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By-product assessment in the Spencer Gulf Prawn Fishery with an emphasis on developing management options for Balmain bugs

SARDI Publication No. F2010/000165-1
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Roberts, S.D. and Steer, M.A.

SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

Government of South Australia

April 2010

Report to PIRSA Fisheries

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The report was reviewed by Dr Stephen Mayfield and Dr Rowan Chick of SARDI Aquatic Sciences. Ms Alice Fistr of PIRSA Fisheries also provided comment on the report. Associate Professor Tim Ward formally approved the report for release.

EXECUTIVE SUMMARY

1. Two by-product species are permitted to be retained by South Australian Prawn Fishers: Balmain bug (*Ibacus peronii*) and southern calamary (*Sepioteuthis australis*).
2. This report provides biological information, survey and commercial catch and effort data on the two by-product species of the Spencer Gulf Prawn Fishery to: 1) assess vulnerability to current trawling activity, and 2) identify management options to address sustainability issues. Additional size of maturity information for bugs in Gulf St Vincent (GSV) is provided for comparative purposes.
3. Retained commercial catch of bugs and calamary in Spencer Gulf during 2008/09 was 7.2 t and 22.7 t, respectively. The total estimated catch of bugs and calamary during 2008/09 was 14.1 t and 93.2 t, or a 2 and 4-fold increase, respectively, from the retained catch. The discrepancies between retained and estimated total commercial catches are due to fishers not always retaining and selling by-product throughout the season.
4. Bugs are a long-lived, slow growing species with low fecundity, exhibiting localised movement, reproduction and recruitment patterns. Survey data indicated that bugs were most widely distributed and at highest abundances at the start of the season (November). Highest catch rates were observed in the northern region of Spencer Gulf. Reproductive activity was apparent during all survey months, peaking in April.
5. Survey catch rates of bugs in regions of high effort (Wallaroo, Middlebank & Shoalwater and Main Gutter) were negatively correlated with commercial trawl intensity over the season, indicating localised depletion. This was not evident in regions of low and medium trawl intensity.
6. Calamary are a short-lived, fast growing and highly mobile species. They were found to be ubiquitous throughout the Spencer Gulf trawl grounds and were predominantly represented by juveniles and sub-adults. Survey and commercial catch and effort data for calamary showed no evidence of depletion due to trawling over the 2008/09 season. The available information suggests that calamary have a low vulnerability to current levels of trawling activity in the SGPF.
7. Continuing by-product data collection during surveys would provide useful long-term information for future assessment.
8. The available information suggests that bugs are vulnerable to the impacts of locally intensive fishing. Additional management measures (eg. minimum legal size, MLS) may warrant consideration. Different MLS limits may require consideration for each of the Spencer Gulf and GSV prawn fisheries in light of differences in size structure and size of maturity between gulfs.

1 INTRODUCTION

1.1 Spencer Gulf Prawn Fishery

The Spencer Gulf Prawn Fishery (SGPF) is managed by Primary Industries and Resources South Australia (PIRSA) under the framework provided by the *Fisheries Management Act 2007*. It is a limited entry fishery with 39 licensed operators. Fishers are entitled to harvest the target species western king prawn, *Penaeus* (*Melicertus) latisulcatus*, and two by-product species: southern calamary, *Sepioteuthis australis,* and slipper lobsters of the genus *Ibacus* (commonly Balmain bug, *Ibacus peronii*). Hereafter they are generally referred to as calamary and bugs. Vessels are permitted to use demersal, otter-trawl, double-rig gear. Considerable technological advancements have been made in the fishery including the use of "crab bags" within the nets to exclude mega-fauna by-catch, and "hoppers" for efficient sorting of the catch and rapid return of by-catch. Trawling is not permitted during daylight hours and must be conducted in waters >10m depth. Effective effort (fishing power) is constrained by gear restrictions including vessel size and power, type and number of trawl nets towed, maximum headline length and minimum mesh sizes. 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.

The SGPF produces approximately 2,000 t of western king prawns annually. Commercial prawn trawling in Spencer Gulf began in 1967 and large areas have been trawled at varying intensities (Carrick, 2003). Catches and trawling intensity increased dramatically over the first six years of the fishery. In 1973/74 more than 2,000 t of prawns were harvested with approximately 25,000 hrs of fishing effort. Since then, annual catches have remained relatively stable (~1,300-2,500 t). Fishing effort has declined from a peak of 45,786 hrs in 1978/79 to 18,438 hrs in 2007/08. The reduction in the number of hours trawled has occurred because the fleet works cooperatively to maximise economic returns and reduce costs. Pre-fishing surveys are conducted to identify areas that support high densities of large (high value) prawns. Fishing is formally confined to these areas through legislative notices signed by a delegate of the Minister for Fisheries (generally the fishery manager). Commercial trawl shots are typically less than 1 hour duration.

Since 1999, the export of prawns from Spencer Gulf has been controlled under the wildlife protection provisions of the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* (DEH, 2004). To gain export status under the act (Part 13 and 13A), the South Australian Government must demonstrate that harvesting strategies for the fishery are ecologically sustainable. This includes demonstrating that impacts on the structure, productivity, function and biological diversity of the ecosystem are minimised. In 2004, the Australian Government provided recommendations to enhance the ecologically sustainable fishing of prawns in the Spencer Gulf (DEH, 2004). These included recommendations to mitigate ecological impacts on 1) by-catch species, 2) by-product species and 3) threatened, endangered and protected species. For this reason, commercial prawn logbooks were modified to quantify retained by-product catches during 2001/02.

An extensive history of by-catch research in the SGPF is available, including some information on the two by-product species. These include a gulf-wide survey conducted in February 2007 that, although with fewer trawl shots, provided spatial catch information relative to other by-catch species in the SGPF (Currie *et al*., 2009). Calamary was found to be the eighth most abundant species, while the bug was ranked 31st in terms of abundance. While there is a paucity of information for bug populations in Spencer Gulf, the life history, ecology and commercial harvest of bugs in Gulf St Vincent (GSV) was previously documented by Dixon *et al* (2006) and Roberts (2008). Calamary is commercially targeted in the Marine Scalefish Fishery (MSF), and as such additional information is available on stock status, structure, biology and resource overlap with the South Australian Prawn Fisheries (Steer *et al*. 2007a).

1.2 Balmain bug

Slipper lobsters are a crustacean belonging to the highly distinctive, yet little-known Scyllaridae family, and are closely related to the well-known and commercially important spiny lobsters (Palinuridae). Lobsters of the Scyllaridae family are generally referred to as slipper lobsters, although they have attracted a variety of other common names including shovel-nosed lobsters, fan lobsters, squat lobsters, butterfly lobsters, locust lobsters and bugs. Two species of slipper lobster are known to inhabit South Australian (SA) waters: the Balmain bug *Ibacus peronii* found at depths of 4–288 m and the Wollongong bug (or deepwater bug) *I. alticrenatus* found at depths of 82–686 m (Brown & Holthuis 1998). In Spencer Gulf, where water depth does not generally exceed 60 m, Balmain bugs are commonly caught as a by-product species of the SGPF, with no reported catches to date (as far as the authors are aware) of the Wollongong bug. Thus the species of slipper lobster that this report presents data for is that of the Balmain bug (*I. peronii*) (Figure 1.1).

The Balmain bug is nocturnal, lives in bare sandy environments where it can bury to avoid predators, and is a long-lived species (>15 yrs) compared with other slipper lobsters (Moreton Bay bug ~6 yrs; Stewart 2003). In general, slipper lobsters are primarily carnivorous scavengers, with a preference for small benthic invertebrates, such as molluscs, polychaete worms and crustaceans. The Balmain bug is relatively sedentary, with recaptured tagged individuals found close to their release site (average 0.35 km), even after several years at liberty (Stewart & Kennelly 1998; Stewart 2003). Reproduction involves the brooding of eggs (3–4 months) under the abdomen, with the number of eggs dependent upon the size of the female (range: 5 500–37 000 eggs; Stewart & Kennelly 1997). The eggs are relatively large (1.0 to 1.4 mm diameter; Haddy *et al*. 2007) compared with other slipper lobsters, and the larval period lasts ~80 days (Stewart & Kennelly 1997). The length of the reproductive process is thought to be largely dependent on water temperature. Females produce multiple broods throughout the year, with peak reproductive activity in NSW populations found to be between July and September (winter/early spring) (Stewart & Kennelly 1997). In GSV, reproductive activity was found to be higher between March and May compared to December (Roberts, 2008).

The Balmain bug has a distinct life-history strategy of localised movement and reproduction in shallow inshore waters where localised larval retention and settlement occurs (Stewart & Kennelly 1997). Small juvenile bugs (minimum 12 mm carapace length, CL) have been observed amongst catches of adults during trawl surveys (Roberts, 2008). For such a life history strategy, diversity between populations may be expected. Preliminary research on genetics and morphology of Balmain bugs of SE Australia (New South Wales (NSW), Tasmania (TAS.), South Australia (SA)) indicated restricted gene flow between States (Sydney-Smith 2006). Furthermore, the data suggested the presence of distinct sub-populations in GSV, Venus Bay and particularly northern Spencer Gulf. For this reason, consideration should be given to manage bugs in GSV and Spencer Gulf as separate populations.

Figure 1.1 The Balmain bug (*Ibacus peronii*) of South Australia varies in colouration from dull orange-brown (left) to orange-purple with dark red mottling (right) (Figure from Roberts, 2008).

Consideration of important life-history parameters, as well as catch information, is critical to assess vulnerability of a species to fishing. The life-history strategy of the Balmain bug alone suggests that this species is likely vulnerable to the impacts of fishing, particularly at local spatial scales. Since it is an incidental by-product species of low total annual value, limiting spatial or temporal fishing effort and/or changing mesh sizes are not feasible options to address any sustainability issues for this species. However, due to their high post-trawl survival (Haddy *et al.* 2005; S. Roberts pers. obs.), Balmain bugs can be returned to the water alive, meaning that a minimum legal size (MLS) would be an effective and appropriate management option for this species.

The former South Australian Prawn Fisheries Management Committee (PFMC) (composed of key stakeholders including members from: the commercial prawn fishing industry, the recreational fishing sector and government) previously discussed appropriate management arrangements to ensure sustainability of slipper lobsters in South Australia's prawn fisheries. Minutes from PFMC meeting #34 (agenda paper 7.3, 2006) documented that: "… the PFMC agreed to implementation of a regulation prohibiting the take of berried female slipper lobster", and "the PFMC required further information and subsequent discussion before agreeing to a suitable size limit for the legal take of slipper lobster". While the recent *Fisheries Management (General) Regulations 2007* provided the first legislation to protect the sustainability of slipper lobster populations in SA by protecting egg-bearing female *Ibacus* spp., there is currently no size restriction on the capture of slipper lobsters (including Balmain bugs) in SA.

In Queensland (QLD) and NSW, management restrictions imposed on trawl fisheries include bans on the taking of egg-bearing female bugs, and a MLS of 100 mm carapace width (CW) (~55 mm carapace length, CL), based on the size at which 50% of females reach maturity (Stewart *et al.* 1997; Haddy *et al.*, 2005). While carapace length (CL) is a more accurate measure of size than carapace width (CW) and thus the preferred scientific measure, CW is generally used for size limits in slipper lobsters as it is a simple and rapid measure for use by commercial and recreational fishers. It is also a conservative measure of size, since carapace width can be negatively influenced by broken carapace spines.

1.3 Southern Calamary

The southern calamary (*S. australis*) (Figure 1.2) is the most common squid species in southern Australian inshore waters and a key component of the marine ecosystem as a primary consumer of crustaceans and fishes, and as a food source for a variety of predators (Coleman 1984; Gales *et al*. 1994). In southern Australia, it ranges from Dampier in Western

Australia to Moreton Bay in Queensland, including Tasmania. It also occurs in northern New Zealand waters. For most of its distribution, calamary inhabits coastal waters and bays, usually in depths of <70 m (Winstanley *et al*. 1983). Like many other inshore squid species, calamary is of increasing commercial significance, contributing to multi-species, multi-gear, marine fisheries in all southern Australian states, particularly South Australia and Tasmania.

The South Australian calamary resource is shared by three key components: the recreational sector; the commercial sector of the MSF, and; South Australia's prawn fisheries. Whilst catches from the MSF are regularly documented (see Steer *et al*. 2007a), poor information on the catches of both recreational and prawn fishing sectors introduces considerable uncertainty in the stock assessment of calamary in South Australia (Steer *et al*. 2007a).

Figure 1.2. Southern calamary (*Sepioteuthis australis*). (Photo Dr. T. Jantzen).

1.4 Aims

In response to Australian Government recommendations, and in accordance with the EPBC Act (1999), this report provides information to inform PIRSA's risk assessment process for the Spencer Gulf Prawn Fishery. The objectives of this report are to:

1. Provide biological and catch information to assess the vulnerability of both by-product species to current levels of trawling activity, and;
2. Identify management options to address any sustainability issues in accordance with the vulnerability assessment.

In light of recent research suggesting distinct sub-populations of bugs between Spencer Gulf and GSV (Sydney-Smith 2006), biological and reproductive data are compared between gulfs to determine size of maturity, and inform management options in regard to a MLS.

2 METHODOLOGY

2.1 Survey design

Fishery-independent trawl surveys are carried out in Spencer Gulf around the new moon in November, February and April by the commercial prawn fishing fleet, primarily for the purpose of prawn stock assessment and harvest strategy development. Similar surveys are conducted in GSV during December, March–May, for the same purposes. By-product data have been opportunistically collected in the past during surveys in Spencer Gulf (2006/07) and in GSV (2004/05–2006/07). However, in Spencer Gulf, during the 2008/09 fishing season, by-product samples were strategically collected to assess spatial and temporal distribution, abundance and biology. Each survey involved nine commercial vessels trawling over two nights, with approximately 12, 30-minute trawl shots carried out by each vessel per night. Up to 209 trawl sites were sampled per month. Each vessel had a trained scientific observer on-board, who counted and weighed calamary and bugs for each survey trawl shot, where possible. Of these, 42 shots were dedicated 'biological' shots where all trawled calamary and bugs were collected, bagged and frozen for processing (Figure 2.1). The spatial distribution of these shots was stratified across the 10 fishing regions. All sites were semi-fixed, with skippers conducting a survey shot as close as possible to a fixed, pre-determined, Global Positioning System (GPS) waypoint. Trawl distances were calculated from GPS marks recorded at the beginning and end of each trawl shot. All vessels were fitted with double-rigged, demersal, otter-trawl gear with a 27.5 m headline and a cod-end mesh size of 4.5 mm (stretched). In situations where only one net was used instead of two, the reported by-product catch was doubled to ensure that the data obtained was standardised across survey vessels.

2.2 Biological samples

All bugs were processed from retained 'biological' samples collected during surveys. Measures for each individual included carapace length (CL), carapace width (CW), total body weight (g), sex, presence of externally carried eggs on females and female gonad stage according to Stewart *et al*. (1997). Female bugs were deemed physiologically mature if they possessed either eggs or gonads at stage III, IV or V. Carapace length was measured dorsally from the mid-point of the rostral sinus to the posterior margin of the carapace while carapace width was measured dorsally between the first post cervical spines (Figure 2.2).

A maximum of 30 calamary were haphazardly sampled from each retained 'biological' shot. From each individual, the dorsal mantle length (ML), total body weight (g) and sex were recorded. Lipinski's (1979) universal maturity scale for squid (Table 2.1) was used to categorise calamary as juvenile (Stage I), sub-adults (Stage II and III) and adults (Stage IV and V). The remaining animals were counted and collectively weighed.

Scientific observers counted and collectively weighed bugs and calamary on all shots at-sea, using calibrated electronic marine scales, during the survey. Both measures were replicated in the laboratory for retained 'biological' shots. Comparison of these data indicated no significant differences in counts and collective weights measured at-sea and in the laboratory for bugs (Two-tailed T-tests: count, t = -1.00, df = 45, P = 0.32; weight, t = 1.59, df = 45, P = 0.12) and calamary (Two-tailed T-test; count, t = -1.41, df = 105, P = 0.16; weight, t = -0.10, df = 105, P = 0.92).

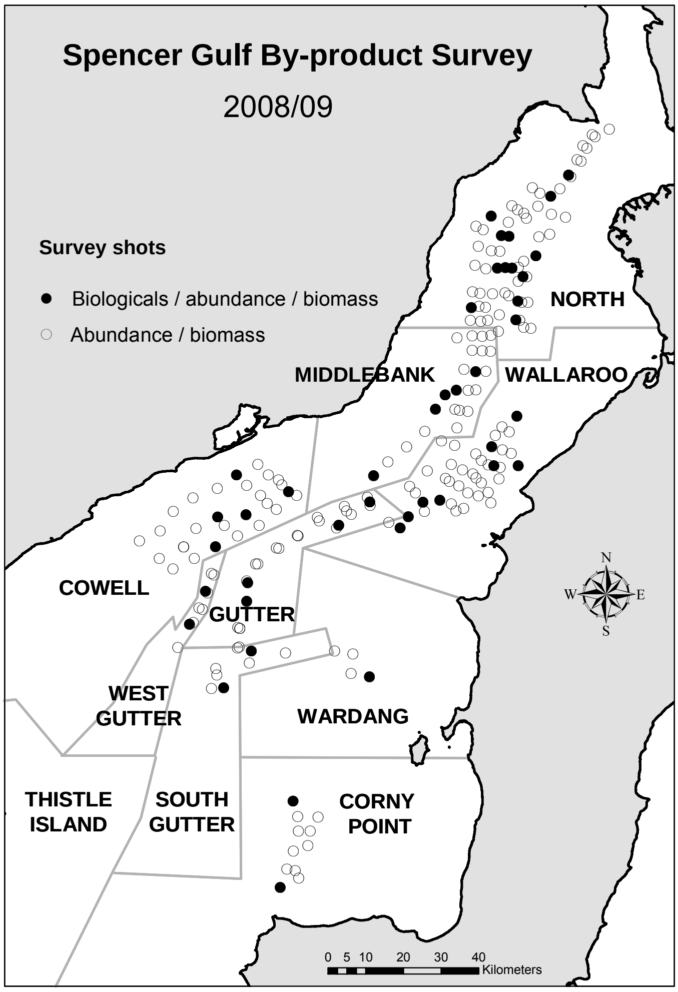

Figure 2.1. Fishery-independent survey shots conducted in the Spencer Gulf Prawn Fishery during 2008/09. Abundance and biomass data for by-product species were collected for every shot, while a subset of shots were used to collect samples for biological analyses.

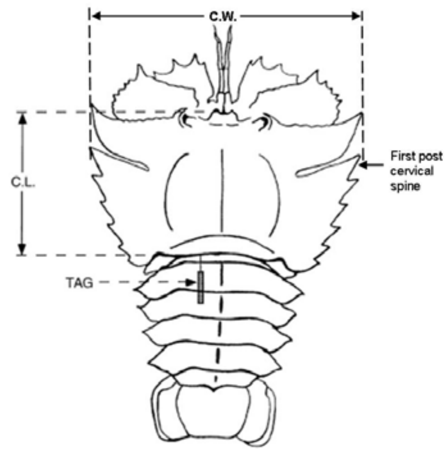

Figure 2.2. Diagram of dorsal view of the Balmain bug showing measurement of carapace length (CL) and width (CW). (Adapted from Stewart and Kennelly (1998)).

Table 2.1. Lipinski's (1979) universal maturity scale for squid.

Maturity Stage	Female	Male
I. Juvenile	Sexual organs very hard to find with the naked eye. The oviducts and nidamental glands appear (if at all) as very fine transparent strips. Ovary translucent and membranous.	Sexual organs very hard to find with the naked eye. Spermatophoric complex appears (if at all) as a transparent or translucent spot. Testes transparent, membranous.
II. Immature	Sexual organs translucent or whitish. Oviducts and nidamental glands form clearly visible translucent or whitish strips. The oviducts meander visible, nidamental glands small; all viscera behind them easily observable. The ovary clearly visible, in most cases immature ova invisible.	Sexual organs translucent or whitish; separate parts of the Spermatophoric complex clearly visible; testes small and their structure invisible.
III. Preparatory	The sexual organs are not translucent. Meander of the oviducts is extended. Nidamental glands enlarged covering some internal organs. Immature ova clearly visible.	Sexual organs not translucent; vas deferens whitish or white, spermatophoric organ with white streak; testes in most cases white or pink, their structure invisible.
IV. Maturing	Nidamental glands large, covering the kidneys and distal part of the digestive gland; oviductal glands fleshy and swollen. Plenty of eggs in the oviducts; meanders hardly noticeable. Eggs not translucent and pressed together, at least in the proximal part of the oviduct.	Vas deferens white, meandering, enlarged; spermatophoric sac long with structureless whitish particles inside, but without formed spermatophores; testis firm and its structure visible.
V. Mature	As above, but the eggs are translucent, at least in the proximal part of the oviduct. Cut open, the nidamental glands secrete a viscous substance	As above, except that spermatophores are present in the spermatophoric sac.

2.3 Data analyses

Analyses of biological data included length-weight relationships, trends in length-frequency data, size of maturity (SOM) and trends in seasonal maturity. SOM was determined as the size at which 50% of the sampled female population reaches physiological maturity. The cumulative percent of mature individuals was plotted against size and then fitted with a logistic curve using equation:

$$P_m = \frac{1}{1 + e^{a(CL-b)}}$$

Where Pm is the proportion of mature animals, CL is the carapace length, *e* is the inflexion point of the curve and *a* and *b* are constants.

Additional bug length-frequency data collected during previous surveys in Spencer Gulf (2006/07) were included in analyses, while additional data from GSV (2004/05 – 2006/07) were used to provide a comprehensive comparison of size of maturity between the two gulfs.

We evaluated the relationship between regional commercial trawl intensity and temporal changes in survey abundance for both species to determine the effects of fishing at a localised scale. Regions were ranked by commercial trawl effort, with regions separated into groups of three, resulting in high (> 90,000 min: Wallaroo, Middlebank & Shoalwater, Main Gutter regions), medium (28,000 – 90,000 min: Corny, North, Wardang regions) and low (<28,000 min: South Gutter, West Gutter and Cowell regions) trawl intensity categories. Commercial effort (min) for each region following November and February surveys (February – April fishing period) was correlated to changes in survey abundance (bugs.min^{-1}) for the same periods using linear regression of the form:

$$A = at + b$$

Where A is mean survey abundance (bugs.min^{-1}), t is time as fishing effort (min) and *a* and *b* are constants.

Retained versus estimated total commercial catches of calamary and bugs were calculated using commercial catch and effort data as well as fishery-independent survey data. Spatial and temporal mean survey catch rates were applied to the prawn fishery's commercial effort data, which reports area fished and duration of trawl shots (mins), to provide an estimate of the total by-product caught by the Spencer Gulf prawn fishery in each fishing season.

Estimates of total by-product catch, both in terms of numbers and weight, were calculated by adding monthly fishing region estimates to incorporate the spatial and temporal variation in catch rates. The error variances were propagated throughout the calculation. Where localised depletion due to fishing effort was found to occur (from trawl intensity and survey abundance correlations) it was incorporated into catch estimations. Depletion was assumed to be the average of two survey catch rates between months, while depletion after the April survey was calculated from the linear regression above (using fishing effort for the post-April harvest). Calculating estimated total by-product catch this way is considered more appropriate than generally applying an overall mean catch rate to total annual fishing effort.

Where statistical analyses were appropriate, analysis of variance (ANOVA) and Tukey's post-hoc tests were used to determine significant differences at various spatial and temporal scales. Homoscedasticity and normality of the data were determined by Levene's test and visually assessing residual plots. Where necessary, $\log_{10}$ (n + 10) transformations of data were employed to increase homogeneity of variances. Spearman's rank correlations were used to test pair-wise differences between two datasets, while for non-parametric data (proportion data), chi-square tests were performed. In all cases, significance was accepted at $P<0.05$. Data analyses were performed using SPSS software (SPSS, version 18.0) and values are presented as mean $\pm$ standard error (SE).

3 BALMAIN BUG

3.1 Survey catch composition

3.1.1 Sex ratio and length-weight relationship

Gender, carapace length and associated weight were available for 1020 individual animals collected from Spencer Gulf during 2006/07 and 2008/09. Equal sex ratios were observed for all months during 2008/09 and for February and April 2006/07, while November 2006 samples were male-biased (χ^2 = 17.8, df = 1, P < 0.001). Female bugs were found to attain a larger maximum size than males (♀ 93 mm CL, ♂ 81 mm CL) and a larger total weight (♀ 434 g, ♂ 286 g). A strong allometric relationship between carapace length and weight was found for both sexes (r^2 = 0.89–0.90) (Figure 3.1). These sex-specific maximum sizes and weights are larger than that reported from GSV (♀ 88 mm CL, ♂ 73 mm CL; ♀ 378 g, ♂ 210 g) (Roberts 2008).

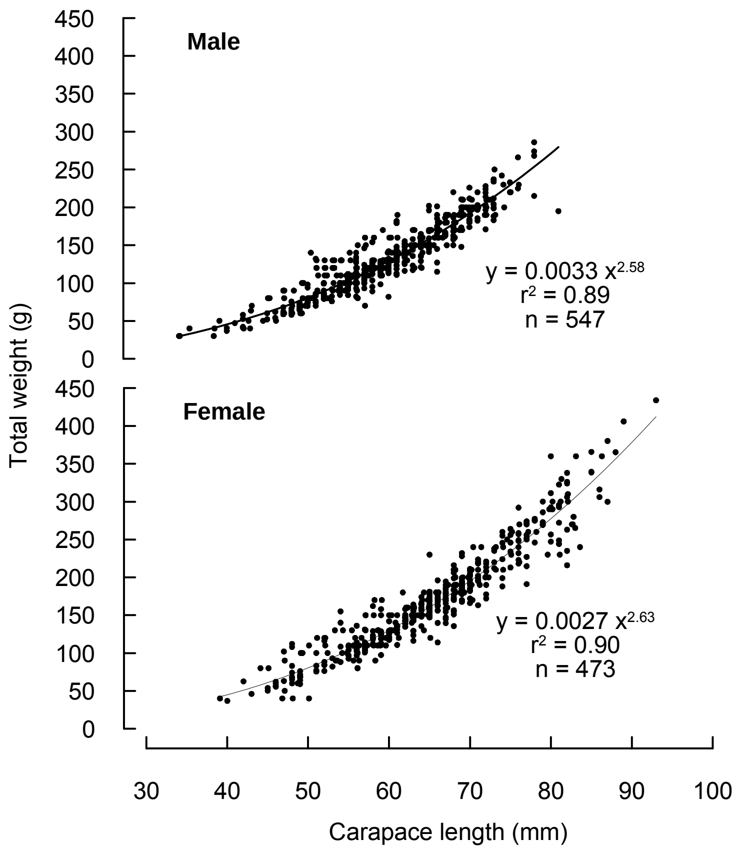

Figure 3.1. Length-weight relationships for male and female bugs in Spencer Gulf.

3.1.2 Length-frequency

Length-frequency data of bugs collected from surveys conducted in Spencer Gulf showed a similar trend among months between 2006/07 and 2008/09 (Figure 3.2). During 2006/07 modal abundances in November and February were 55–60 mm CL and increased to 65–70 mm CL in April. Similarly, during 2008/09 modal abundances in November and February were 60–65 mm CL and increased to 65–70 mm CL in April. This increase in modal abundance between February and April is indicative of an increase in mean size, likely a result of growth during this time of year.

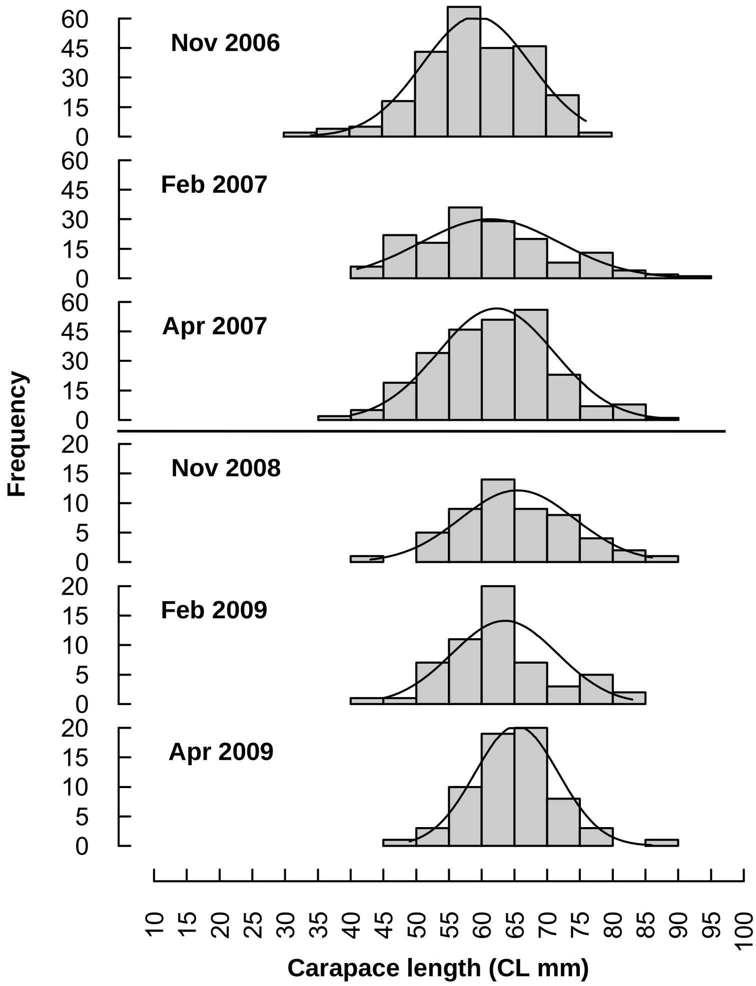

Figure 3.2. Length-frequency distributions of bugs collected from Spencer Gulf surveys conducted in November, February and April during 2006/07 and 2008/09 (n=1021).

Total length-frequency data from surveys conducted in Spencer Gulf (2006/07 and 2008/09) and GSV (2004/05–2006/07) provided a comparison between Gulfs. Modal and mean size of bugs was greater in Spencer Gulf (65.0 and 61.9 mm CL, respectively) compared to GSV (53.6 and 54.4 mm CL, respectively) (Figure 3.3).

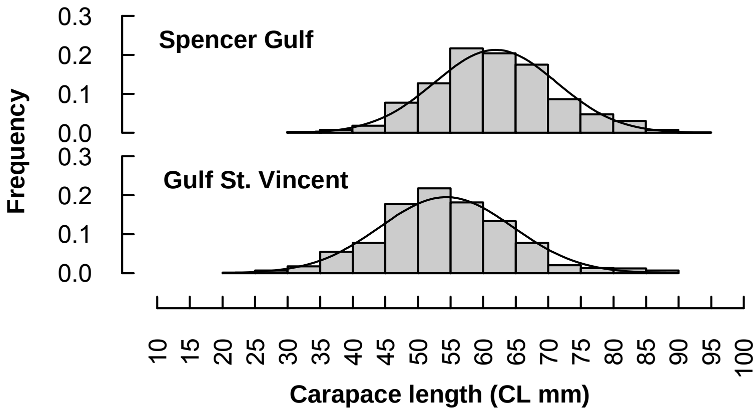

Figure 3.3. Length-frequency distribution data of the total surveyed population of bugs collected from Spencer Gulf (2006/07 & 2008/09, n=1021) and GSV (2004/05–2006/07, n=1350).

3.1.3 Size of maturity

SOM data was well represented among months for both Spencer Gulf and GSV. The smallest ovigerous female observed during surveys conducted in Spencer Gulf was 46 mm CL, while in GSV the smallest was 49 mm CL. The size at which 50% of female bugs reach physiological maturity was also found to be different between gulfs. Fifty percent maturity in Spencer Gulf and GSV was determined to be 67 mm CL (117 mm carapace width, CW), and 64 mm CL (113 mm CW) respectively (Figure 3.4). If one size limit were to be adopted across gulfs at 67 mm CL, 65% of females would be physiologically mature in GSV, while 58% and 75% of the current biomass would be protected in Spencer Gulf and GSV, respectively. However, if two size limits were considered that reflected the differences in SOM (50% of females) between gulfs, then the proportion of the current biomass that would be protected in GSV (64 mm CL) would reduce to 67% (Table 3.1).

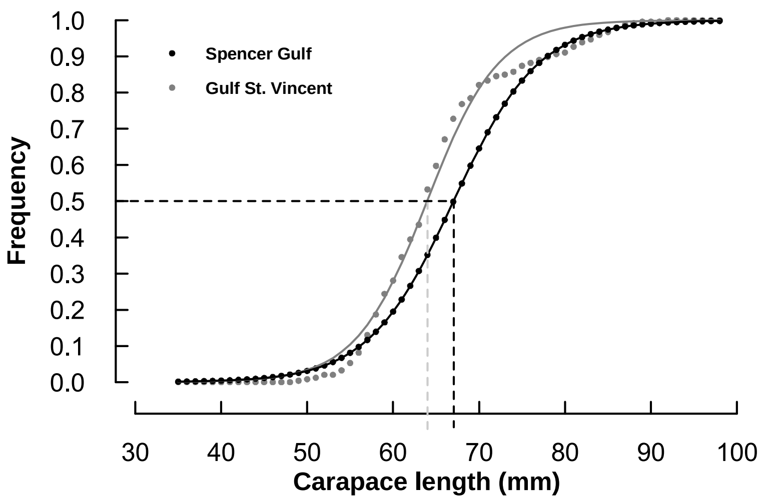

Figure 3.4. Logistic curve to determine 50% maturity (dashed lines) of female bugs collected and staged from Spencer Gulf (2006/07 & 2008/09, n=333) and GSV (2004/05–2006/07, n=246).

Table 3.1. Percent of female bugs mature and total biomass that would be protected at five different size limits for both Spencer Gulf and GSV. Shaded cells indicate size at which 50% maturity.

Gulf		CW (mm) 110	113	115	117	120
Spencer Gulf	CL (mm)	62	64	65.5	67	69
	% Females mature	27%	35%	42%	50%	60%
	% tot. biomass protected	36%	46%	52%	58%	67%
Gulf St. Vincent	CL (mm)	62	64	65	66.5	68
	% Females mature	39%	50%	56%	65%	73%
	% tot. biomass protected	59%	67%	71%	75%	81%

3.1.4 Temporal trends in maturity

The proportion of females physiologically mature (mature gonads or egg-bearing) was high during survey months, ranging from 57% (February) to 71% (April) during 2006/07 and from 79% (February) to 93% (November) during 2008/09 (Figure 3.5). No significant difference among months was detected for either season (2006/07: χ^2 = 1.6, df = 1, P > 0.05; 2008/09: χ^2 = 1.1, df = 1, P > 0.05). The proportion of female bugs carrying eggs at the time of survey ranged from 14% (February 2009) to 24% (April 2009). While the highest proportion was observed during April for both seasons, no significant difference among months was detected (2006/07: χ^2 = 1.1, df = 1, P > 0.05; 2008/09: χ^2 = 3.6, df = 1, P = 0.06) (Figure 3.6).

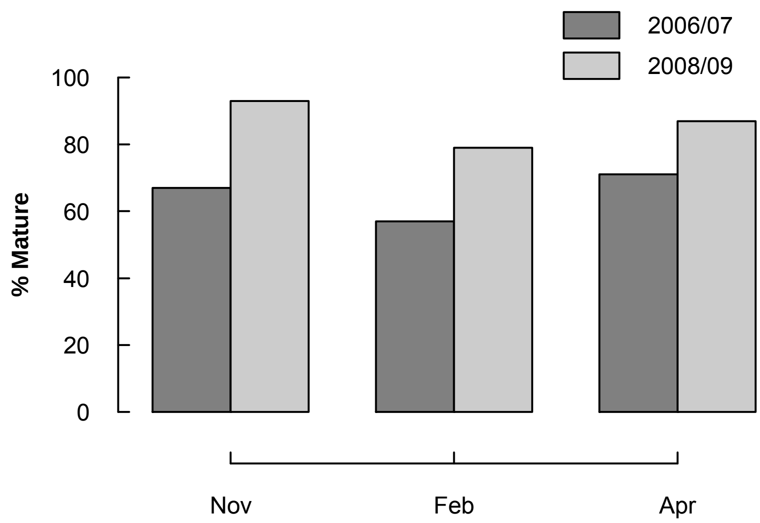

Figure 3.5. Percent of female bugs physiologically mature (mature gonads or egg-bearing) during November, February and April fishery independent surveys conducted in Spencer Gulf (2006/07 & 2008/09, n=333)

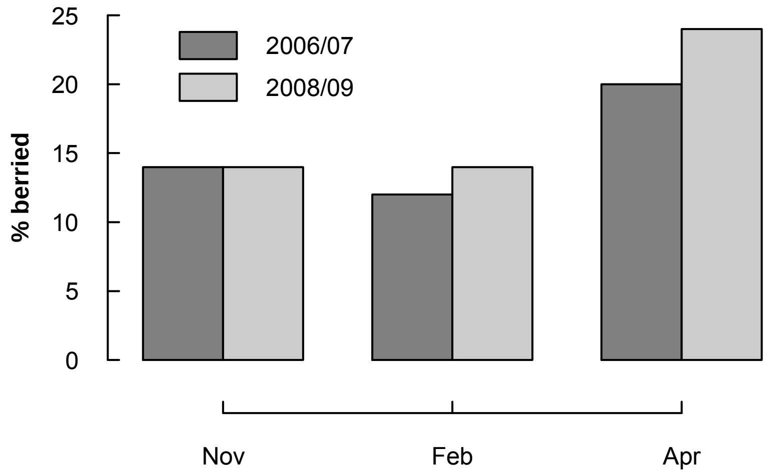

Figure 3.6. Percent of female bugs carrying eggs (berried) during November, February and April fishery independent surveys conducted in Spencer Gulf (2006/07 & 2008/09, n=333).

3.2 Distribution and abundance

Of 594 survey shots with data, 299 shots (50%) were observed with bug abundance ranging from 0.26 to 22.87 bugs.km^{-1} and biomass estimates ranging from 0.02 to 4.00 kg.km^{-1}. Abundance and biomass were positively correlated (Spearman's rank, $r = 0.96$, $n = 297$, $P < 0.001$). Bugs were more abundant in the North, with bugs found at 140 of 188 shots (75%) while 25 shots exceeded 8 bugs.km^{-1} (Figure 3.7). Bugs were more widely distributed during November (occurring at 122 of 204 shots) compared to February (86 of 207) or April (91 of 183). Catch rates were generally high in the North region with 29 shots greater than 0.75 kg.km^{-1} during November (Figure 3.8). Sizes were mixed within each region which is in agreement with the life history strategy of localised movement, reproduction and recruitment for this species. However, some differences among months were observed. Throughout the gulf, shots observed with large mean size bugs (>200 g) decreased from 28 of 201 shots (14%) during November to 13 of 183 shots (7%) during February, before increasing to 27 of 208 shots (13%) during April (Figure 3.8). This trend was particularly evident in the Wallaroo region. In the North region during November, medium sized bugs (150-200 g) were most prevalent, being observed at 34 of 63 shots, while this reduced to 19 of 63 shots by April. This was in contrast to the number of shots with large mean size bugs increasing from 6 shots during November to 14 shots during April.

Mean abundance varied both spatially and temporally (region*month interaction: $F_{16, 565}$= 2.44, $P = 0.001$). Abundances in the North were significantly higher ($P<0.05$) compared to all other regions. Temporal trends were only evident in the North region where abundance during November was significantly higher than that during February and April ($P<0.01$) (Figure 3.9).

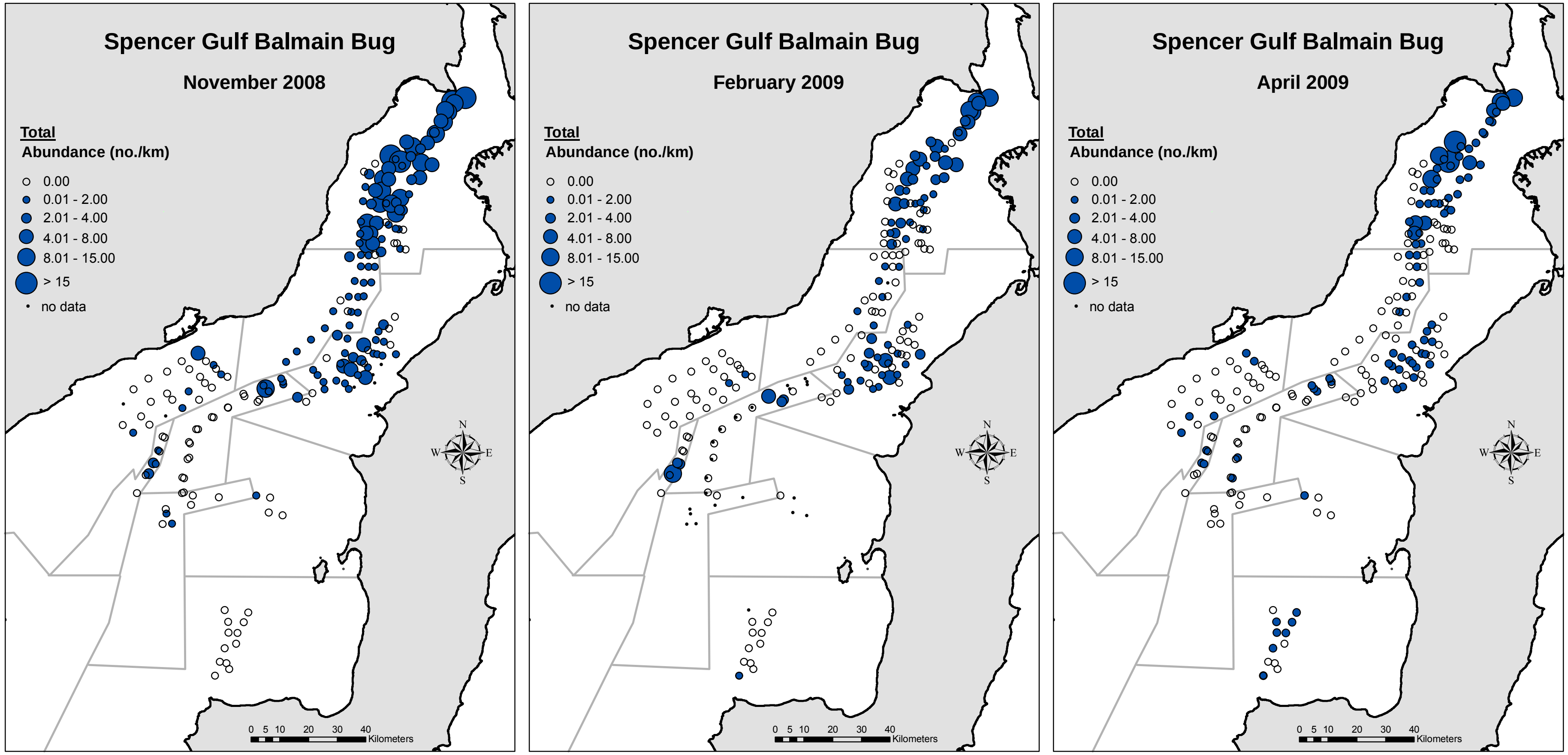

Figure 3.7. Bug abundance (bugs/km) for up to 209 trawl shots conducted in Spencer Gulf during November, February and April fishery-independent surveys in 2008/09.

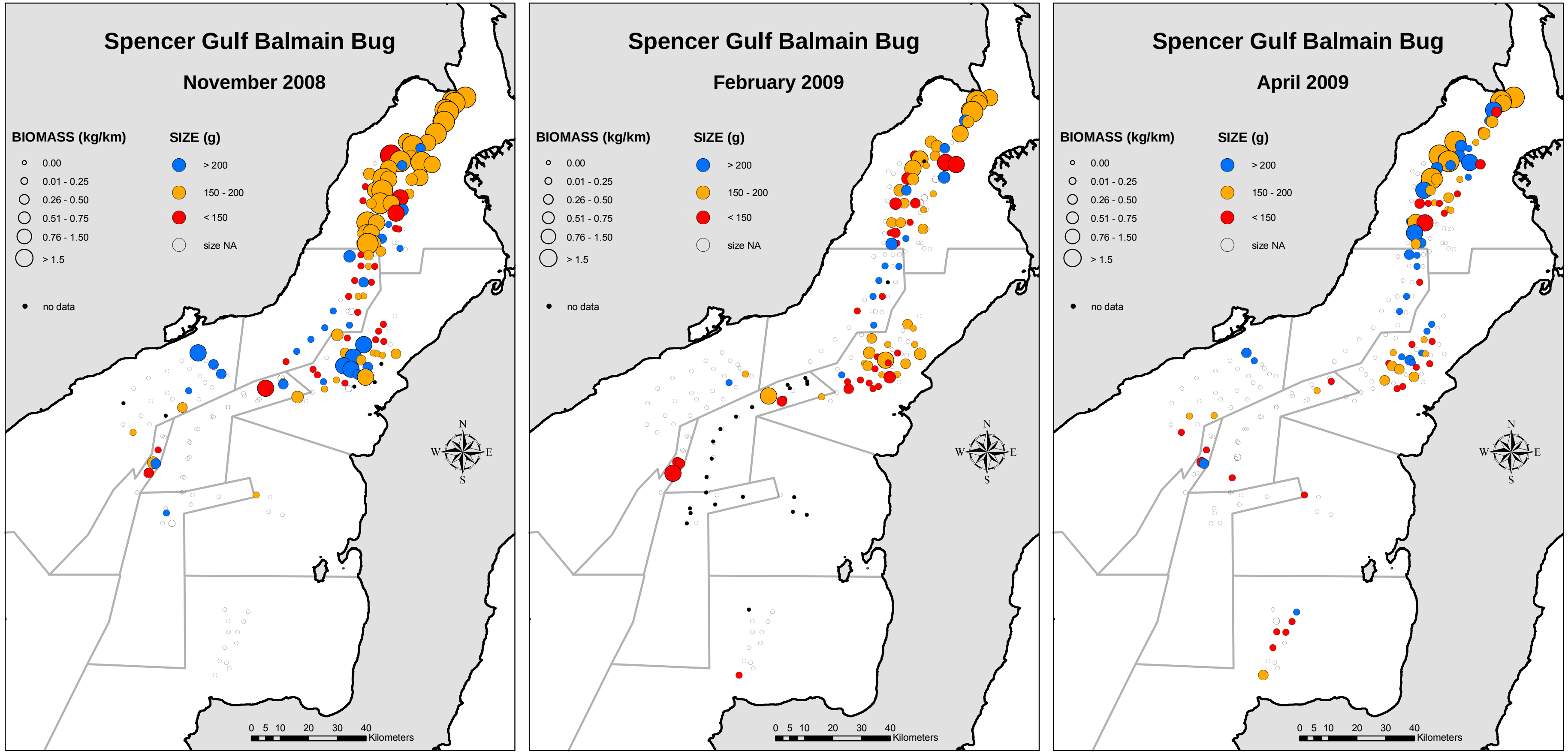

Figure 3.8. Bug biomass (kg/km) and average size (g) for up to 209 trawl shots conducted in Spencer Gulf during November, February and April fishery-independent surveys in 2008/09

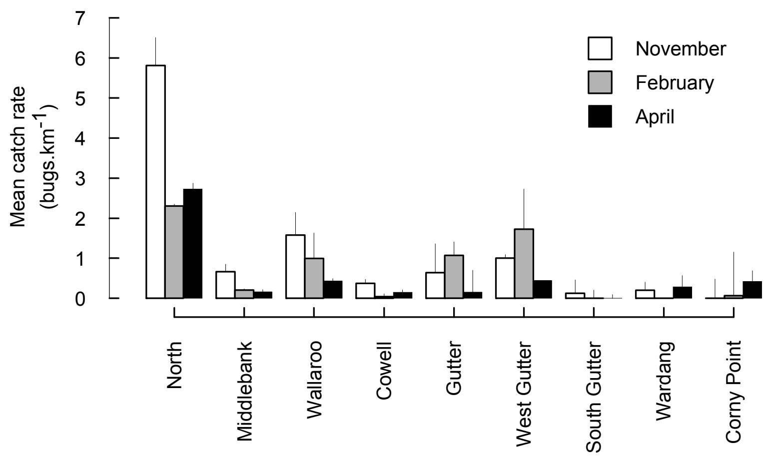

Figure 3.9. Mean abundance of bugs (bugs.km^{-1}) among months and regions during fishery-independent surveys conducted in Spencer Gulf (2008/09).

3.3 Commercial Balmain bug catch and effort: retained versus total catches.

Regional commercial trawl effort was found to positively correlate to temporal differences in survey biomass of bugs for regions of high trawl intensity (Wallaroo, Middlebank & Shoalwater, Main Gutter) ($P<0.05$, R^2 = 0.69; Figure 3.10 and Table 3.2). This is indicative of localised depletion being linked to current commercial fishing effort, which could be expected for a species with a life history strategy of localised movement, reproduction and recruitment. No correlation was found for regions of low and medium trawl intensity.

Since it became mandatory to report landed by-product in the 2001/02 fishing season, retained catches of bugs have generally increased from 1.1 t (2001/02) to 7.2 t (2008/09) (Figure 3.11). The estimated bug catch calculated from the 2008/09 fishery independent prawn surveys was 85,109 animals with an estimated total weight of 14.1 t (Table 3.3, Table 3.4). Overall, this estimate represents a 2-fold increase to the actual reported retained annual catch of 7.2 t. However, this trend was different between months, with an almost 3-fold difference estimated for the pre-Christmas fishing period (November: retained 3.4 t versus total 9.6 t) compared to a similar retained versus total weight for the fishing period following the April survey (retained 2.8 t versus total 2.9 t) (Figure 3.12). These estimates took into account depletion for areas of high trawl intensity as documented above. The discrepancy between retained and estimated total catch may be due to: 1) by-product being discarded, 2) by-product being used for personal consumption, and/or 3) uncertainty in reporting.

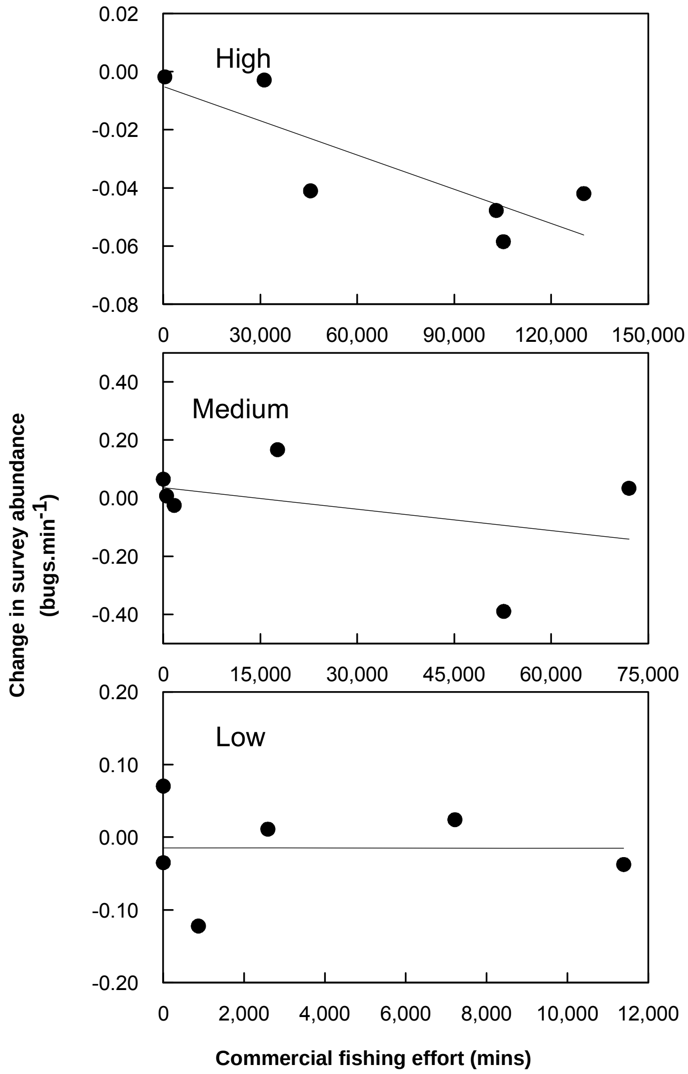

Figure 3.10. Correlation between change in fishery-independent survey abundance (bugs.min^{-1}) and commercial fishing effort (min) for regions of high (>90,000 min) medium (28,000–90,000 min) and low (<28,000 min) fishing intensity. Data points represent November and February effort for each region correlated to subsequent change in survey abundance.

Table 3.2. Linear regression analyses of fishing intensity and change in survey abundance of bugs as displayed in Figure 3.10. Regressions were of the form A=at+b; A, mean survey abundance (bugs.min^{-1}); a, constant; t, fishing effort (min); b, constant; asterisk indicates significant P value (<0.05).

Fishing Intensity	a (±se)	b (±se)	r^2	F	P
High	-3.9×10^{-7} (1.3×10^{-7})	-5.1×10^{-3} (1.1×10^{-2})	0.688	8.8	0.041*
Moderate	-2.5×10^{-6} (2.8×10^{-6})	3.6×10^{-2} (1.1×10^{-1})	0.158	0.8	0.435
Low	-2.3×10^{-8} (7.1×10^{-6})	-1.5×10^{-2} (4.0×10^{-2})	0.000	0.000	0.998

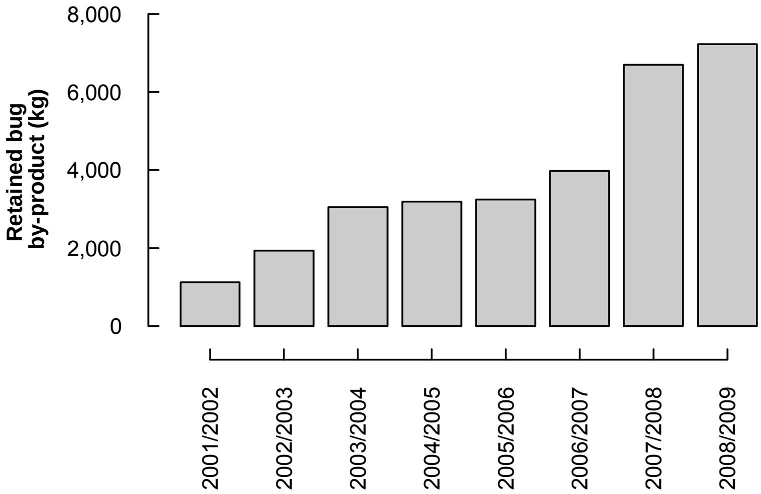

Figure 3.11. Retained commercial catches of bugs in Spencer Gulf between 2001/02 and 2008/09.

Table 3.3. Total bug abundance (SE) estimated from spatial and temporal survey abundances (bugs/min) multiplied by spatial and temporal commercial effort (min) for 2008/09. Asterisks indicate no data available, in which case data from Corny Point was used as a surrogate for estimations. Hat symbols indicate no standard errors due to re-calculation of survey catch rates to incorporate depletion.

Region	Data	November	February	April	Total
North	effort (mins)	52640.5	0	22068.5	
	bugs/min	0.63 (0.07)	0.24 (0.03)	0.30 (0.05)	
	total	33388.38 (3890.93)	0	6835.15 (1270.78)	40223.54 (5161.71)
Middlebank & Shoalwater	effort (mins)	102987.5	470	130592.75	
	bugs/min	0.05 ^	0.02 ^	0.01 ^	
	total	4748.86 ^	10.01 ^	1331.53 ^	6090.41 ^
Wallaroo	effort (mins)	130052.5	105184	280353.75	
	bugs/min	0.13 ^	0.08 ^	0.02 ^	
	total	16546.88 ^	8098.77 ^	6692.38 ^	31338.02 ^
Cowell	effort (mins)	0	2587	4410	
	bugs/min	0.03 (0.02)	0	0.01 (0.00)	
	total	0	9.95 (7.29)	65.85 (28.41)	75.80 (35.71)
Wardang	effort (mins)	1685	17665	9003	
	bugs/min	0.02 (0.02)	0	0.16 (-)	
	total	42.12 (42.12)	0	1500.50 (0)	1542.62 (42.12)
Main Gutter	effort (mins)	31223.5	45543.67	16384	
	bugs/min	0.06 ^	0.04 ^	0.01 ^	
	total	1937.38 ^	1825.90 ^	160.37 ^	3923.67 ^
West Gutter	effort (mins)	0	868.33	0	
	bugs/min	0.09 (0.04)	0.16 (0.10)	0.04 (0.02)	
	total	0	144.72 (90.50)	0	144.72 (90.50)
South Gutter	effort (mins)	7216	11393	8467	
	bugs/min	0.01 (0.00)	0.03 (0.03)	0	
	total	96.21 (65.55)	427.23 (427.23)	0	523.45 (492.79)
Corny Point	effort (mins)	502	72019	14451	
	bugs/min	0	0	0.04 (0.01)	
	total	0	553.99 (398.92)	602.36 (222.95)	1156.35 (621.87)
Thistle Island	effort (mins)	436	975	2000	
	bugs/min	0	0	0.04 (0.01)*	
	total	0	7.50 (5.40)	83.36 (30.85)	90.86 (36.25)
				Total effort (mins)	**1,071,178**
				Estimated total bug catch (# animals)	**85,109.48 (4,142.67)**

Table 3.4. Total bug catch (SE) estimated from spatial and temporal survey biomass (kg/min) multiplied by spatial and temporal commercial effort (min) for 2008/09. Hat symbols indicate no standard errors due to re-calculation of survey catch rates to incorporate depletion

Region	Data	November	February	April	Total
North	effort (mins)	52640.5	0	22068.5	
	kg/min	0.10 (0.01)	0.03 (0.00)	0.05 (0.00)	
	total	5653.35 (647.30)	0	1216.22 (216.02)	6869.58 (863.32)
Middlebank & Shoalwater	effort (mins)	102987.5	470	130592.75	
	kg/min	0.01 ^	0	0	
	total	859.80 ^	2.17 ^	304.97 ^	1166.94 ^
Wallaroo	effort (mins)	130052.5	105184	280353.75	
	kg/min	0.02 ^	0.01 ^	0	
	total	2801.11 ^	1257.96 ^	1074.48 ^	5133.56 ^
Cowell	effort (mins)	0	2587	4410	
	kg/min	0	0	0	
	total	0	1.97 (1.45)	14.57 (7.02)	16.55 (8.47)
Wardang	effort (mins)	1685	17665	9003	
	kg/min	0	0	0.02 (-)	
	total	6.59 (6.59)	0	213.07 (0)	219.67 (6.59)
Main Gutter	effort (mins)	31223.5	45543.67	16384	
	kg/min	0	0	0	
	total	271.15 ^	234.74 ^	12.45 ^	518.36 ^
West Gutter	effort (mins)	0	868.33	0	
	kg/min	0.01 (0.00)	0.01 (0.01)	0	
	total	0	16.08 (9.78)	0	16.08 (9.78)
South Gutter	effort (mins)	7216	11393	8467	
	kg/min	0	0	0	
	total	12.26 (8.19)	39.79 (39.79)	0	52.05 (47.98)
Corny Point	effort (mins)	502	72019	14451	
	kg/min	0	0	0	
	total	0	45.57 (45.57)	91.75 (40.02)	137.33 (85.59)
Thistle Island	effort (mins)	436	975	2000	
	kg/min	0	0	0	
	total	0	0.61 (0.61)	12.69 (5.53)	13.31 (6.15)
			Total effort (mins)		**1,071,178**
			Estimated total bug catch (kg)		**14,143 (686.46)**

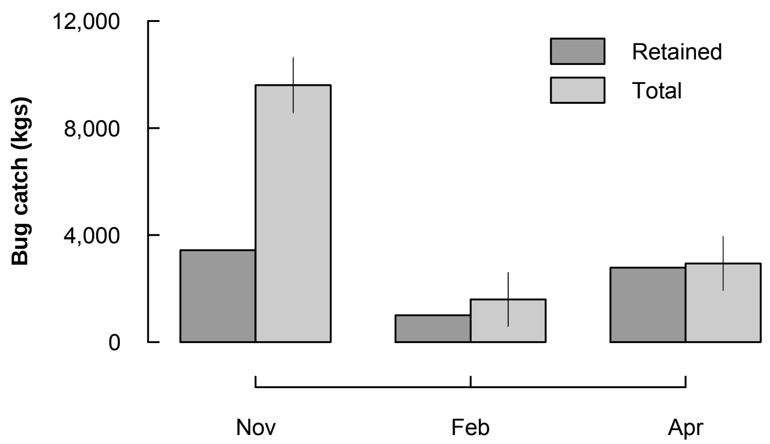

Figure 3.12. Retained versus estimated total (SE) commercial catch of bugs for fishing periods following the November, February and April surveys during 2008/09.

4 SOUTHERN CALAMARY

4.1 Survey catch composition.

4.1.1 Sex ratio and length-weight relationship.

Biological parameters were measured for 1,921 individuals. Of these, 164 were juvenile, 823 were female and 930 were male ranging in size from 38 to 253 mm ML. Equal sex ratios were observed in November and February, whereas April samples were slightly male-biased ($\chi^2 = 4.96$, df = 1, P = 0.03). A tight allometric relationship between mantle length and weight was found for both sexes ($r^2 = 0.97$) (Figure 4.1).

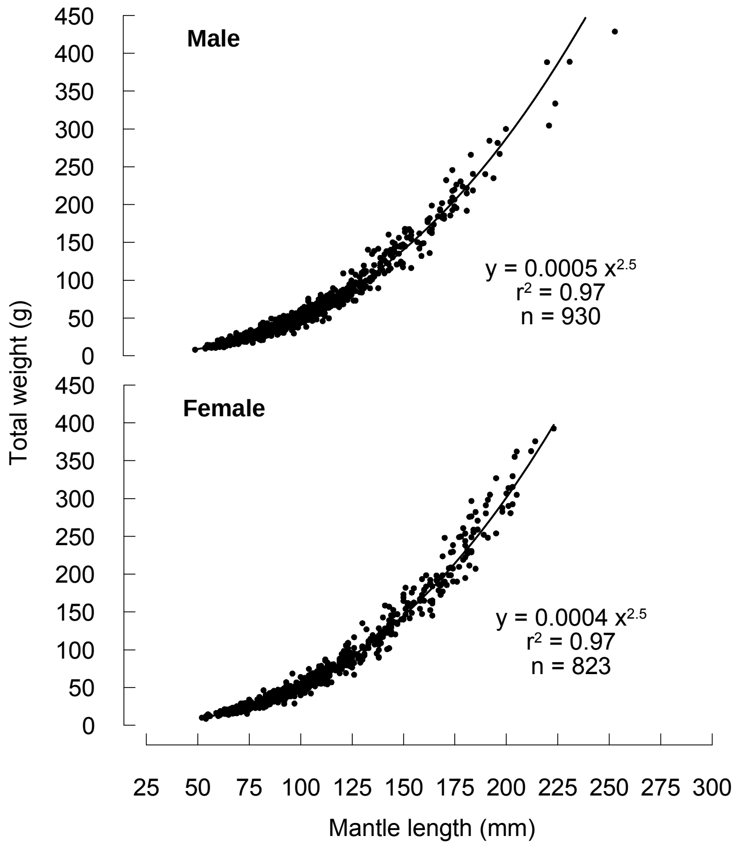

Figure 4.1. Length-weight relationships for male and female calamary in the Spencer Gulf trawl samples.

4.1.2 Length-frequency

Sub-adults dominated the catch representing 80.7% of the sampled population; adults comprised 10.7% and juveniles 8.5%. The size structure of the sub-adults varied throughout the fishing season (Kruskal-Wallis $\chi^2 = 31.98$, df = 2, P < 0.001). Sub-adults sampled in November were relatively evenly distributed within the 70–130 mm size range. This, however, changed, as catches in subsequent surveys were dominated (>60%) by small <110 mm sub-adults (Figure 4.2).

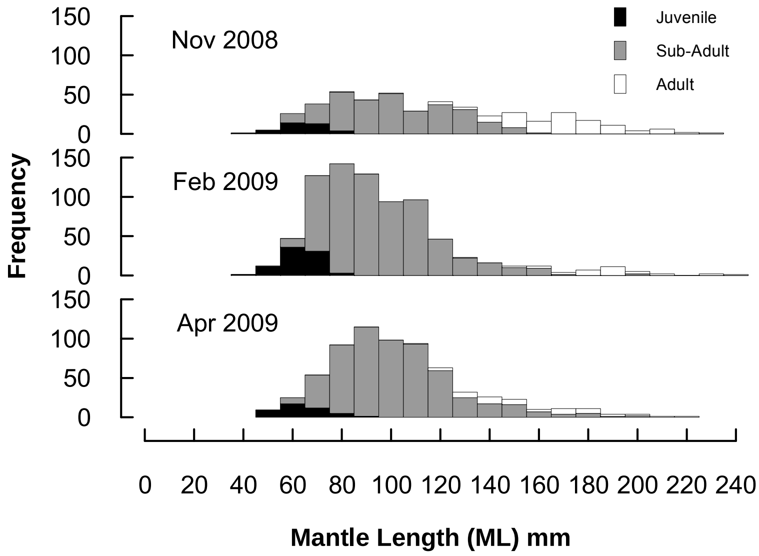

Figure 4.2. Length frequency of three maturity stages (juveniles, sub-adults, adults) for calamary in Spencer Gulf during November (n=457), February (n=789) and April (n=673) fishery-independent surveys in 2008/09.

4.1.3 Size of maturity

The smallest mature male and female was 71 and 94 mm (ML), respectively. The size at which 50% of the sampled population reached sexual maturity was 153 mm for males and 173 mm for females (Figure 4.3).

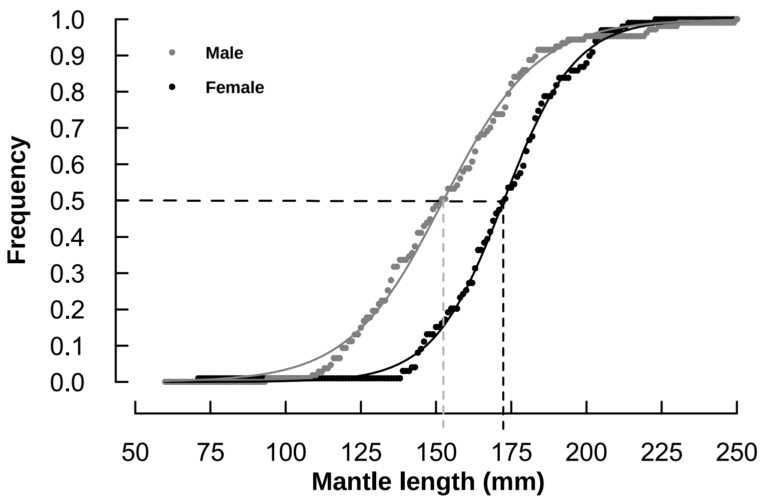

Figure 4.3. Logistic curve to determine 50% maturity (dashed line) of male (n=934) and female (n=823) calamary from Spencer Gulf trawl samples.

4.1.4 Temporal trends in maturity.

All three maturity stages were evident throughout each survey month. The relative proportion of juveniles and sub-adult remained relatively consistent (χ^2_{Juv} = 0.97, df = 4, P = 0.91; χ^2_{Sub} = 3.34, df = 4, P = 0.5) throughout the entire survey, although the relative proportion of adults significantly differed (χ^2_{Adult} = 21.27, df = 4, P < 0.001) from 26.0% in November to <7% in February and April. Adults were most evident in southern Spencer Gulf in November, particularly in the South Gutter and Corny Point regions (Figure 4.4). The greatest proportions of juveniles were found in the South Gutter region in February and April (Figure 4.4).

4.2 Distribution and abundance.

Calamary were ubiquitous throughout the Spencer Gulf trawl grounds. Of the 594 survey shots, 576 incidentally (96.9%) caught calamary with abundances ranging from 0.28 to 167.4 calamary.km^{-1} and biomass estimates ranging from <1 to 15.6 kg.km^{-1}. Numerical and biomass catch rates were positively correlated (Spearman's rank, r = 0.52, n = 596, P < 0.001). Calamary were generally more abundant in the North and Wallaroo regions with abundances frequently exceeding 20 calamary.km^{-1} and 1.0 kg.km^{-1} (Figure 4.5 and Figure 4.6). Mean abundances varied both spatially and temporally (region*season interaction: $F_{16, 595}$= 7.05, P < 0.001) peaking in November and April in North Spencer Gulf at 11.5 and 23.4 calamary.km^{-1}, respectively, and in February at 29.5 calamary.km^{-1} in the Wallaroo region (Figure 4.7). With the exception of Wallaroo, calamary abundance generally increased in each region throughout the fishing season (Figure 4.7).

4.3 Commercial calamary catch and effort: retained versus total catch.

Regional trawl intensity did not affect calamary abundance as there was no relationship between temporal differences in calamary catch rates and associated trawl effort in regions of low, medium and high levels of trawling activity (Figure 4.8 and Table 4.1). Since it became mandatory to report landed by-product in the 2002/03 fishing season catches of calamary have varied around 25 t, peaking at 30.8 t in 2003/04 (Figure 4.9). The estimated calamary catch calculated from the 2008/09 fishery independent prawn surveys was 1,488,833 animals with an estimated total weight of 93.2 t (Table 4.2 and Table 4.3). This estimate represents a 4-fold increase to the actual retained catch of 22.7 t (Figure 4.9). This trend was consistent for each month of the fishing season (Figure 4.10). The discrepancy between retained and estimated total catch may be due to: 1) by-product being discarded, 2) by-product being used for personal consumption, and/or 3) uncertainty in reporting.

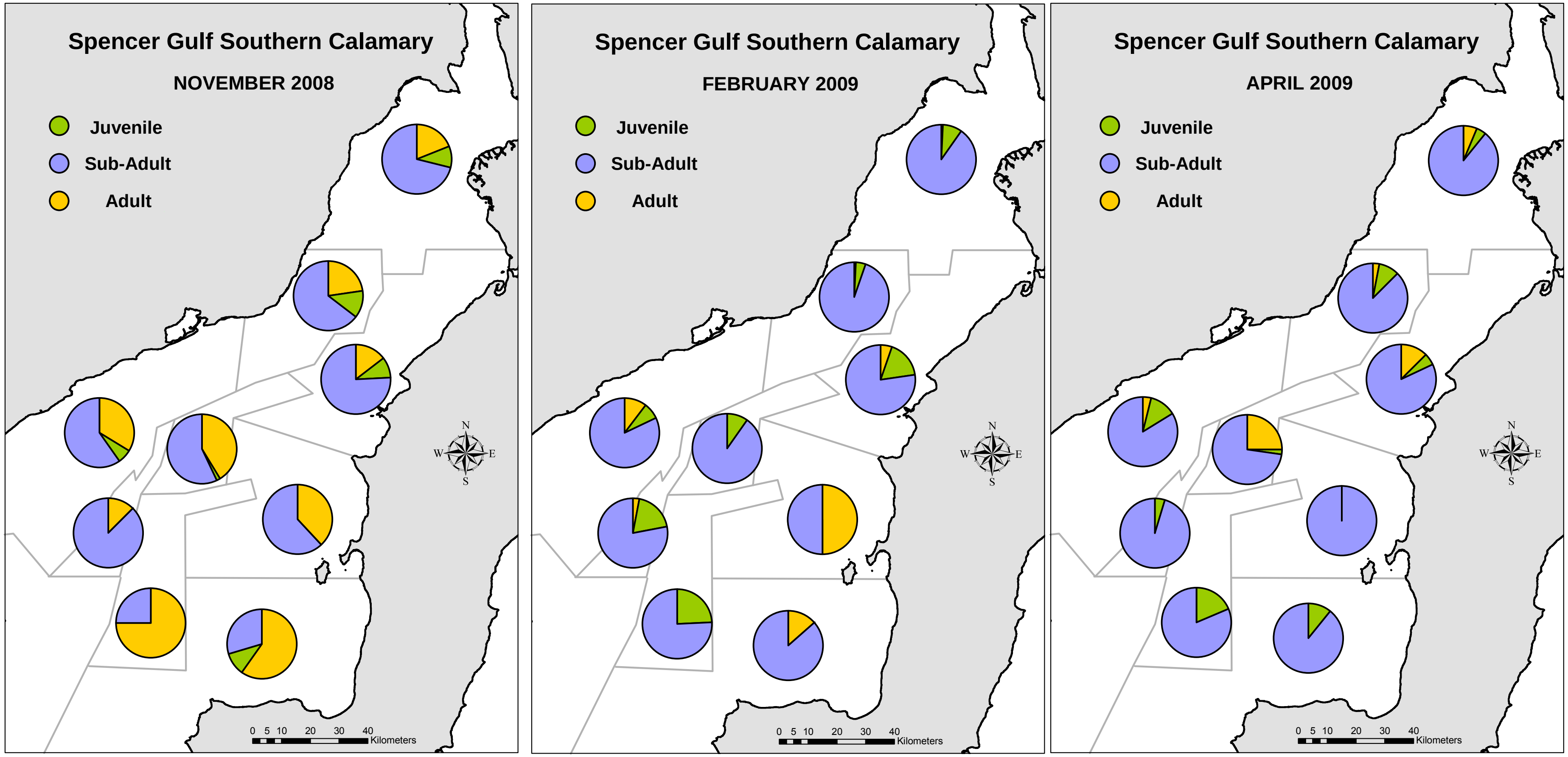

Figure 4.4. Regional proportion of maturity stages (juvenile, sub-adults, adults) for calamary in Spencer Gulf during November, February and April fishery-independent surveys in 2008/09.

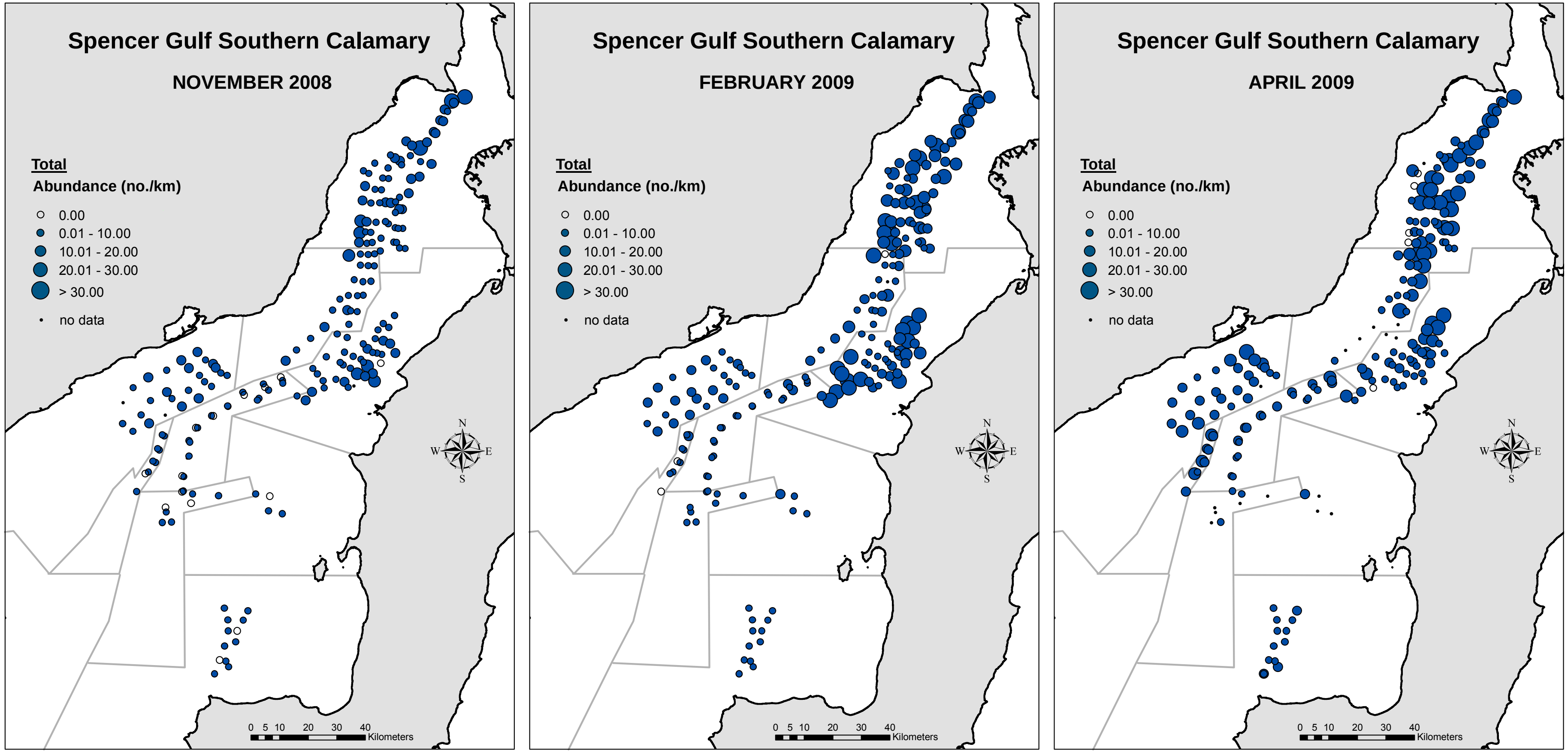

Figure 4.5. Calamary abundance (no./km) for up to 209 trawl shots conducted in Spencer Gulf during November, February and April fishery-independent surveys in 2008/09

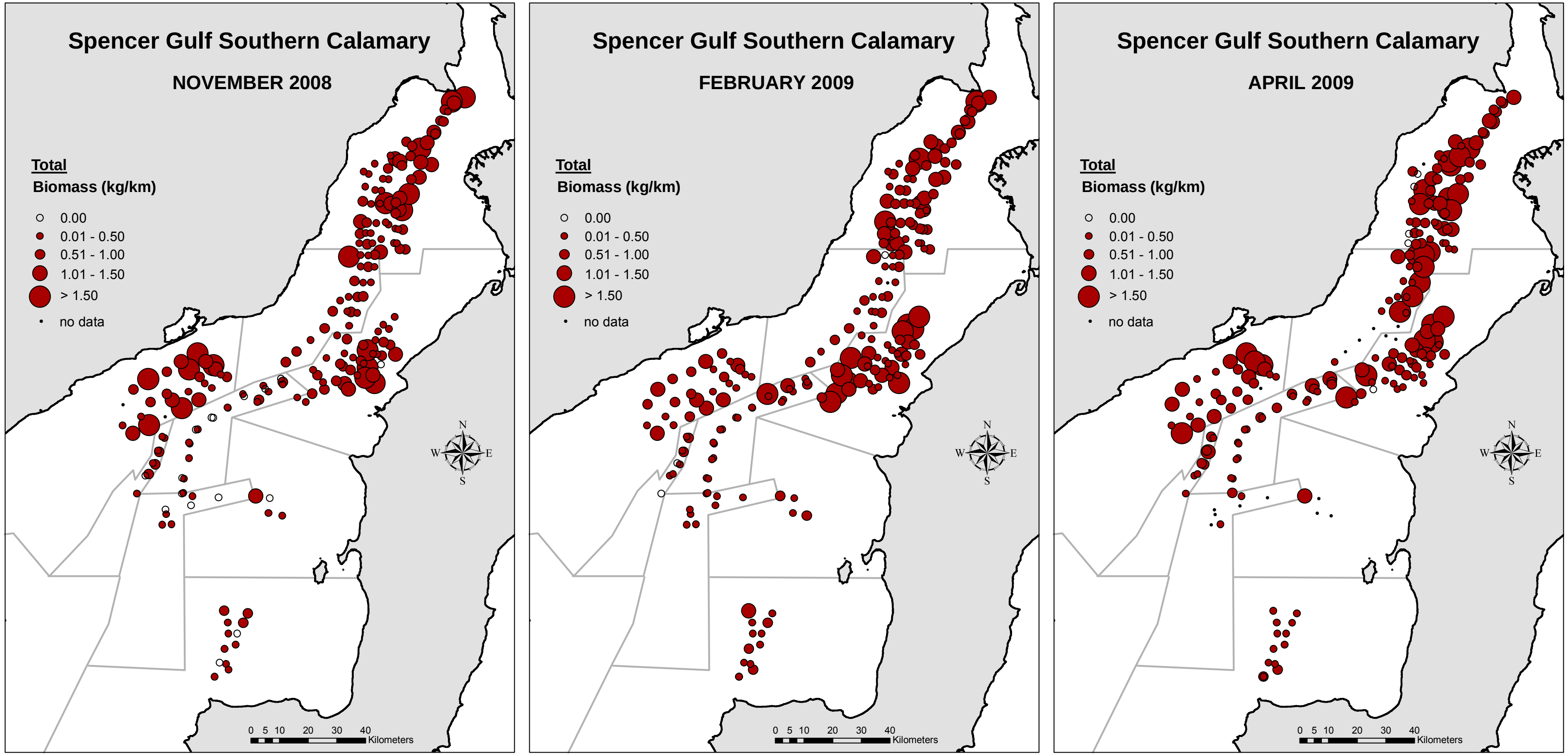

Figure 4.6. Calamary biomass (kg/km) for up to 209 trawl shots conducted in Spencer Gulf during November, February and April fishery-independent surveys in 2008/09.

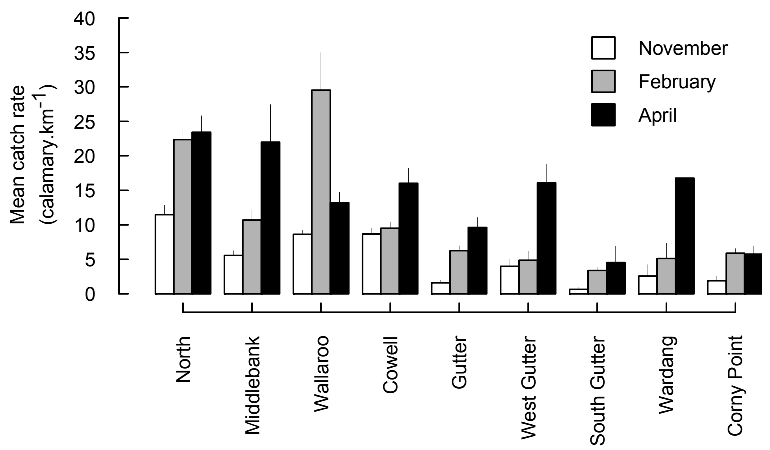

Figure 4.7. Mean (SE) abundance of calamary (calamary.km^{-1}) among months and regions during fishery-independent surveys conducted in Spencer Gulf (2008/09).

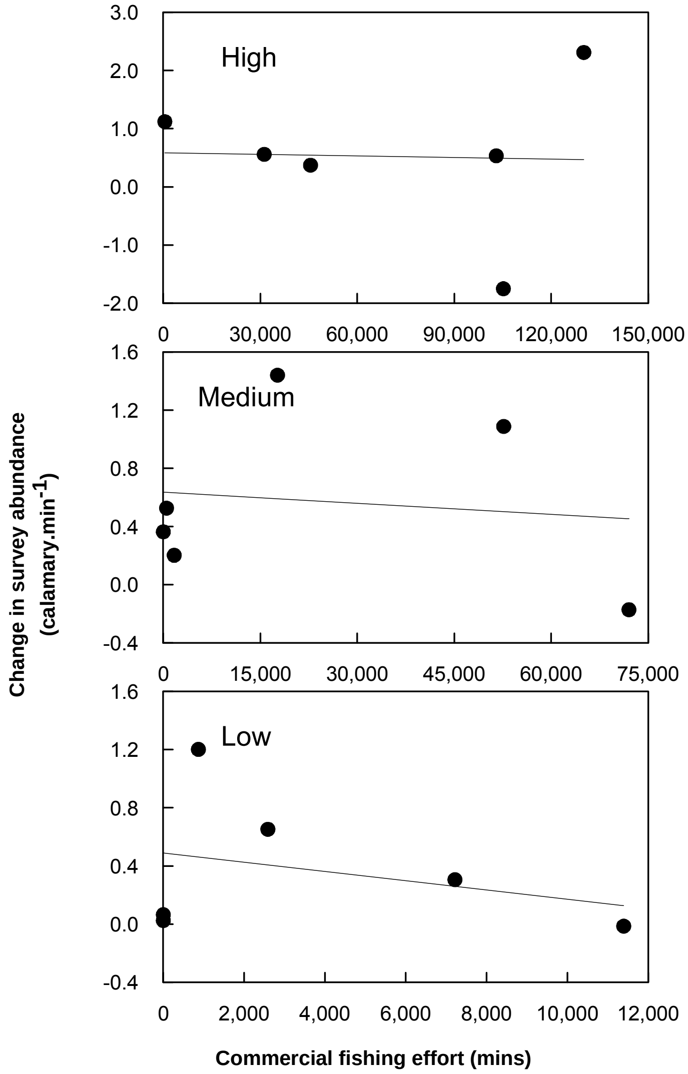

Figure 4.8. Correlation between change in fishery-independent survey abundance (calamary.min^{-1}) and commercial fishing effort (min) for regions of high (>90,000 min) medium (28,000–90,000 min) and low (<28,000 min) fishing intensity. Data points represent November and February effort for each region correlated to subsequent change in survey abundance.

Table 4.1. Linear regression analyses of fishing intensity and change in survey abundance of calamary as displayed in Figure 4.8. Regressions were of the form A=at+b; A, mean survey abundance (calamary.min^{-1}); a, constant; t, fishing effort (min); b, constant; asterisk indicates significant P value (<0.05).

Fishing Intensity	a (±se)	b (±se)	r^2	F	P
High	-9.0×10^{-7} ($<1.0\times10^{-7}$)	0.585 (1.09)	0.001	0.005	0.948
Moderate	-2.5×10^{-3} ($<1.0\times10^{-7}$)	0.635 (0.352)	0.018	0.071	0.803
Low	-3.2×10^{-5} ($<1.0\times10^{-7}$)	0.489 (0.273)	0.097	0.427	0.549

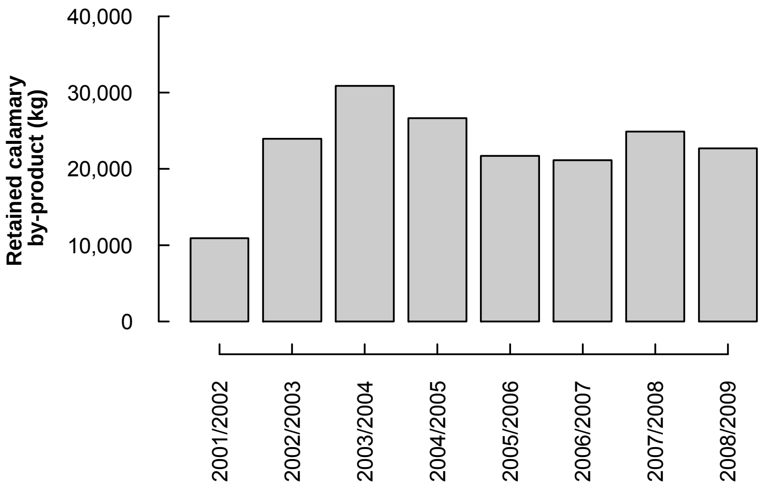

Figure 4.9. Retained commercial catches of calamary in Spencer Gulf between 2001/02 and 2008/09

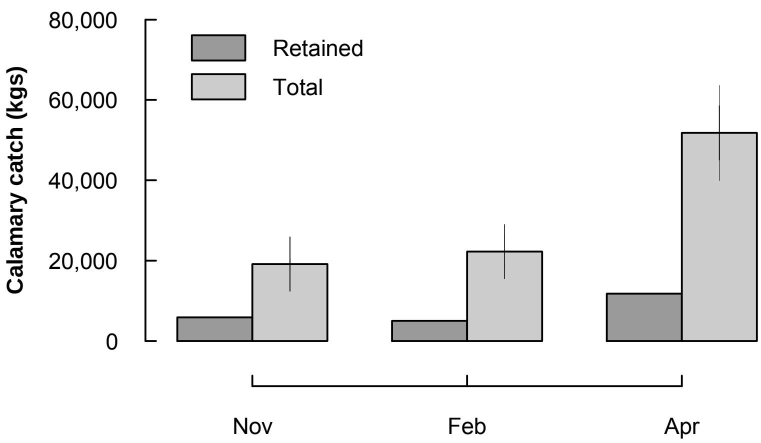

Figure 4.10. Retained versus estimated total (SE) commercial catch of calamary for fishing periods following the November, February and April surveys during 2008/09.

Table 4.2. Total calamary abundance (SE) estimated from spatial and temporal survey abundances (calamary/min) multiplied by spatial and temporal commercial effort (min) for 2008/09. Asterisks indicate no data available, in which case data from Corny Point was used as a surrogate for estimations.

Region	Data	November	February	April	Total
North	effort (mins)	52640.5	0	22068.5	
	calamary/min	1.25 (0.13)	2.33 (0.15)	2.70 (0.26)	
	total	65576.08 (6858.84)	0 (0)	59512.16 (5825.79)	125088.24 (12684.63)
Middlebank & Shoalwater	effort (mins)	102987.5	470	130592.75	
	calamary/min	0.57 (0.07)	1.10 (0.15)	2.22 (0.56)	
	total	58453.21 (7003.30)	516.71 (71.96)	289778.73 (73881.95)	348748.65 (80957.21)
Wallaroo	effort (mins)	130052.5	105184	280353.75	
	calamary/min	0.87 (0.10)	3.18 (0.58)	1.43 (0.16)	
	total	113737.68 (13646.32)	334890.52 (60915.44)	401516.91 (45592.47)	850145.10 (120154.23)
Cowell	effort (mins)	0	2587	4410	
	calamary/min	0.91 (0.09)	0.93 (0.08)	1.58 (0.19)	
	total	0	2405.67 (216.97)	6973.68 (818.73)	9379.35 (1035.70)
Wardang	effort (mins)	1685	17665	9003	
	calamary/min	0.33 (0.19)	0.53 (0.22)	1.97	
	total	547.63 (324.58)	9303.57 (3942.97)	17705.9	27557.09 (4267.57)
Main Gutter	effort (mins)	31223.5	45543.67	16384	
	calamary/min	0.16 (0.04)	0.71 (0.08)	1.08 (0.17)	
	total	4906.55 (1165.06)	32538.77 (3916.29)	17779.67 (2742.73)	55224.99 (7824.07)
West Gutter	effort (mins)	0	868.33	0	
	calamary/min	0.40 (0.10)	0.47 (0.12)	1.67 (0.29)	
	total	0	405.22 (102.22)	0	405.22 (102.22)
South Gutter	effort (mins)	7216	11393	8467	
	calamary/min	0.07 (0.03)	0.37 (0.05)	0.36 (0.21)	
	total	493.09 (242.54)	4253.39 (557.40)	3039.05 (1806.00)	7785.53 (2605.95)
Corny Point	effort (mins)	502	72019	14451	
	calamary/min	0.20 (0.07)	0.72 (0.08)	0.55 (0.12)	
	total	99.00 (33.94)	52075.28 (5710.68)	7952.28 (1720.83)	60126.57 (7465.43)
Thistle Island	effort (mins)	436	975	2000	
	calamary/min	0.53 (0.09)*	1.15 (0.17)*	1.50 (0.25)*	
	total	231.08 (40.12)	1121.25 (165.08)	3020.00 (492.60)	4372.33 (697.801)
				Total effort (mins)	**1,071,178**
				Estimated total calamary catch (# animals)	**1,488,833.08 (107,908.47)**

Table 4.3. Total calamary catch (SE) estimated from spatial and temporal survey biomass (kg/min) multiplied by spatial and temporal commercial effort (min) for 2008/09. Asterisks indicate no data available, in which case data from Corny Point was used as a surrogate for estimations.

Region	Data	November	February	April	Total
North	effort (mins)	52640.5	0	22068.5	
	kg/min	0.09 (0.01)	0.09 (0.01)	0.11 (0.01)	
	total	4710.57 (422.09)	0	2473.61 (255.02)	7183.96 (677.12)
Middlebank & Shoalwater	effort (mins)	102987.5	470	130592.75	
	kg/min	0.047 (0.01)	0.05 (0.01)	0.09 (0.02)	
	total	4862.32 (478.07)	23.307 (2.91)	11438.24 (2667.82)	16323.86 (3148.80)
Wallaroo	effort (mins)	130052.5	105184	280353.75	
	kg/min	0.07 (0.01)	0.15 (0.04)	0.12 (0.04)	
	total	8948.55 (1277.04)	15636.35 (4238.69)	34671.33 (11561.80)	59256.23 (17077.54)
Cowell	effort (mins)	0	2587	4410	
	kg/min	0.12 (0.01)	0.06 (0.01)	0.10 (0.01)	
	total	0	164.09 (16.02)	437.77 (60.64)	601.86 (76.66)
Wardang	effort (mins)	1685	17665	9003	
	kg/min	0.04 (0.03)	0.03 (0.01)	0.133	
	total	68.45 (44.43)	567.63 (206.15)	1197.4	1833.49 (250.59)
Main Gutter	effort (mins)	31223.5	45543.67	16384	
	kg/min	0.01 (0.00)	0.06 (0.02)	0.05 (0.01)	
	total	478.72 (132.85)	2074.93 (824.00)	810.79 (173.24)	3364.45 (1130.10)
West Gutter	effort (mins)	0	868.33	0	
	kg/min	0.03 (0.01)	0.02 (0.01)	0.06 (0.01)	
	total	0	17.67 (6.76)	0	17.67 (6.76)
South Gutter	effort (mins)	7216	11393	8467	
	kg/min	0.01 (0.00)	0.01 (0.00)	0.03 (0.02)	
	total	67.41 (36.26)	153.91 (35.58)	228.36 (148.49)	449.69 (220.33)
Corny Point	effort (mins)	502	72019	14451	
	kg/min	0.03 (0.01)	0.05 (0.01)	0.03 (0.01)	
	total	14.06 (4.40)	3598.97 (671.60)	376.51 (68.85)	3989.54 (744.79)
Thistle Island	effort (mins)	436	975	2000	
	kg/min	0.05 (0.01)*	0.06 (0.01)*	0.08 (0.02)*	
	total	21.83 (4.40)	55.84 (11.75)	160.57 (32.37)	238.24 (48.53)
			Total effort (mins)	**1,071,178**	
			Estimated total calamary catch (kg)	**93,258.99 (12,732.57)**	

5 DISCUSSION

Two by-product species are legally permitted to be retained by Spencer Gulf and GSV prawn fishers: southern calamary (*S. australis*) and slipper lobsters of the genus *Ibacus* (exclusively the Balmain bug, *I. peronii* as determined from survey catches). Fishery-independent data and commercial catch and effort data provided information to assess biology, catch composition and spatial and temporal trends in catches for both species in Spencer Gulf during 2008/09. Fishery-independent data from Spencer Gulf in 2006/07 and GSV from 2004/05–2006/07 provided additional information to assess options for a minimum legal size (MLS) for bugs in South Australia.

5.1 Balmain bug

In Spencer Gulf, female bugs were found to attain a larger maximum size and weight than that of males. Modal size of the total population increased between February and April during both 2006/07 and 2008/09 which was likely attributed to a period of growth. Further, reproductive activity was apparent during all survey months, with the percent of egg-bearing females greatest during April. Similarly, from survey data collected in GSV during 2005, moulting frequency of *I. peronii* increased between March and June, while peak reproductive activity was in April (Dixon *et al*., 2006). Note that survey data from both Spencer Gulf and GSV were collected during the fishing season (November to May/June). In a tagging study conducted in NSW, Stewart and Kennelly (2000) found that sex-specific differences in size of *I. peronii* was due to faster growth rates of females, while the majority of growth (moulting frequency) occurred between October and January. Females produced multiple broods throughout the year, with peak reproductive activity in NSW populations found to be between July and September (winter/early spring) (Stewart and Kennelly, 1997).

Bugs were more widely distributed and at higher abundances at the start of the season (November) in Spencer Gulf, and were observed at significantly higher catch rates in the north region compared to the rest of the gulf. Survey catch rates were negatively correlated with trawl intensity in areas of high commercial effort (Wallaroo, Middlebank & Shoalwater and Main Gutter) throughout the season, which is likely indicative of localised depletion. When estimating total catch in this report, we assumed a linear rate of depletion with trawl effort between surveys. Thus, total catch estimates are potentially sensitive to this assumption. Further, trawl catchability of bugs, particularly effects of seasonality, is unclear, which contributes a source of uncertainty in how representative survey data is of the actual bug population throughout the season.

Localised depletion could be expected for bugs in Spencer Gulf as i) they exhibit minimal movement, ii) they have low fecundity, iii) they display localised reproduction and recruitment, which results in sub populations for Spencer Gulf and GSV (Sydney-Smith 2006), iv) they are long-lived (>15 years), v) they are vulnerable to capture, and vi) fishing effort in Spencer Gulf is limited in range such that some areas are intensively fished.

In 2007, the South Australian government legislated the protection of egg-bearing female slipper lobsters (*Ibacus* spp.) to aid sustainability of the species. Their inherent biological traits and the observed depletion patterns shown in this report suggest that the addition of further management controls for bugs may require consideration to ensure their sustainable harvest. Previously, a minimum legal size (MLS) had been suggested as a potential management tool to use in combination with protection of berried females as done in other States. Further, the introduction of a size limit may provide the potential for a future increase in stock biomass. Size limits are an appropriate management option for slipper lobsters due to their hardy nature and high post-trawl survival. In the absence of yield per recruit or egg per recruit models for most slipper lobster species, setting a MLS that ensures at least 50% of females breed at least once before recruitment into the fishery is a common alternative (Haddy *et al.*, 2005). The size at which 50% of female bugs reach physiological maturity (size of maturity; SOM) was determined as 67 mm CL (117 mm CW) in Spencer Gulf and 64 mm CL (113 mm CW) in GSV.

The difference in SOM between gulfs may be due to: 1) genetic diversity between these sub-populations (Sydney-Smith 2006), 2) faster growth rates and larger size in Spencer Gulf compared to GSV, 3) differences in environmental and population parameters or 4) a combination of these factors. In the closely related spiny lobsters, spatial differences in SOM between populations appear to be influenced by a range of factors including temperature, growth rates, density dependence and food availability, while SOM appears to be age related, rather than size related (Annala & Bycroft, 1987; MacDiarmid, 1989; Melville-Smith *et al.*, 1995; Hobday & Ryan, 1997; Linnane *et al.*, 2008). The difference in SOM between gulfs complicates implementation of a single size limit, particularly given that the larger SOM of 117 mm CW in Spencer Gulf, if imposed in the GSVPF, would protect a substantial proportion of the current GSV bug population (75%). Furthermore, if 115 mm CW (average between both SOM's) was used as a single MLS in South Australia, only 42% of females would have reached maturity in Spencer Gulf, while in GSV 71% of the current biomass would be protected. However, it should be noted that a MLS may provide the potential for a future increase in stock biomass, and inherently through growth, a larger proportion of the biomass being available for harvest in the future.

Alternatively, to ensure 50% of females in both gulfs are protected, particularly within areas of high fishing effort, and to maximise the current fishable biomass, two separate MLS based on the SOM in each gulf (Spencer Gulf: 117 mm CW; GSV: 113 mm CW) would warrant consideration as a management strategy. This would optimise egg production and the current harvestable biomass in both gulfs.

5.2 Southern calamary

Calamary were ubiquitous throughout the Spencer Gulf trawl grounds and were predominantly represented by juvenile and sub-adults. It is likely that the Spencer Gulf calamary population shares similar characteristics to the adjacent GSV population, where it is spatially segregated into an offshore nursery ground and inshore spawning grounds (Triantafillos 2001, Steer *et al*., 2007a, b). Such spatial segregation is common amongst inshore squid species (Sauer 1991). Approximately 11% of the sampled calamary consisted of mature adults, indicating that the observed level of population structuring is unlikely to be an artefact of gear selectivity or squid catchability. The greatest proportion of adults (26%) was caught during November. Higher catches of adults were expected during this time of the year, as it coincides with the seasonal peak in spawning activity (Steer *et al*. 2007a). Similarly, a higher number of juveniles and sub-adults were expected in the February and April surveys as they are the product of the spring/summer spawning season.

Although calamary have a peak spawning season they reproduce throughout the year. Consequently, there is a continual "conveyor belt" of recruits that migrate onto the offshore nursery grounds. This partially explains why there was no clear evidence of localised depletion on the trawl grounds between the successive surveys as the local areas are continually replenished. Squid, in general, are highly dynamic in terms of their life history characteristics and ecology. They are short-lived (<12 months) and exhibit rapid growth, the rate of which is determined by the environment (i.e. temperature and food), and therefore populations are capable of increasing rapidly in response to favourable environments. Given these life history characteristics, calamary populations typically exhibit large natural fluctuations, which as a result, make it extremely difficult to isolate the effect of fishing on the overall population. The SGPF has been operating since 1968 (Carrick 2003) and during this time they have also been incidentally catching calamary. Although it is estimated that the trawling fleet catches appreciable numbers of squid (~90 t) over the course of the fishing season it does not appear to compromise the sustainable harvest of the species. This also appears to be the case in the Marine Scalefish Fishery, which share the resource with the commercial prawn fishers but predominantly target mature calamary on the inshore spawning grounds, as long-term trends in catch have remained relatively stable (> 270 t) since the early 1990s (Fowler *et al*. 2009).

5.3 Retained versus total catch

Retained commercial catches during 2008/09 for both bugs and calamary were 7.2 t and 22.7 t, respectively. However, estimated total catches (using survey catch rates and commercial trawl effort) for bugs and calamary during 2008/09 were 14.1 t and 93.2 t, respectively, or a 2 and 4-fold increase respectively, from the retained catches. It should be noted that estimated total catches for bugs incorporated depletion rates, which were found to be significant for regions of high trawl intensity (Wallaroo, Middlebank & Shoalwater, Main Gutter). The discrepancy between retained and estimated total catches was most evident during the pre-Christmas fishing period for bugs, and during the post April-survey fishing period for calamary. This discrepancy may be due to: 1) by-product being discarded, 2) by-product being used for personal consumption, and/or 3) uncertainty in reporting. It is widely accepted (S. Roberts & M. Steer pers. obs.) that retained by-product catches are an under-representation of the total catch as not all are retained and sold as by-product.

5.4 Future Research

Since both bugs and calamary are exploited as by-product species by South Australian prawn fisheries, future monitoring and research would: 1) provide increased confidence in the sustainable harvest of these species, 2) meet the requirements of the Australian Government (in accordance with the EPBC Act,1999) and 3) partly address community perceptions and concerns regarding the impacts of trawling. The extent of future monitoring and research would be determined by: 1) the level of risk ranked for each species through PIRSA's risk assessment process; and 2) the vulnerability for each species based on their life-history and ecology. From information provided in this report, vulnerability to the impacts of prawn trawling is greater for bugs than for calamary.

Continuing the current opportunistic data collection for by-product species during fishery-independent surveys would provide for a useful long-term database on spatial and temporal abundance and biomass for future assessment. Such information for calamary has previously been shown to be of importance for forecasting inshore recruitment into South Australia's calamary fisheries (Steer *et al.*, 2007b), and additionally addresses issues of resource sharing between the commercial sectors that harvest this species. Furthermore, ongoing data collection would address the lack of information for bugs, particularly for South Australian populations.

Depletion effects during fishing were assessed in this report by comparing survey data to that of fishing effort at the scale of survey regions and months, with an assumed linear rate of depletion with trawl effort. This would be best confirmed by on-board observers during commercial fishing.

5.5 Summary

This report provides detailed biological, survey and catch information for both by-product species of the SGPF, for the purpose of informing PIRSA's risk assessment process. The life-history strategy, biological data and commercial catch and effort data for calamary indicates that this species has low vulnerability to current levels of trawling activity in the SGPF, and additional management measures would unlikely result in improving the sustainable harvest of this species. However, the same information for bugs indicates that this species is susceptible to the impacts of intensive localised fishing, which is a characteristic of the current harvest strategy process in South Australian prawn fisheries. While the current management control for this species is the protection of egg-bearing females, a MLS would provide an additional management option to gain greater confidence in the sustainability of this species. Furthermore, a MLS may provide the potential for a future increase in stock biomass particularly in areas of high trawl effort. Two options for a MLS warrant consideration: 1) a single size limit for the State, which would either a) protect less than 50% SOM in Spencer Gulf (115 mm CW), or b) protect a substantial proportion (75%) of the current GSV biomass (117 mm CW), or 2) different size limits for each of Spencer Gulf (117 mm CW) and GSV prawn fisheries (113 mm CW) based on 50% SOM in each gulf. The latter option ensures sustainability based on 50% protection of mature females, as well as equity of access to the current available biomass for both fisheries.

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