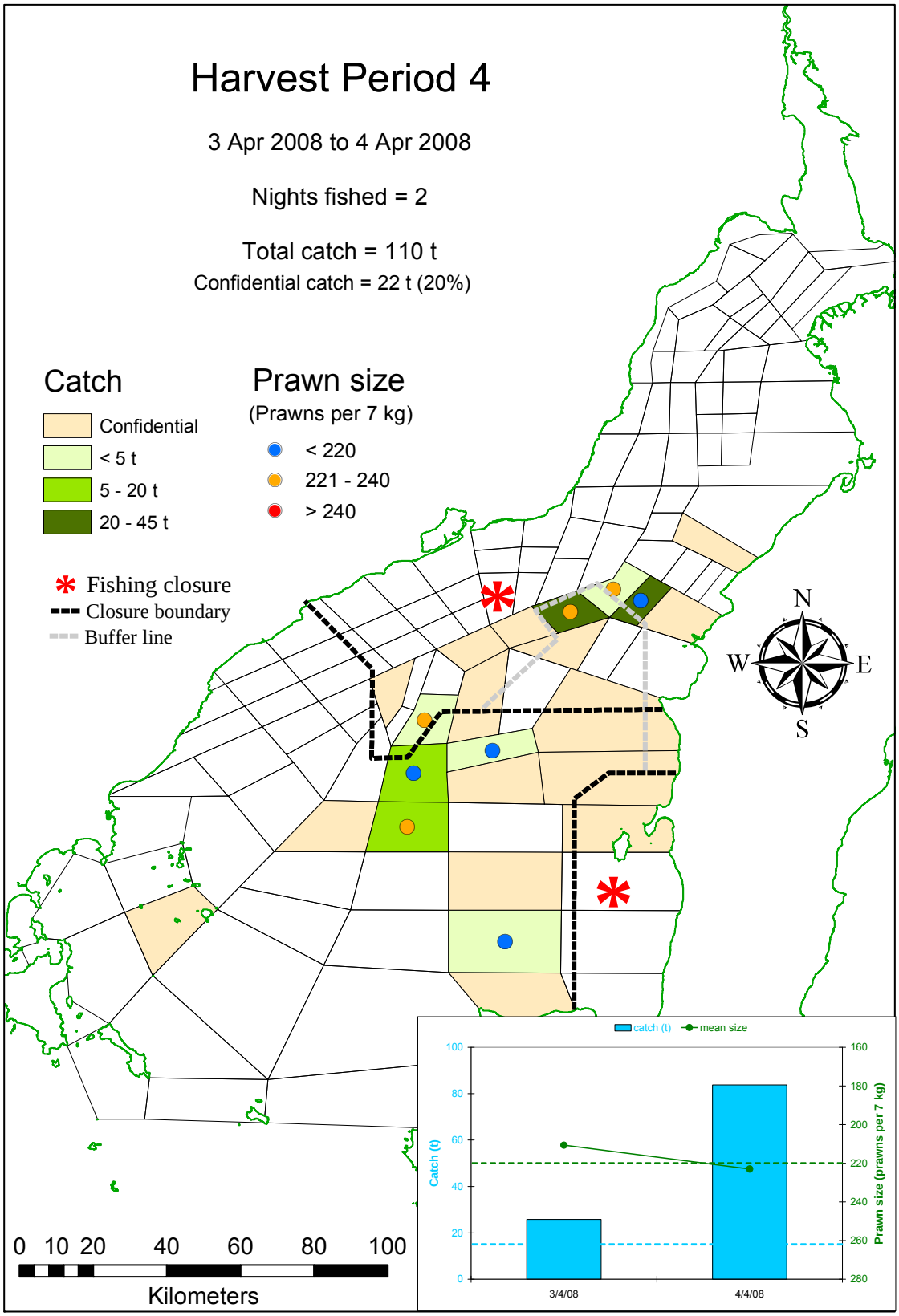

Figure 4.7 Commercial catch and mean size from blocks fished during harvest period 4. Black dotted lines represent harvest strategy closure lines. Grey dotted lines represent harvest strategy amendments for night 2. Inset graphs display daily total catch (blue bars), daily mean prawn size (green line) and at sea decision rules for daily total catch (blue dotted line) and mean daily prawn size (green dotted line).

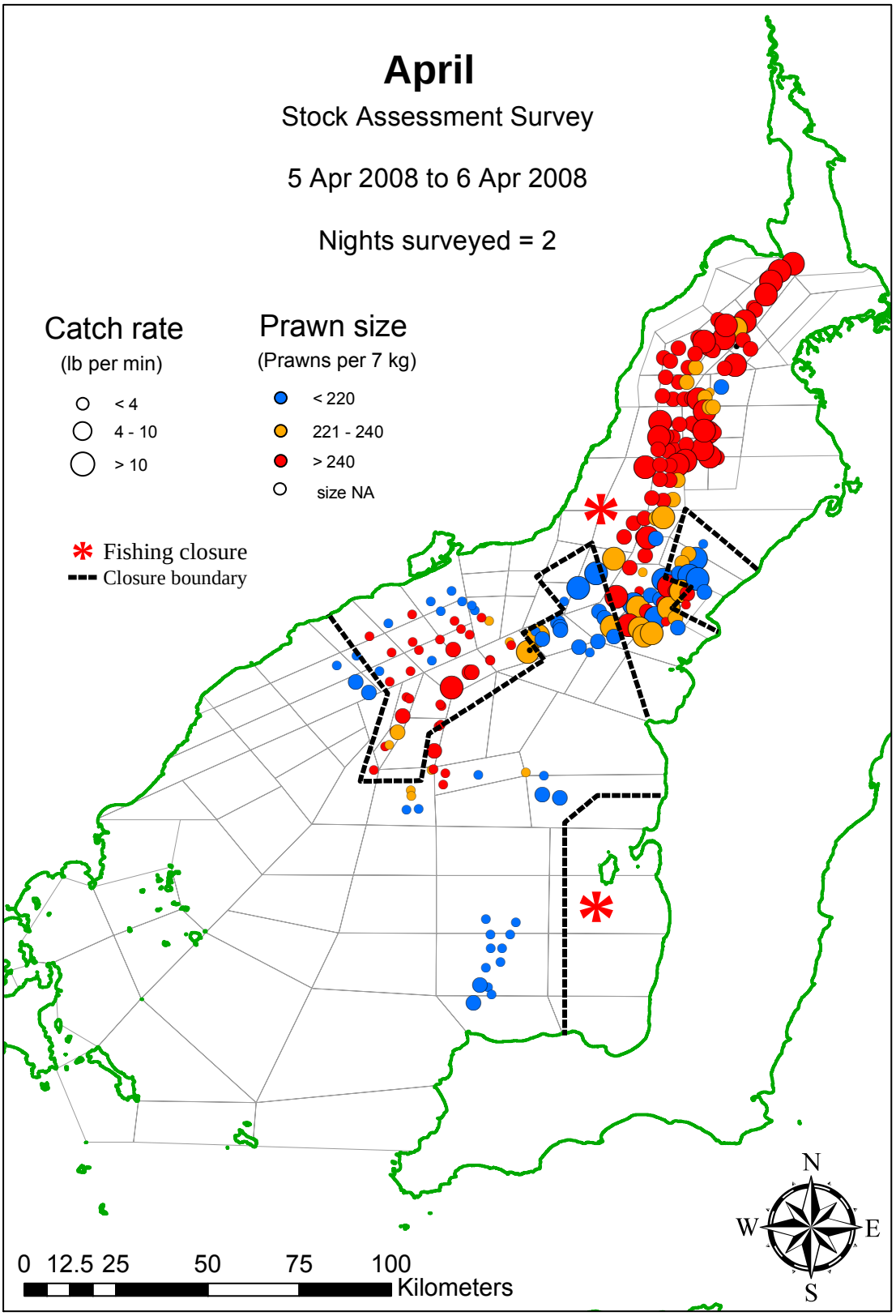

Figure 4.8 Catch rate and mean size during the April 2008 Stock Assessment survey, prior to harvest period 5. Black dotted lines represent harvest strategy closure lines.

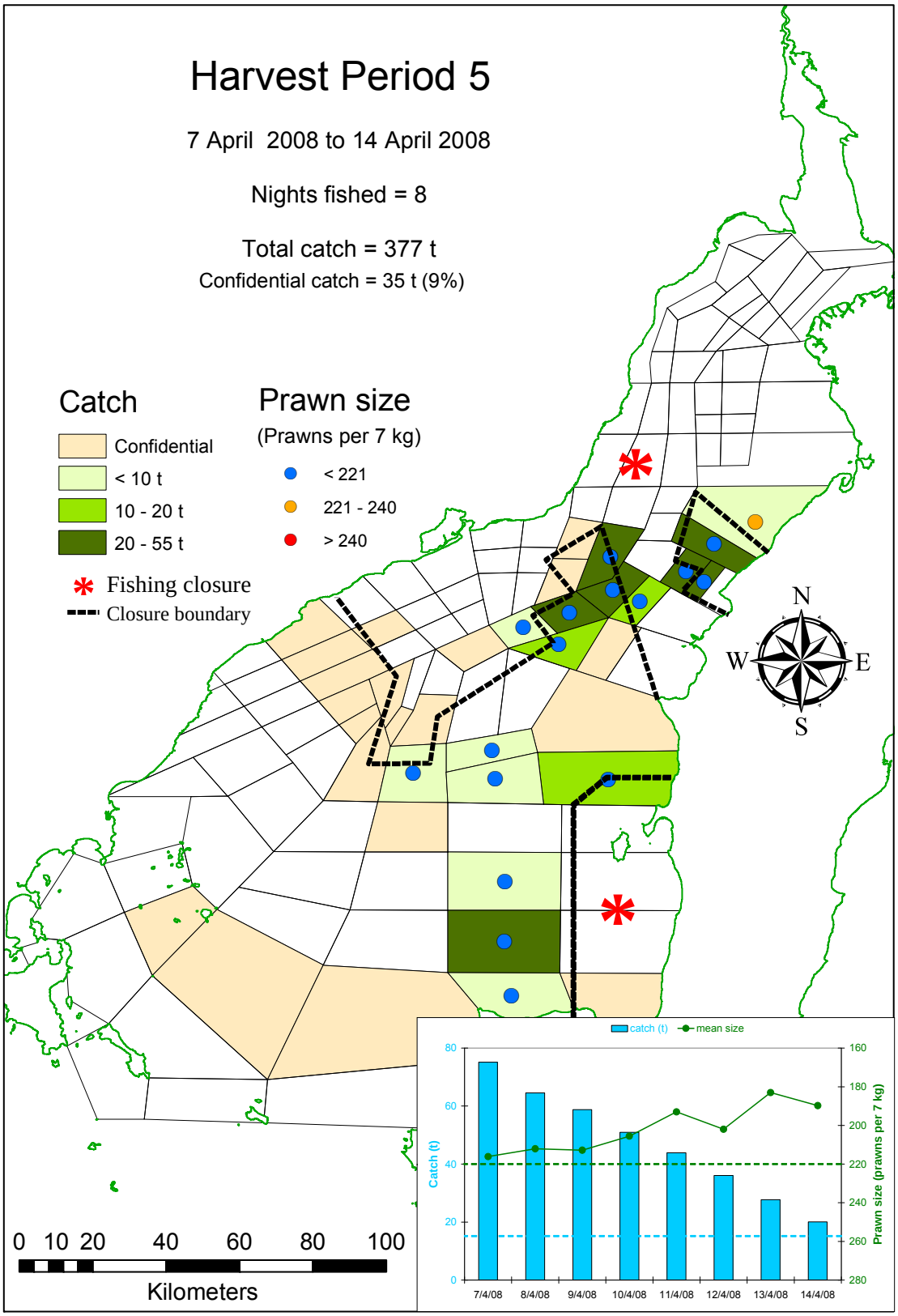

Figure 4.9 Commercial catch and mean size from blocks fished during harvest period 5. Black dotted lines represent harvest strategy closure lines. Inset graphs display daily total catch (blue bars), daily mean prawn size (green line) and at sea decision rules for daily total catch (blue dotted line) and mean daily prawn size (green dotted line).

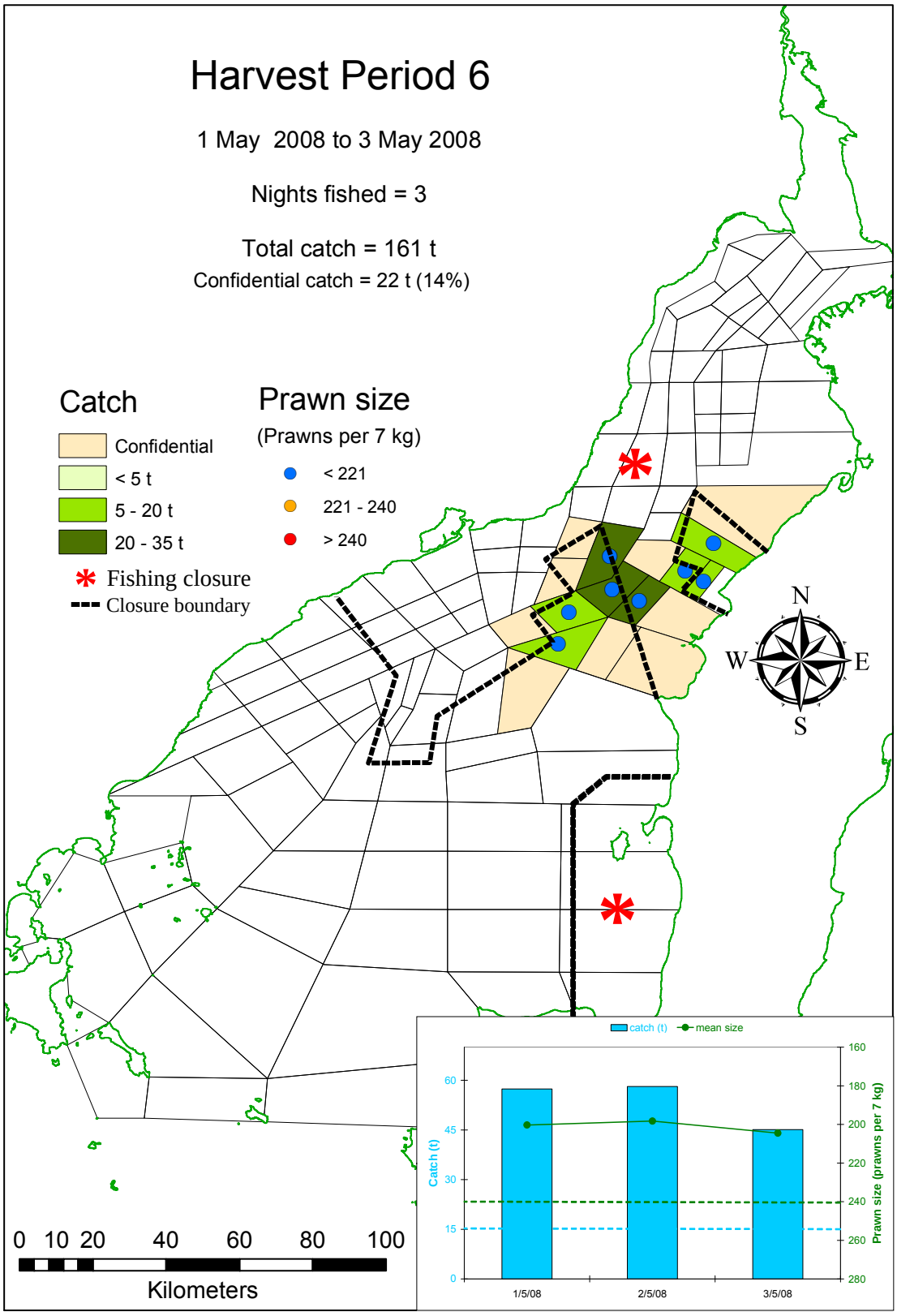

Figure 4.10 Commercial catch and mean size from blocks fished during harvest period 6. Black dotted lines represent harvest strategy closure lines. Inset graphs display daily total catch (blue bars), daily mean prawn size (green line) and at sea decision rules for daily total catch (blue dotted line) and mean daily prawn size (green dotted line).

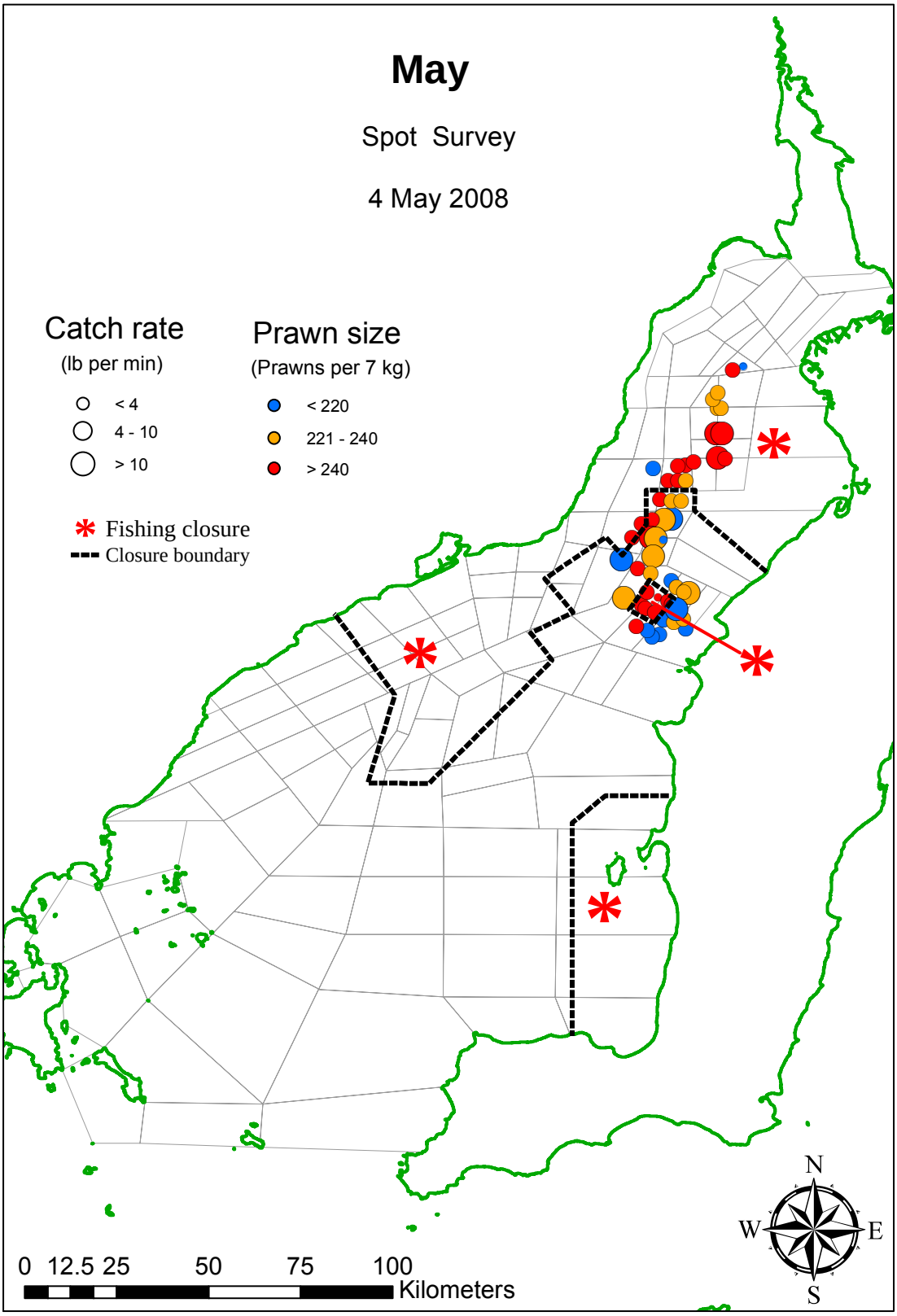

Figure 4.11 Catch rate and mean size during the May 2008 Spot survey, prior to harvest period 7. Black dotted lines represent harvest strategy closure lines.

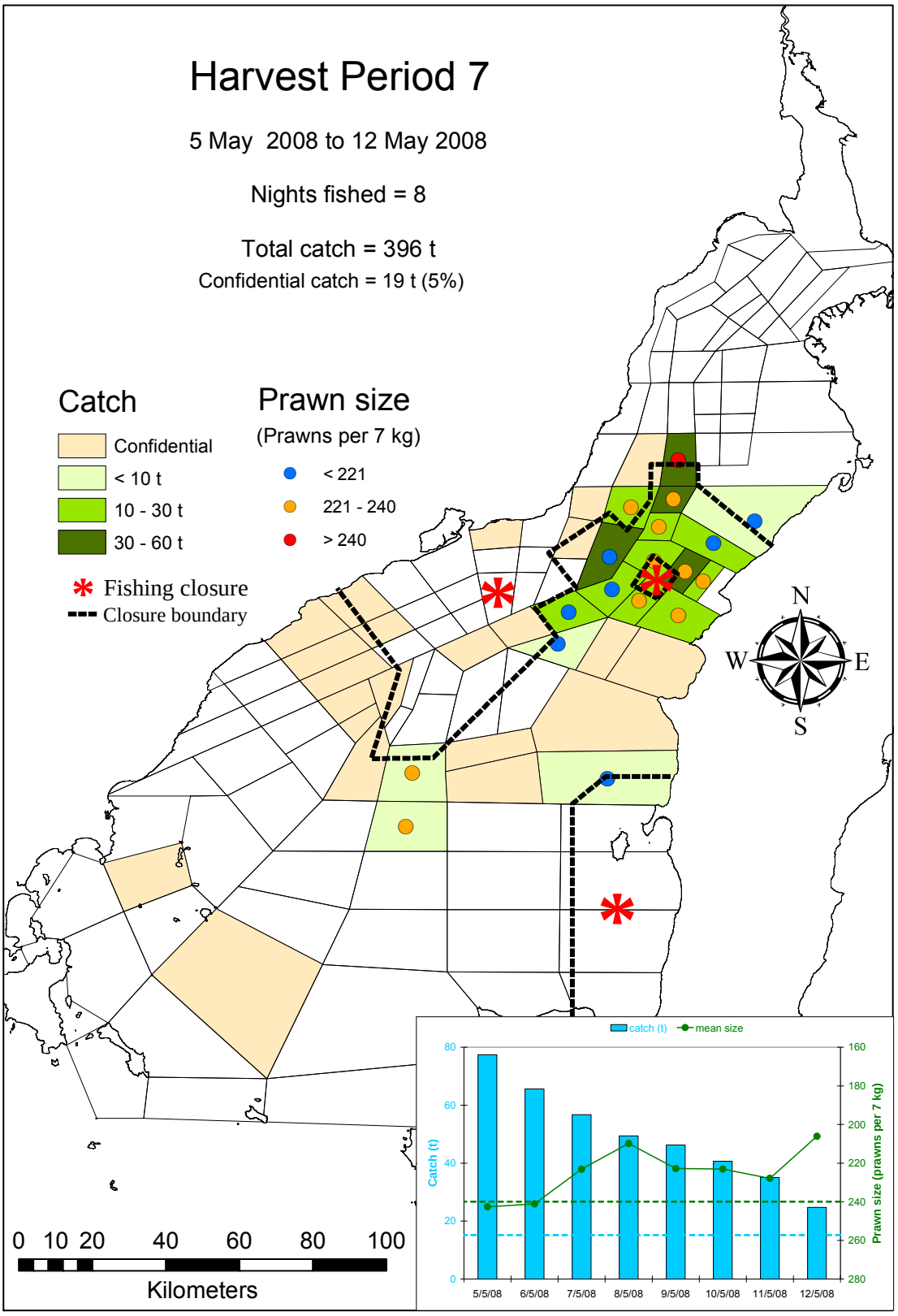

Figure 4.12 Commercial catch and mean size from blocks fished during harvest period 7. Black dotted lines represent harvest strategy closure lines. Inset graphs display daily total catch (blue bars), daily mean prawn size (green line) and at sea decision rules for daily total catch (blue dotted line) and mean daily prawn size (green dotted line).

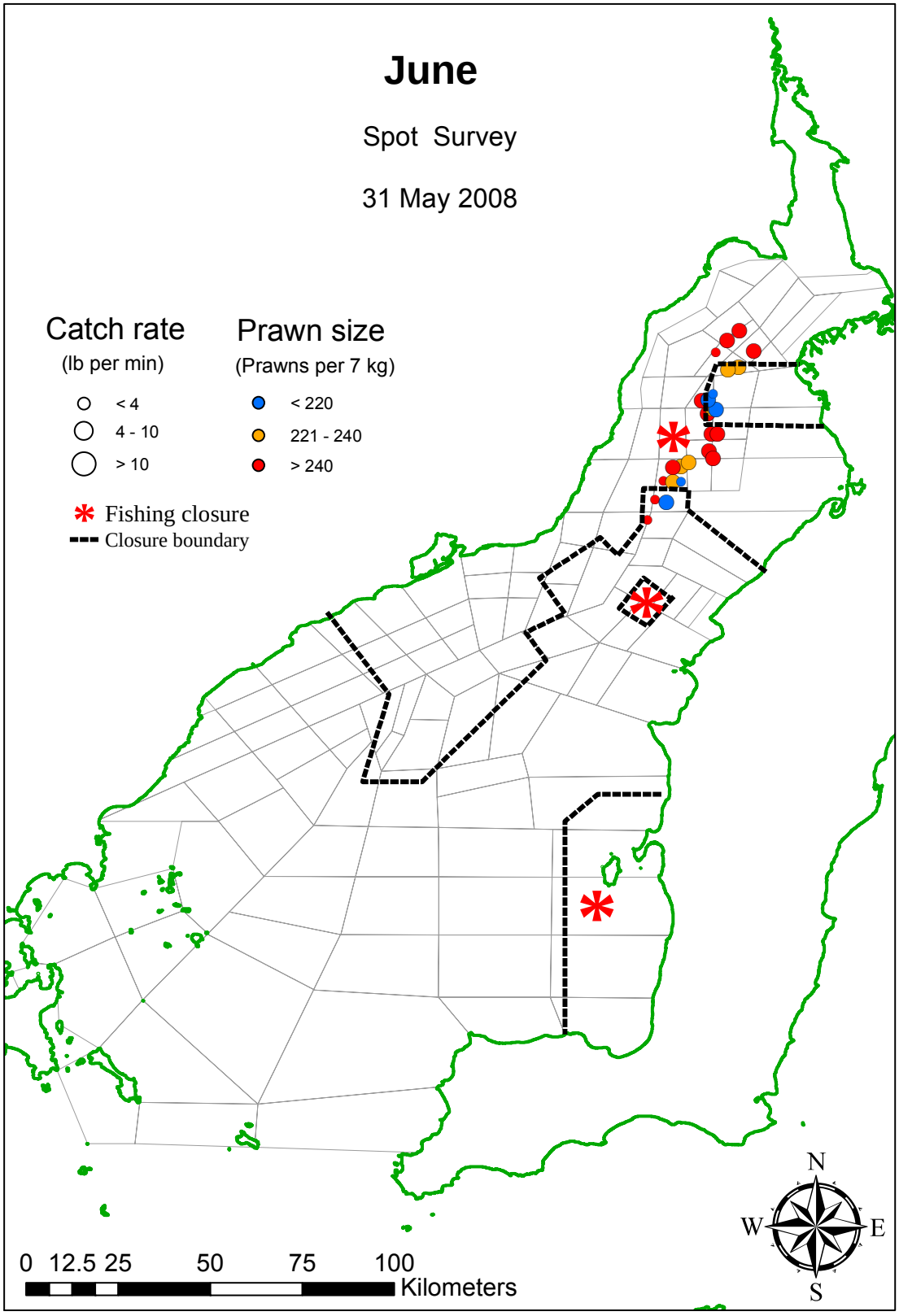

Figure 4.13 Catch rate and mean size during the June 2008 Spot survey, prior to harvest period 8. Black dotted lines represent harvest strategy closure lines

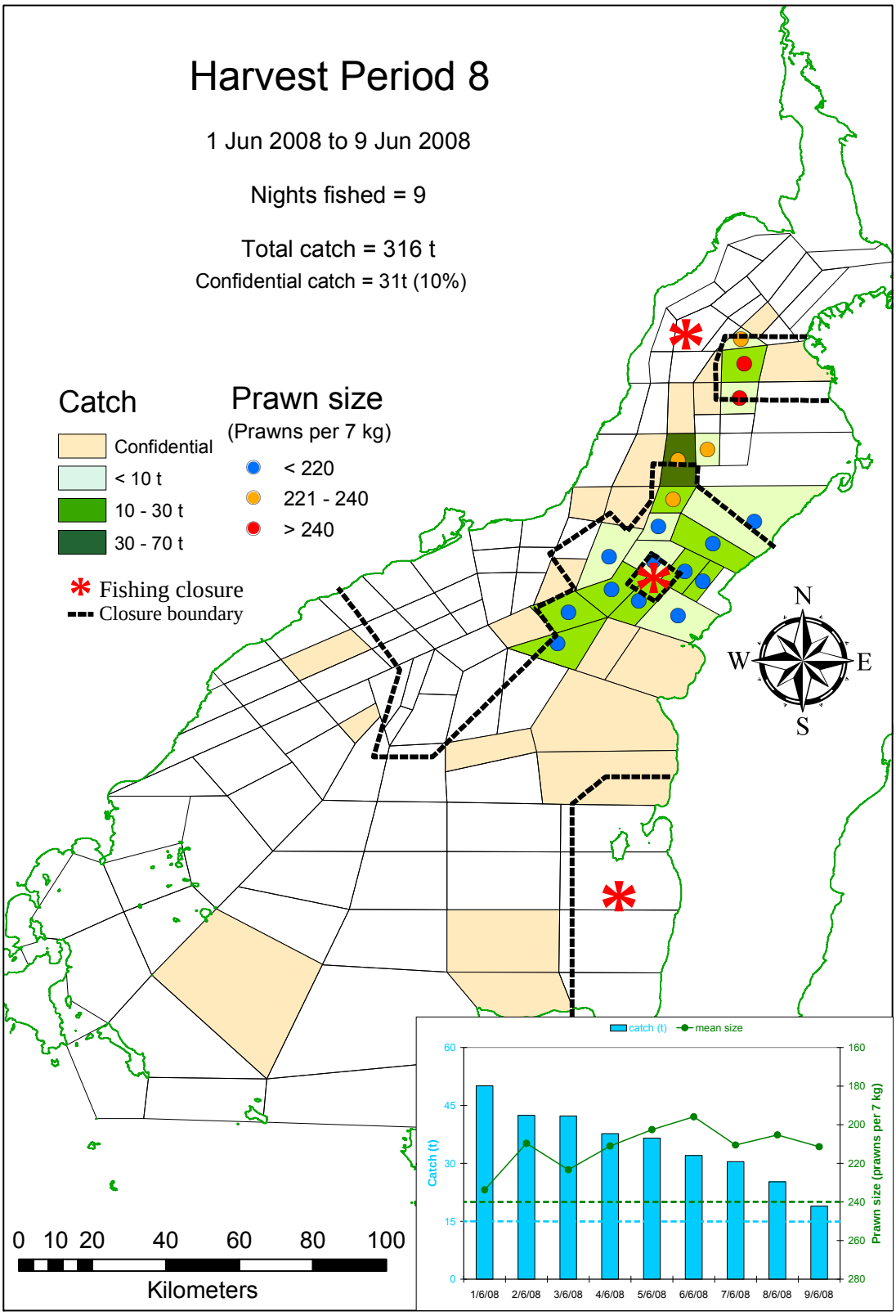

Figure 4.16 Commercial catch and mean size from blocks fished during harvest period 8. Black dotted lines represent harvest strategy closure lines. Inset graphs display daily total catch (blue bars), daily mean prawn size (green line) and at sea decision rules for daily total catch (blue dotted line) and mean daily prawn size (green dotted line).

4.4 Discussion

The 2007/08 season began with the November stock assessment survey. A harvest strategy was developed that included the North, Middlebank/ Shoalwater, Wallaroo and Main Gutter regions. Notably, an area of large prawns in the north of the Wallaroo region was excluded from fishing in harvest period 1 to protect large spawning females. During six fishing nights in November, 222 t was harvested of target size prawns. During harvest period 2, 251 t was harvested from nine fishing nights in December. In this period, the spawning prawns protected during November were fished. Fishing was also conducted for one night in the south. Prawns were harvested at the target size except for one fishing block in the South Gutter region.

A stock assessment survey was conducted in February 2008, followed by a spot survey in March. From these surveys, a harvest strategy was developed that included the north of the Main Gutter and all southern regions. The opening in the Main Gutter region was based on March spot survey results, and included shots with high catch rates of small, medium and large prawns. Subsequently, 197 t was harvested from six fishing nights in harvest period 3. Prawn size was outside of the target range in four fishing blocks, particularly in the Main Gutter region. Furthermore, the average size of prawns caught across the fleet during night 1 was outside of the target range for this period. Notably, the catch during night 1 was approximately 30% of the total catch for this period.

Harvest period 4 consisted of two nights fishing prior to the April stock assessment survey, from which 110 t was harvested. Night 1 was conducted in southern regions only and the total catch was low (25.8 t). Prawns outside of the target range were caught in two of the five blocks fished. On night 2 the harvest strategy was changed to include the area of the Main Gutter fished during harvest period 3. Total catch increased, but sub-optimal sized prawns were again caught in two of the three fishing blocks. Furthermore, this again resulted in the average size of the catch for the fleet falling outside of the target range on night 2.

A stock assessment survey was conducted over two nights in April. Subsequently, a harvest strategy was developed that included the Wallaroo, Middlebank/ Shoalwater, Main Gutter, and all southern regions. A total of 377 t was harvested from eight fishing nights. Prawn size was within the target range in all but one fishing block. The same harvest areas were used for harvest period 6, with 161 t taken from three fishing nights. Again, prawn size was within the target range.

A spot survey was conducted prior to harvest period 7 in the North, Middlebank/ Shoalwater and Wallaroo regions. Subsequently, a harvest strategy was developed that included some small prawns, particularly at its northern boundaries. An area of small prawns was excluded from fishing in the Wallaroo region. During harvest period 7, 396 t was caught from eight fishing nights. Prawns were caught within target size criteria in all but the northernmost fishing block, where 30–60 t of small prawns were caught. The average size of prawns caught across the fleet was also outside of the target size criteria on the first two nights of fishing during this period.

A spot survey was conducted in June in the North and Middlebank/ Shoalwater regions. The closure lines from harvest period 7 were maintained and a new area in the North region was also opened. During harvest period 8, 316 t was harvested from nine fishing nights. Target size prawns were caught in all regions except the North, where the majority of catch was outside of the target range (<240 prawns per 7 kg).

These analyses identify several occasions when prawn size was outside of the target range specified in the Management Plan. This occurred at the scale of fishing blocks within harvest periods and also at the scale of mean daily capture size from the fleet. These breaches were most prevalent during March, early April, May and June following harvest strategies determined from spot surveys.

Sub-optimal size prawns were caught during March in the Main Gutter from a harvest strategy developed from the March spot survey. Notably, only one of the four shots with high catch rates that were included in the open area were of target size prawns, while two of the four were small prawns (>240 per 7 kg). This same area was fished in early April, and again high catches of sub-optimal sized prawns were caught.

Sub-optimal sized prawns were also caught in May and June following harvest strategies developed after spot surveys. The issue in May regarded the northern boundary of the strategy, which did include some small prawns observed on survey. It is also likely that the small prawns immediately to the north of the closure boundary were constantly moving into the fished area, which has contributed to the small average size. The opening in the North region during June was based on low and medium catch rates of medium and large prawns observed during spot survey. Prawns sizes caught during fishing were smaller than those observed on the spot survey.

5. PERFORMANCE INDICATORS

In this section, performance of the fishery is assessed against the Performance Indicators (PIs) identified in the Management Plan (Dixon and Sloan 2007). The Plan provides a set of key PIs (Table 5.1) that, if breached, initiate a management response. That response includes a comprehensive assessment of additional performance measures (Table 5.2).

Table 5.1 Summary of key Performance Indicators for the 2005/06, 2006/07 and 2007/08 fishing years of the Spencer Gulf Prawn Fishery (Dixon and Sloan 2007).

PI	Limit RP	'05/'06	'06/'07	'07/'08
Recruitment index	>35	42.1	47.0	44.3
Total commercial catch (t)	>1800	1,870	2,023	2,028
Mean commercial CPUE (kg/h)	>80	105	109	110
% vessel nights with mean size >280 prawns/7 kg	<2%	0.8	0.2	0.6
Fishery independent surveys	3 surveys completed	Yes	Yes	Yes
Indices of future and current biomass	Neither index is below threshold levels in 2 consecutive surveys	N/A	✓	✓
Committee comply with harvest strategy decision rules	Committee develops all harvest strategies based on results of surveys and in accord with decision rules	N/A	✓	✓

N/A: Not applicable

5.1 Recruitment index

Recruitment indices were calculated as the square root transformation of the numbers of prawns (males <33 and females <35 mm carapace length) per nautical mile trawled (after Carrick 2003). The recruitment index of 44.3 during 2007/08 was above the limit RP.

5.2 Total commercial catch

Total commercial catch was higher in 2007/08 (2,028 t) than the two previous years and was above the limit RP for the fishery.

5.3 Mean commercial CPUE

Mean commercial CPUE was higher during 2007/08 (110 kg/h) than the two previous years and was above the limit RP for the fishery.

5.4 Percent of vessel nights where mean size was smaller than 280 prawns per 7 kg

The mean size of prawns harvested for each vessel night was calculated from commercial logbook prawn grade data. During 2007/08, prawns with an average size smaller than 280 prawns per 7 kg were harvested on 12 of 1938 (0.6%) vessel nights when prawn grade data were reported. This was above the limit RP for the fishery.

5.5 Fishery independent surveys

Three fishery independent surveys were conducted during 2007/08.

5.6 Indices of current and future biomass

Indices of current and future biomass were above threshold levels for all three stock assessment surveys. Standard strategies were applicable throughout 2007/08.

5.7 Committee comply with harvest strategy decision rules

Standard strategies suggest that 1) total pre-Christmas catch does not exceed 450 t, 2) average prawn sizes smaller than 220 prawns per 7 kg are not captured during March and April and 3) average prawn sizes smaller than 240 prawns per 7 kg are not captured during May and June. The Management Plan allows that a strategy may be exceeded for one period, but not for consecutive periods.

During 2007/08, the pre-Christmas catch (473 t) exceeded the suggested limit for a standard strategy. A lack of appropriate quantitative measures currently prevents objective assessment of harvest strategy decision rules for prawn size. However, it should be noted that sub-optimal sized prawns were harvested on some occasions during March, May and June.

5.8 Additional performance measures

The Management Plan provides a set of additional performance measures that are critically assessed if a key PI is breached (Table 5.2). Triggering additional performance measures does not evoke a management response.

Table 5.2 Summary of additional performance measures for the 2005/06, 2006/07 and 2007/08 fishing years of the Spencer Gulf Prawn Fishery (Dixon and Sloan 2007).

Performance Measure	Limit RP	'05/'06	'06/'07	'07/'08
Recruit index November survey all shots	>12	15.7*	12.7	**10.2**
Recruit index February survey all shots	>19	34.3*	22.4	24.2
Recruit index April survey all shots	>15	29.0*	19.6	21.2
Egg production (eggs*10^6/ hr trawled)	>500	710	**423**	870
% of 20+ in the catch – Nov & Dec	<12%	2.8	4.3	3.0
% of 20+ in the catch – March to June	<7%	6.0	2.0	4.1
% of 16–20 in the catch – Nov & Dec	25–35%	27.9	26.7	25.0
% of 16–20 in the catch – March to June	<30%	28.0	23.8	28.0

PI breached

N/A: Data not available

* Estimated from a reduced number of survey shots

Recruitment Indices were calculated as the square root of the numbers of prawns (males <33 and females <35 mm carapace length) per nautical mile trawled (after Carrick 2003). As GPS data were unreliably reported on some occasions during surveys, a mean trawl distance of 1.593 nm per 30 minute trawl shot was used to convert to distance measures (calculated from reliable survey GPS data). Recruitment index was determined from a reduced number of survey shots during 2005/06. During 2007/08, recruitment indices were within the reference range for February and April, but outside the reference range for November.

Egg production estimates were determined from the model presented in Section 3.6. Egg production in 2007/08 (870 eggs*10^6/ hr trawled) was the highest observed in the last three years and was above the limit RP.

From November to December and March to June 2007/08 the proportion of 20+ and 16–20 grade prawns were within acceptable reference ranges.

5.9 Discussion

All of the seven key PI's for the fishery were either achieved or were above the acceptable limit reference range during 2007/08. One of the eight additional performance measures (November recruitment index) was below the limit RP.

The PI for "Committee comply with harvest strategy decision rules" can not be objectively assessed as there are currently no quantitative measures in which to assess harvest strategy development and management by the Committee-At-Sea. In particular, this requires assessment of prawns size and catch rate data from survey shots included in harvest strategies. Without such measures, harvest strategy development can only be assessed in a subjective manner.

As discussed in previous reports, the current egg production model is in its infancy of development, and will be substantially augmented in the next two years with the completion of FRDC project 2008/011. Also, the limit RP for egg production is determined as a fixed value, when a more appropriate approach may be to link the limit RP to a reference year (e.g. 2004/05) to ensure that the assessment is relevant to a modified egg production model in the future.

The relatively low recruit abundance observed during November 2007/08 from all sites is contrary to the strong position reflected in other recruitment indices. It should be noted that recruit abundance is generally low in November compared to other months and that the limit RP was determined from a short time series of data (since 2004/05 only). As such, it is not deemed that the breach of this PI provides concern for the sustainability of the fishery.

There is an urgent need to collect information on the fishing power of the fleet. These data are critical for interpreting changes in CPUE data that underpin the PI for "indices of current and future biomass" and "commercial CPUE".

6. DISCUSSION

6.1 Limitations in the Information Available for Assessment

Annual fishery assessments are underpinned by fishery-dependent catch and effort information, and fishery-independent survey and biological data. Annual catch and effort data are available since the inception of the fishery in 1968, daily logbook data are available since the early 1980's and data at the scale of fishing block are available from 1988/89. Whilst these data provide a considerable resource for historical assessment, the greatest periods of change in the fishery were during the late 1970's and early 1980's when surveys were first introduced and effort shifted from the North region to contemporary fishing grounds. A lack of data at appropriate spatial and temporal scales during this period inhibits historical assessment of the fishery. This is exacerbated by a lack of historical data on prawn size, although some information is available for 1978/79.

Fishery-independent surveys have been conducted since February 1982. In the past, these data were primarily used for the determination of harvest strategies. As such, the high degree of spatial and temporal variability in the selection of survey sites has limited their use as an index of relative biomass. This report provides useful comparisons from a sub-set of consistently surveyed sites from as early as 1991/92. More recently site selection has been fixed within and between years with the explicit objective of obtaining more robust estimates of relative biomass. It is envisaged that five years of consistent survey data will enable determination of the most appropriate survey design in the long-term.

Both catch and effort and survey data are limited by a lack of knowledge on the effect of fishing power (efficiency) of the fleet. Whilst GPS data are available for the start and finish of survey shots, GPS data provided in commercial logbooks are limited to centre points of a shot only and thus trawl speed during commercial fishing cannot be reliably calculated. Further, there have been many other changes to commercial trawl gear that increase vessel power over time, few of which have been documented. Ascertaining changes in fleet power are critical to understanding CPUE data that underpin harvest strategy development and performance assessment of the fishery.

Whilst considerable studies have been conducted on the biology of *P. latisulcatus* in Spencer Gulf, recent reports have identified a lack of knowledge on reproductive biology. The current FRDC Project 2008/011 aims to resolve many of these issues.

6.2 Current Status of the Spencer Gulf Prawn Fishery

6.2.1 Annual stock assessment

As indicated in recent stock assessment reports (Dixon *et al.* 2005a, 2007, 2008), there are several lines of evidence that suggest the Spencer Gulf Prawn Fishery is being fished within sustainable limits: catches have been relatively stable since 1987/88; effort has reduced to 40% of the 1978/79 peak; and mean harvested prawn size was larger in recent years than in 1978/79. This success can be largely attributed to the fishery-independent surveys conducted since 1982 that have established an understanding of the patterns of prawn distribution and abundance to enable the development of harvest strategies that ensure sustainability.

Comparisons of relative biomass (from survey catch rate) indicate that the biomass in the last four fishing-years has stabilised compared to the highly fluctuating levels observed since the mid 1990's. This has likely resulted from the investment in constraining pre-Christmas catch. Evidence in support of this position includes: an average recruitment index over the last four years that was 17% higher than the historic average; stable February survey catch rates; stable total catches that have ranged from 1870 to 2038 t and were 55 t higher than historic average catches, and; steady CPUE increases from 91 to 110 kg/hr. It is unclear if these increases in performance can be maintained or further increased in the long-term.

Whilst sustainability measures were within acceptable bounds, there was an increase in the proportion of vessel nights when prawns of small average size were captured during 2007/08. From a general perspective this may be in part explained by regional trends, as catches in the Middlebank/Shoalwater region during 2007/08 were the highest recorded (since 1988/89) and catches in the North region were the highest recorded since 1999/2000. These regions are the northernmost fished and prawn size generally increases from north to south.

6.3.2 Assessment of harvest strategy development and management for 2007/08

Assessment of daily total catch and daily mean size for the fleet was made against the decision rules of the Management Plan for eight harvest periods during 2007/08. Minimum daily catch criteria were met on all fishing days however, there were

several instances of prawns harvested at sizes outside of the target criteria. Whilst the performance of the fishery was within target ranges for 2007/08, these analyses provide useful information to improve harvest strategy development and management at sea.

Sub-optimal size prawns were caught from harvest strategies developed after all three spot surveys conducted during 2007/08. The harvest strategy developed following the March spot survey included an area in the Main Gutter where high catch rates of small and medium size prawns were prevalent. This strategy was also employed during early April. Both harvest periods resulted in sub-optimal sized prawns being caught at the scale of fishing block for a harvest period as well as at the scale of average daily prawn size for the fleet.

Harvest strategies developed from May and June spot surveys also resulted in prawns of sub-optimal size being harvested. During May, small prawns were caught in the most northern block fished. This likely resulted from a combination of the inclusion of shots with small prawns observed on survey and the movement of small prawns from areas immediately north of the closure boundary. Following the June spot survey, an area was opened to fishing in the North region. This was based on the capture of large and medium sized prawns at low and moderate catch rates during survey, however during fishing predominately small prawns were harvested.

In combination, these strategies resulted in small prawns (mean size >240 prawns per 7 kg) being caught on 290 of 1938 (15%) fishing nights during 2007/08. This was the highest proportion of nights with small prawns harvested since 2002/03 and suggests that improvements can still be made in harvest strategy development and management at sea.

Assessment of the harvest strategies developed by the Committee-At-Sea is currently inhibited by a lack of quantitative measures regarding the shots included in fished areas. Appropriate decision rules that define acceptable limits of how many shots with prawns of sub-optimal size can be incorporated into harvest strategies may 1) reduce the total catch of small prawns and 2) provide a robust framework for government in the auditing of harvest strategy decision-making in an environment of co-management.

6.4 Performance Indicators

The Management Plan identifies seven key PIs and eight additional PIs for the fishery. There are several issues identified in this report that require further consideration for future assessment.

Most importantly, there is a need to determine quantitative measures for assessment of harvest strategy development by the Committee-At-Sea. Currently, only subjective assessments of harvest strategy decision rules can be made for harvest periods from March to June where the key decision-making tool is maximum prawn size. Whilst it is understood that survey shots which identify areas of small prawns often need to be included into harvest strategy development for logistic reasons, this and previous reports have identified that such practices can lead to the harvest of considerable volumes of sub-optimal size prawns. Useful parameters to consider include the weighted mean size of prawns within each harvest area and the proportion (by number and catch rate) of survey stations included in each harvest area that are outside of the target size criteria.

The secondary PI for recruitment index during November was below the limit RP during 2007/08. Given the generally low levels of recruitment at this time of year, the lack of historic data for this PI and the general strength of recruitment in other months and recent years, failure to reach this PI is not considered a concern for the fishery. The secondary PI for egg production will be improved considerably in future assessments after the completion of the FRDC project 2008/011. Until this time the PI for egg production should be interpreted cautiously.

The effects of changes in fishing power on commercial CPUE and survey catch rate data are unknown. An assessment of historic changes in fishing power should be conducted as a priority, and methods for ongoing assessment should be developed.

6.5 Future Research

Stock assessment surveys provide a critical source of information for the ongoing assessment and sustainability of the SGPF. In recent years, the fishery-independent survey design has been standardised, enabling robust comparisons among and within fishing-years. The collection of survey data at these spatial and temporal scales is approaching five years. At that point, an informed assessment can be applied to determine the most appropriate survey design for the future.

A high priority for research in the SGPF is an ability to determine changes in fishing power (efficiency) of the fleet. These changes can result from improvements in gear technology (vessel speed, heavier ground chains, larger or more effective otterboards etc.) or changes in fisher behaviour (increasing experience, increased knowledge through surveys, vessels sharing knowledge as “teams”). Understanding changes in fishing efficiency, particularly changes in vessel speed, is essential for interpretation of the CPUE data that underpins performance assessment of the sustainability of the fishery and the development of harvest strategies.

Appropriate quantitative methods for assessing harvest strategy development at fine temporal scales must also be established. Analyses presented in this report identified several impediments to these assessments: a lack of quantitative measures for assessing harvest strategy development; the discrepancy between the spatial scale of catch and effort reporting blocks and the development and management of harvest strategies, and; confidentiality of catch and effort data.

An improved understanding of prawn grade data, including studies on the size composition of prawns within various grades, the variability between commercial grading machines, and validation of commercial catch and effort data on prawn grades would reduce the uncertainty associated with prawn size data.

7. REFERENCES

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8. APPENDIX

8.1 Egg production model

The egg production model utilises much of the current knowledge of the biology of *P. latisulcatus* (see Section 1.5). It should be noted that there is considerable uncertainty associated with the outputs. Thus, these outputs are likely to change as more data become available. The model is underpinned by a range of assumptions including:

- the catchability of prawns was constant during the survey,
- female prawns spawned three times during the spawning period,
- spawning frequency does not vary with size,
- natural mortality was zero,
- the % of females within each grade does not vary during the spawning season,
- the size at maturity doesn't vary with time, and
- sex-specific length frequency data from surveys were representative of the population.

Data on the biology of prawns (see Section 1.5) and on prawn grades obtained from commercial processors were used in the model. Also, fertilization success for each size grade was determined visually from figures presented by Courtney & Dredge (1988). The following steps (1–11) describe the estimation of egg production and Table 3.2 presents the associated values:

1) The mean weight of prawns for each prawn grade was obtained from commercial processors;
2) Data from 1) were used to calculate the mean size (mm, CL) of prawns in each grade.
3) Data from 2) were used to calculate the mean number of eggs produced per female prawn for each prawn grade;
4) The proportion of mature female prawns (egg bearing) for each prawn grade was estimated from the logistic equation provided by Carrick (1996);
5) Spawning frequency was assumed to be 3 for all prawn grades;
6) Fertilisation success for each prawn grade was determined from Courtney & Dredge (1988);
7) Mean (SE) catch weight per grade per shot was calculated directly from prawn grade weight data collected during November 2006;

8) Data from 7) and 1) were used to calculate the mean (SE) number of prawns captured per hour;
9) The proportion of female prawns in each prawn grade was calculated from sex-specific length-frequency data;
10) Data from 8) and 9) were used to calculate the mean (SE) number of female prawns captured per hour;
11) Data from 3), 4), 5) and 10) were used to calculate the number of potential fertilized eggs per hour that captured females could have contributed to egg production prior to fishing.

Table 8.1 Egg production from female prawns captured from surveys conducted during November 2007.

Prawn grade	21+	16-20	10-15	U10	U8
Mean individual weight (g)	18.0	27.0	38.0	50.0	60.0
Mean CL (mm)	32.2	37.5	42.7	47.3	50.7
Eggs per female	132361	224358	350034	500302	634289
% mature	23.7%	57.5%	84.9%	95.3%	98.1%
Spawning frequency	3	3	3	3	3
Fertilization success	40%	85%	90%	98%	99%
Mean (SE) catch (kg) per hr	19.7 (1.8)	35.7 (2.4)	19.2 (1.2)	4.3 (0.4)	0.9 (0.1)
Prawns per hr	1096	1321	507	86	14
% females	18.1%	28.7%	39.7%	92.7%	97.8%
Females per hr	198	379	201	79	14
Eggs ($x10^7$) per hr (SE)	0.7 (0.1)	12.4 (0.9)	16.1 (1.0)	11.1 (1.2)	2.6 (0.5)

8.2 Spot surveys

Spot surveys have been conducted since May 2002 to determine whether it may be appropriate to open areas that were previously closed to fishing. Spot surveys have been undertaken in the Northern, Middlebank/Shoalwater, Cowell, Gutter, Wallaroo and Wardang regions (Table 3.4). In all instances, where more than 10 survey shots had been conducted in a region and subsequently more than 10 t had been harvested from that region, the survey catch rate was consistently higher than the fishing catch rate, primarily because spot surveys were generally conducted on the new moon. Despite the higher catch rates, there was a strong correlation between spot survey and subsequent commercial CPUE (r^2=0.61, n=17; Figure 3.10). This indicates that when industry survey methods incorporate more than 10 shots in a region, catch rates are likely to be indicative of subsequent commercial CPUE and of prawn abundance.

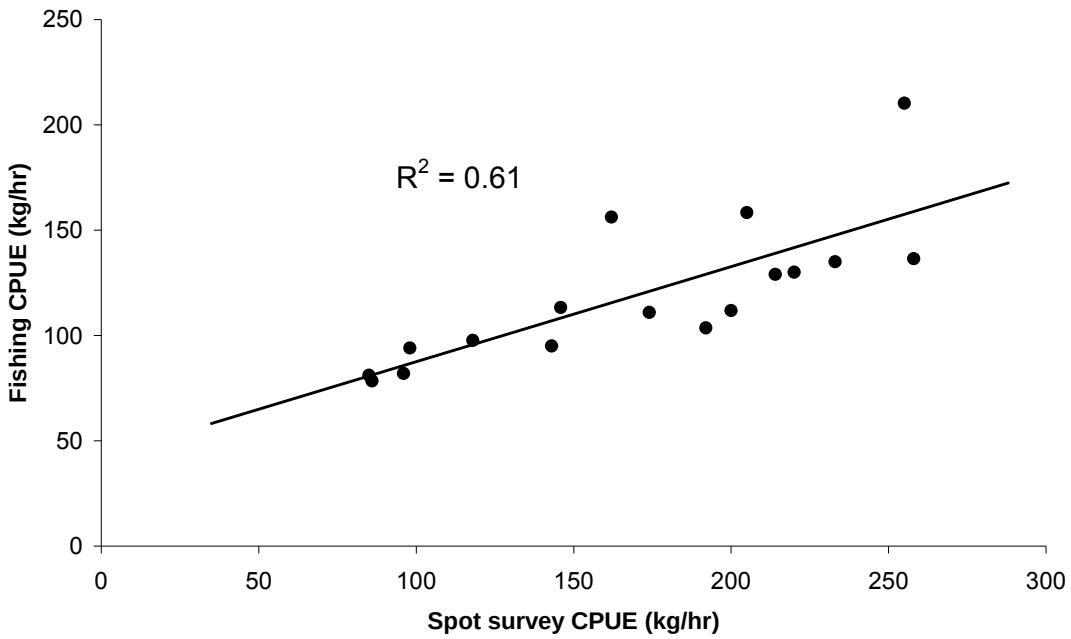

Figure 8.1 Correlation between regional spot survey CPUE (when >10 shots) and subsequent regional fishing CPUE (when >10 t harvested) in the same month (r^2 = 0.61, n=17).

Table 8.2 Mean (SE) catch rates and prawn size from spot surveys, and regional total catch and CPUE in the remaining of the fishing month immediately subsequent to spot surveys. 'C' indicates confidential data.

Year	Month	Region	Shots	Mean (SE) size (prawns/kg)	Mean (SE) rate (kg/hr)	Subsequent reg. catch (t)	Subsequent reg. CPUE(kg/hr)
2002	May	North	1	45.7 (0.0)	353 (-)	–	–
2002	May	M'bank/S'water	15	31.4 (1.1)	220 (18)	146.7	130
2002	May	Cowell	9	35.0 (5.1)	103 (31)	–	–
2002	May	Gutter	9	26.4 (2.1)	77 (26)	4.9	112
2002	May	Wallaroo	16	35.4 (1.1)	174 (17)	86.4	111
2002	Dec	North	46	39.0 (0.7)	101 (7)	0.3	35
2003	Mar	North	11	62.0 (3.6)	160 (13)	–	–
2004	Mar	Gutter	4	30.5 (4.6)	204 (57)	26.2	115
2004	Mar	Wallaroo	32	32.7 (1.2)	214 (28)	142.1	129
2004	May	North	17	33.4 (1.3)	187 (16)	3.0	144
2004	May	M'bank/S'water	14	39.9 (2.4)	233 (25)	243.0	135
2004	May	Wallaroo	22	33.3 (1.2)	96 (10)	130.5	82
2004	Dec	Gutter	13	40.1 (1.4)	81 (12)	C	C
2004	Dec	M'bank/S'water	3	32.4 (2.0)	151 (18)	85.9	70
2004	Dec	North	24	42.1 (1.4)	148 (14)	8.7	88
2005	Mar	Gutter	5	38.0 (1.8)	140 (38)	6.5	69
2005	Mar	North	5	33.6 (4.1)	422 (174)	–	–
2005	Mar	Wallaroo	27	35.9 (1.8)	200 (23)	30.1	112
2005	May	Gutter	12	39.2 (2.9)	146 (28)	28.9	113
2005	May	M'bank/S'water	19	34.4 (0.6)	258 (18)	59.3	137
2005	May	South Gutter	5	30.9 (3.4)	75 (27)	15.5	71
2005	May	Wallaroo	24	34.2 (0.8)	143 (9)	138.7	95
2005	June	M'bank/S'water	21	34.2 (0.8)	192 (16)	163.9	104
2005	June	North	13	34.1 (1.0)	167 (18)	–	–
2005	June	Wallaroo	14	36.0 (2.0)	85 (12)	30.3	81
2005	Dec	North	38	36.6 (1.0)	98 (7)	78.2	94.1
2006	Mar	Cowell	14	47.3 (4.4)	50 (8)	–	–
2006	Mar	Gutter	15	41.2 (2.9)	162 (25)	20.17	156.2
2006	Mar	M'bank/S'water	11	39.4 (1.6)	205 (118)	12.3	158.3
2006	Mar	Sth Gutter	5	36.9 (3.6)	91 (12)	–	–
2006	Mar	Wallaroo	39	33.8 (1.1)	255 (28)	401	210.3
2006	Mar	Wardang	2	35.9 (12.1)	44 (30)	C	C
2006	May	Gutter	9	36.9 (6.2)	78 (20)	12.5	70.4
2006	May	M'bank/S'water	20	35.8 (1.3)	118 (13)	148.5	97.7
2006	May	North	10	35.3 (1.2)	160 (24)	C	C
2006	May	Wallaroo	17	35.8 (1.5)	86 (6)	53	78.4