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Adopting a Citizen Science approach to develop cost-effective methods that will deliver annual information for managing small-scale recreational fisheries: The Southwest Recreational Crabbing Project

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Table of Contents

1 Non-technical summary

Fishing for the blue swimmer crab, *Portunus armatus*, represents an iconic Western Australian recreational fishing experience. State-wide integrated surveys of boat-based recreational fishing conducted by the Department of Fisheries, Western Australia (DoF) in 2011/12 and 2013/14 reported that three times more blue swimmer crabs were caught than any other recreational species (Ryan *et al.,* 2013; Ryan *et al.*, 2015). DoF is responsible for the sustainable management of the state's blue swimmer crab resource, and receives considerable information from fisheries with a significant commercial sector such as Cockburn Sound and the Peel-Harvey Estuary. However, the resource-intensive nature of recreational fishing surveys means the same level of information is not always available for recreational-only crab fisheries.

Funding was granted through the Recreational Fishing Initiatives Fund (RFIF) for the Southwest Recreational Crabbing Project (SWRCP), a three-year study that commenced on June 1st 2013. The SWRCP aimed to engage local crabbing communities in developing ongoing, cost-effective programs that could deliver annual information on recreational crabbing and stock dynamics in the iconic recreational blue swimmer crab fisheries of the Swan-Canning Estuary (SCE), the Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB). The specific objectives of this study aimed to:

1. Establish a Recreational Angler Program (RAP) in the SCE, LE and GB;
2. Develop methods for the ongoing assessment of blue swimmer crab recruitment and breeding stocks in the SCE, LE and GB.
3. Determine the effectiveness of tagging methods to provide information on the movement of blue swimmer crabs that occurs between the SCE, LE and GB and their adjacent marine environments (including Cockburn Sound and Koombana Bay).

Research Angler Program (RAP)

A successful RAP based on the existing state-wide RAP run by DoF was established with recreational fishers in the SCE, LE and GB maintaining logbook records of their crabbing activity to provide temporal and spatial information on recreational catch and effort and catch composition.

A total of 208 fishers registered with the RAP, with 103 fishers in the SCE, 43 in LE and 62 in GB. However, only 43%, 37% and 21% of these fishers submitted log sheets in the SCE, LE and GB, respectively. The majority of fishers were male and lived near their specific fishery.

Drop netting accounted for 84%, 85% and 92% of all trips in the SCE, LE and GB, respectively, while fishers using scoop nets accounted for just 4% of trips in the SCE and GB, and for 9% in LE. Fishers catching crabs by hand while diving or snorkelling accounted for 11% of trips in the SCE, but there was no diving or snorkelling for crabs reported in either the LE or GB.

The mean annual catch rate (crabs kept per 10 drop net pulls) for drop net fishers in the SCE was consistent, increasing marginally from 1.6 for the 2013/14 fishing season (June 2013 to May 2014 inclusive) to 1.7 in 2014/15 before declining to 1.3 in 2015/16. Drop net catch rates were generally higher and more variable in the LE and GB than in the SCE. The catch rate of kept crabs caught by drop netters per ten drop net pulls in LE almost doubled from 1.7 in 2013/14 to 3.0 in 2014/15, before falling to just 1.4 in 2015/16. The mean annual drop net catch rate in GB was 2.9 crabs in 2013/14, before declining to 2.0 and 1.9 crabs in 2014/15 and 2015/16, respectively.

Clear temporal and spatial patterns were evident in the catch and effort reported by SWRCP fishers in each fishery. Most fishing in the SCE occurred over summer and into autumn, with fishing occurring throughout much of the estuary. The catch was almost exclusively male, and distinctive by the large size of crabs (mean carapace width ~153 mm CW). Fishing focused on the lower reaches of the Swan River during winter and spring with the catch composed mainly of large female and sub-legal (< 127mm CW) male crabs. The majority of fishing in the LE occurred over summer within the Leschenault Estuary where the catch was almost exclusively male and much smaller than in other southwest Western Australian fisheries (mean carapace width ~123 mm CW). A small amount of crabbing also occurred in Bunbury Harbour, with the catch a mix of male and female crabs. Fishing continued in the estuary into autumn, before shifting solely to Bunbury Harbour during winter and into spring. The catch during this period was largely female, with about half the catch over the legal-size limit. Fishing in GB was more evenly spread throughout the year with a peak in activity from September to January. The catch during this peak period was mostly female with a number released because they were bearing eggs. The catch over summer and autumn was composed of equal numbers of male and female crabs, with relatively equal numbers of size and undersize female crabs, and predominantly undersize males. Fishing in GB occurred exclusively in the shallow nearshore waters around the bay, with most activity between the Busselton Jetty and Wonnerup Estuary.

Fishery-independent research – breeding stock and recruitment surveys

Small mesh (2”) hourglass traps were found to be an effective method for assessing blue swimmer crab breeding stocks in the SCE, LE and GB, with significant quantities of sexually mature and berried female crabs captured during all surveys conducted in October and November each year.

Mean annual catch rates of sexually mature female crabs (SCE ≥ 94 mm CW; LE ≥ 95 mm CW; GB ≥ 92 mm CW) were not significantly different ($p \geq 0.05$) between years in either the SCE or LE. Catch rates in the SCE increased from 3.0 crabs/traplift in 2013 to 3.4 in 2014 and 3.7 in 2015, while there was a decrease in the LE, from 7.3 crabs/traplift in 2013 to 6.0 and 5.4 in 2014 and 2015, respectively. A significant decline ($p<0.05$) was evident in GB, with the catch rate of sexually mature female crabs falling from 10.6 crabs/traplift in 2013 to 5.6 crabs/traplift in 2015. A longer dataset is required to determine if this decline represents the beginning of a long term trend or a return to more normal breeding stock levels.

Sexually mature female crabs captured in the SCE were consistently larger in size than crabs sampled in either the LE or GB. While the mean annual catch rates were higher in the LE and GB than in the SCE, the breeding potential of the respective stocks was more comparable as larger female blue swimmer crabs produce more eggs per breeding season. The annual proportions of berried female crabs in each fishery were consistent with levels reported in other southwest Western Australian crab fisheries.

Highest catch rates of sexually mature female crabs in the SCE were consistently encountered in the very lower reaches of the Swan River, downstream from Bicton. Catch rates in the LE were relatively consistent across sites throughout Bunbury Harbour, with a noticeable increase at the two most oceanic sites between the end of the harbour breakwater and the shipping channel. Catch rates in GB were relatively consistent across sites west of the Busselton Jetty through to Meelup, with a noticeable increase at sites east of the jetty to Forrest Beach.

Beach seining was found to be an effective method for the assessment of blue swimmer crab recruitment in the LE, with significant quantities of sub-adult male and female crabs captured in surveys during all months and years. However, seining was not found to be a suitable method for sampling juvenile crabs in either the SCE or GB. Otter trawling was trialled in the SCE during March and April 2016 and was more successful, and so considered the most appropriate method for sampling juvenile crabs in this fishery. Significant quantities of sub-adult crabs were captured during all trawls, with highest abundances at sites downstream from Point Resolution. Particularly high catch rates were recorded in the shallow (≤4 m) waters on the bank in the middle of Rocky Bay and around the Swan Yacht Club in North Fremantle, and Karrakatta Bank in Freshwater Bay. As this spatial pattern closely matches the spatial abundance of berried females, we conclude that the breeding stock in this area contributes to the juvenile recruitment in this fishery. Beach seining, small mesh hourglass crab traps and otter trawling were all trialled for sampling juvenile blue swimmer crabs in GB, but none of these methods were successful. Consequently, the locations of nursey areas for blue swimmer crab stocks in GB and appropriate methods for sampling these areas needs further investigation.

Tagging studies

Suitable tagging techniques for *P. armatus* were examined through four separate investigations: two *in situ* field surveys and two laboratory-based aquarium trials.

The FloyTag polyvinyl glue-on tag (GT) proved successful as a short-term marker for blue swimmer crabs during the first field survey as it was readily identifiable by fishers and generated good recapture rates, was subject to minimal tag loss and had no apparent impact on marked animals. The survey provided valuable information on the movement of crabs in the SCE, LE and GB and the suitability of these fisheries for mark-recapture surveys. However, reporting of tag recaptures declined rapidly over the peak moult period for mature (1+) crabs as expected. Therefore, we investigated the use of T-bar anchor tags as a method of marking blue swimmer crabs that would survive a moult to provide information on crab movement over a longer period.

The tank trials were conducted in the DoF aquarium to test whether a T-bar tag could successfully be retained by a blue swimmer crab during a moult without adverse stress or mortality. Low levels of mortality were experienced by crabs tagged with the Hallprint TBF-1 fine anchor T-bar tag (ST) trialled during the first tank trial over 7 weeks from January to March 2014. However, animals tagged in the muscle between the first and second walking leg developed physical deformities during the moult. Furthermore, the discarded moult of crabs tagged in the muscle that connects the right swimmeret to the dorsal carapace became caught on the barrel of the tag. Therefore, the ST was not considered acceptable and the TBF-1 Micro T-bar tag (MT) was developed where the filament and first couple of millimetres of the tag resided within the animal leaving nothing to restrict the discarded moult. However, the second tank trial from January to March 2015 to test this tag was marred by high levels of crab mortality. Investigation by the DoF Fish Health unit suggested these mortalities were caused by stress from the tank environment and bacterial entry through the tag wound. This hypothesis was tested during the second field survey.

The MT trialled as a long-term option for the mark and recapture of blue swimmer crabs during the second field survey proved superior to the GT. A total of 2,621crabs were tagged with the MT during the survey, with a reported recapture rate of 8.6%. While there was similar recapture data for crabs tagged with either marker, 4.4% of recaptured crabs tagged with the MT moulted over the peak moult period and retained the tag which provided additional information on movement, along with moult increment data. Further research on the MT tag design will improve levels of post-moult tag retention and survival.

Tag recaptures from the field surveys suggested that while there was substantial movement by individual crabs, movement for the majority of recaptured animals was minimal. During the first field survey, 72% and 82% of marked crabs were recaptured less than 2 km from where they were released in the SCE and LE, respectively. This was also the case for two thirds of the crabs recaptured in the SCE during the second field survey.

The tagging field surveys identified clear movement patterns amongst blue swimmer crabs in the SCE. There was upstream movement by both male and female crabs from late spring through summer and into autumn, with movement downstream from late autumn, through winter and into early spring. This pattern was supported by catch rates of crabs caught in hourglass traps during the monthly tagging surveys between March 2015 and February 2016. This movement is most likely due to reduction in salinity caused by winter rains, which force crabs to move downstream from Point Resolution during winter and early spring where salinity remains marine at lower depths and spawning generally takes place.

Future research

The SWRCP RAP will be maintained in its current form and consideration will be given to incorporating CS and the Peel-Harvey Estuary (PHE) to supplement existing recreational fishing survey data in these fisheries. Refined fishery-independent breeding stock surveys in the SCE, LE and GB, and recruitment surveys in the SCE (as there is minimal cost due to its close proximity to Perth), will be continued on an annual basis to generate the long term datasets that could form the basis of effective harvest strategies to monitor these fisheries into the future. Consideration will be given to further tagging work during existing DoF crab surveys to refine the MT and hopefully improve levels of post-moult tag retention and survival, while further examining migratory patterns and the interrelatedness of crab stocks in the estuaries and embayments of southwest Western Australia.

2 General Introduction

Fishing for blue swimmer crabs represents an iconic recreational fishing experience for Western Australian fishers. State-wide integrated surveys of boat-based recreational fishing conducted by the Department of Fisheries, Western Australia (DoF) in 2011/12 and 2013/14 reported that three times more blue swimmer crabs were caught than any other recreational species, with around 900,000 crabs caught during each period surveyed (Ryan *et al.,* 2013; Ryan *et al.*, 2015). The majority of this crabbing activity occurs in the estuaries and near-shore embayments fringing the southwest of the state, from the Swan-Canning Estuary to Geographe Bay (Figure 2.1).

Recreational fishing pressure in Western Australia has increased significantly in recent years, due largely to population growth and a significant increase in boat ownership associated with the resource boom experienced in Western Australia during the 2000s. In 2009, the Western Australian population was 2.3 million, with about a third of the population estimated to participate in recreational fishing (Department of Fisheries, Western Australia, 2012). Given the Western Australian population is predicted to double over the next 50 years (Australian Bureau of Statistics, 2009), timely and relevant data on the state's wild-stock fisheries will continue to be required to assess stock status and inform appropriate management responses to meet the community's expectations regarding sustainable fishery stewardship.

Fisheries stock assessment involves the use of statistical analyses to understand the dynamics of fisheries and make quantitative predictions about the reactions of fish populations to alternative management choices that aim to ensure sustainable production of fish stocks over time while promoting the economic and social well-being of the fishers and industries that access the resource (Hilborn and Walters, 1992). DoF currently receives considerable information to assess stocks in Western Australian blue swimmer crab fisheries that have a commercial sector, such as Cockburn Sound, the Peel-Harvey Estuary and Shark Bay (Johnston *et al.*, 2011; Johnston *et al.*, 2014; Harris *et al.*, 2014; Fletcher and Santoro, 2015). Commercial fishers submit statutory monthly catch and effort returns, DoF research staff conduct monthly catch monitoring surveys aboard commercial vessels, and undertakes fishery-independent sampling regimes. However, the same level of information is not readily available for Western Australia's recreational-only blue swimmer crab fisheries. By their nature, recreational fishing surveys that provide reliable data for managers are particularly resource intensive due to the large number of participants, varied methods of accessing the resource, and diffuse spatial and temporal scales of fishing activity (Conron *et al.*, 2014).

The Recreational Fishing Initiatives Fund (RFIF) supports initiatives, projects and research that aligns with recreational fishing community priorities and enhances the recreational fishing experience in Western Australia. The RFIF is administered by Western Australia's peak representative body for recreational fishers, RecFishWest, and accounts for 25% of state recreational fishing licence revenue. RFIF funding was approved for the Southwest Recreational Crabbing Project (SWRCP), a three-year study commencing on June 1st 2013. The SWRCP aimed to engage local crabbing communities in developing ongoing, cost-effective programs that could deliver annual information on recreational crabbing and stock dynamics in the iconic recreational blue swimmer crab fisheries of the Swan-Canning Estuary (SCE), the Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB).

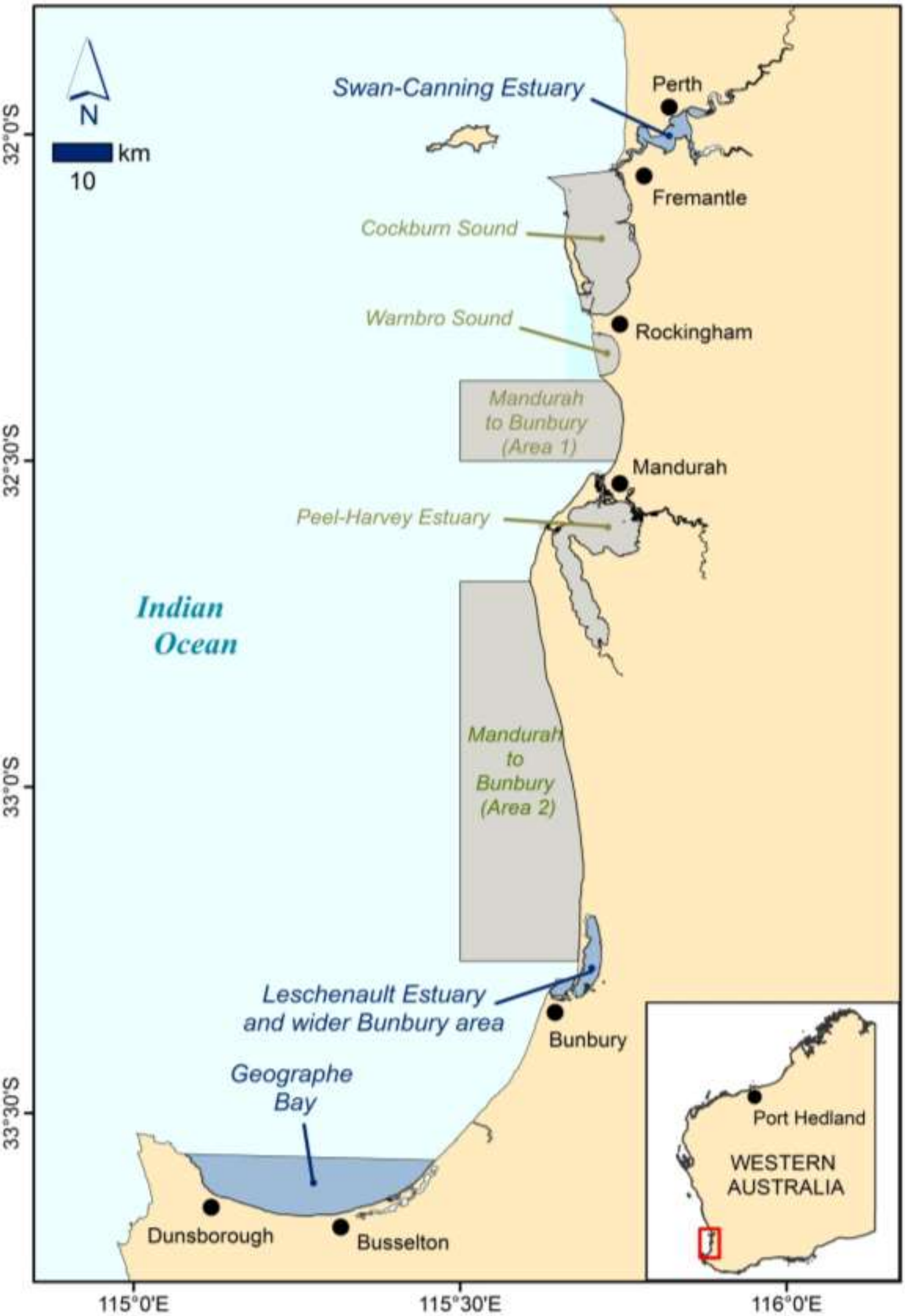


Figure 2.1. Map showing the location of the key blue swimmer crab fisheries in southwest Western Australia, including the three recreational crab fisheries examined during the Southwest Recreational Crabbing Project: The Swan-Canning Estuary, the Leschenault Estuary and wider Bunbury area, and Geographe Bay.

2.1 The Swan-Canning Estuary

2.1.1 Physical description

The SCE flows through Perth, the capital city of WA, spanning 53 km^2 of tidal plains where the Swan-Avon River converges with the Indian Ocean (Swan River Trust, 2001). The estuary comprises three distinct regions: the lower estuary is a narrow inlet channel approximately 8 km in length that forms the basis of Fremantle Harbour; the middle estuary is a relatively deep basin with shallow margins approximately 12 km in length and up to 2 km wide; and the upper estuary which incorporates the tidal reaches of the Swan and Canning rivers (Fig. 2.2).

Both the SCE and its catchment (which covers ~121,000 km^2) have been highly modified since European settlement in 1829, leading to a substantial reduction in freshwater input (Smith, 2006). Much of the catchment and freshwater environments upstream from the estuary are in relatively poor condition, with most sections of the Avon River and its tributaries brackish or saline (Pen, 1999; Smith, 2006). Extensive modifications have also been made to the estuary entrance, most notably the removal of a limestone bar in 1897 as part of the construction of Fremantle Harbour. Much of the estuary was fresh or brackish prior to the bar's removal, with the subsequent increased flushing and tidal range creating a more saline environment (Thomson *et al.*, 2001, Smith, 2006).

The hydrology of the estuary is influenced by its geomorphology, tidal movement, and localised climatic conditions (Chaplin & Sezmis, 2008). The microtidal regime in the estuary has maximum tidal amplitude of about 1 metre, although water levels are also subject to barometric pressure fluctuations. During the summer months, this tidal movement maintains salinity within the estuary similar to that of surrounding marine waters. However, increased rainfall during the winter months dilutes the upper and middle estuaries with fresh water that lowers salinity and oxygen levels (Chaplin & Sezmis, 2008).

Eutrophication from past and present anthropogenic nutrient sources has caused major environmental problems in SCE (Smith, 2006). Although poor water quality and macroalgal blooms were most evident in the 1950s and 1960s, nutrient input remains relatively high and blooms of phytoplankton, macroalgae and exotic weeds continue to occur in upstream areas (Gerritse *et al.*, 1998; Swan River Trust, 2000; Smith, 2006).

Figure 2.2. Aerial image of the Swan-Canning Estuary, including the boundaries ( ) of Area 1 of the commercial West Coast Estuarine Managed Fishery.

Blue swimmer crabs currently represent the largest and most valuable component of both recreational and commercial catches in the SCE (Smith, 2006; Johnston *et al.*, 2011).

2.1.2 Recreational crab fishery

Recreational fishing for blue swimmer crabs has been a popular pastime in the SCE since at least the early 1900s, with the total recreational catch considered to be substantial and even excessive of the commercial take in some years (Lenanton, 1978, Smith, 2006). This is even more likely to be the case now, with only one commercial licence in the SCE (Area 1 of the West Coast Estuarine Managed Fishery) remaining since 2008.

The majority of DoF surveys quantifying recreational catch and effort in WA have not included the fine scale spatial resolution to accurately report on the SCE alone. Furthermore, the surveys that have allowed for estimates for the SCE were generally analysed for finfish species only. However, Malseed and Sumner (2001) undertook a 12-month creel survey between August 1998 and July 1999 that focussed on recreational blue swimmer crab catch and effort in the SCE. They reported a retained recreational catch of 20,875 crabs equating to 7.3 t, compared to a commercial catch of 24.3 t over the same period. The recreational catch was dominated by male crabs, accounting for 95% of retained crabs and 70% of released crabs, respectively.

2.1.3 Commercial crab fishery

Blue swimmer crabs have been fished commercially in the SCE since European settlement in 1829 (Smith, 2006). Although as many as 130 commercial fishers have operated annually in post war years, a succession of Voluntary Fishery Adjustment Schemes (VFAS) have reduced the numbers of registered fishers in the SCE from around 30 in the 1960s and 1970s, to a single operator since 2008 (Johnston *et al.*, 2011).

The commercial fishery covers the waters upstream from Point Walter to Heirisson Island on the Swan River, and to Salter Point in the Canning River (Fig. 2.2). It is a multi-species fishery that uses set demersal tangle nets, although blue swimmer crabs have increasingly become the target species.

In comparison with other southwest WA crab fisheries, the annual commercial catch of blue swimmer crabs from the SCE is small. While historical catches have fluctuated in response to variations in environmental conditions, annual landings in recent years have been relatively constant between 6-11 t (Fig. 2.3).

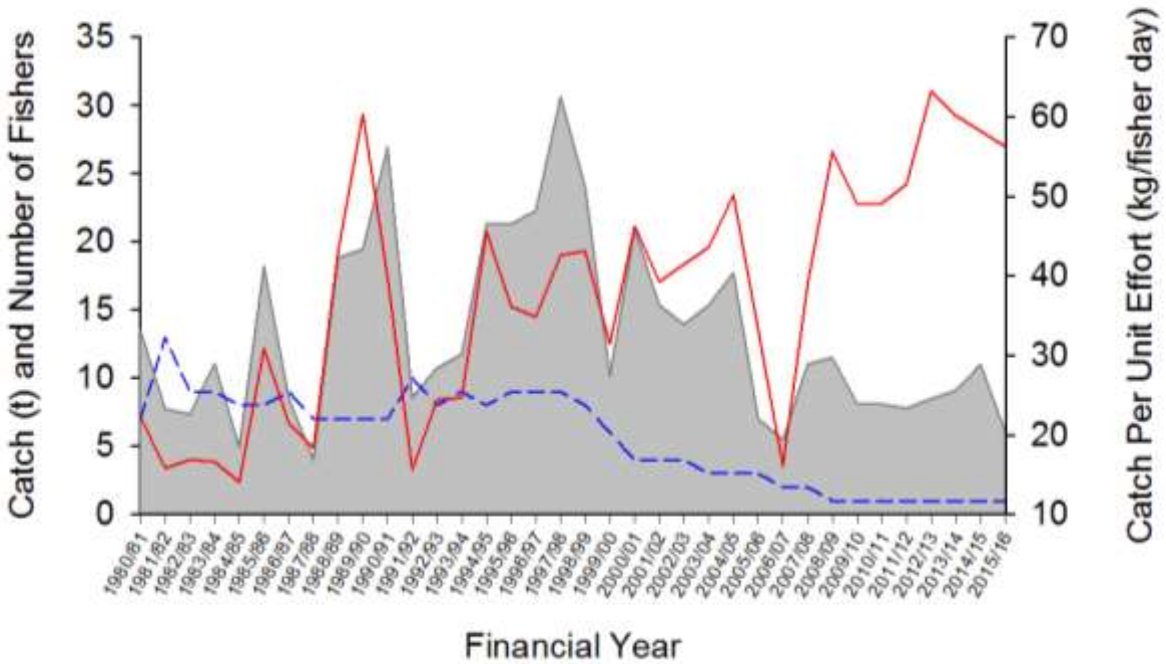


Figure 2.3. Annual commercial catch of blue swimmer crabs in tonnes (■), number of commercial fishers (----) and catch per unit effort in kg/fisher day (—) by financial year for the Swan-Canning Estuary (Area 1 of the West Coast Estuarine Managed Fishery) between 1980/81 and 2015/16.

The majority of the commercial SCE catch is landed over the summer months into autumn, and is almost exclusively male during this period (Figs 2.4; 2.5). Significant quantities of female crabs first begin to appear in commercial catches in April, and dominate the catch for the remainder of the season (Fig. 2.5). Commercial fishing tails off in the winter months as winter rains cause salinity and dissolved oxygen levels in the areas of the SCE open to commercial fishing to fall, pushing most of the crab stock downstream of the lower fishery boundary (Figs 2.2; 2.4).

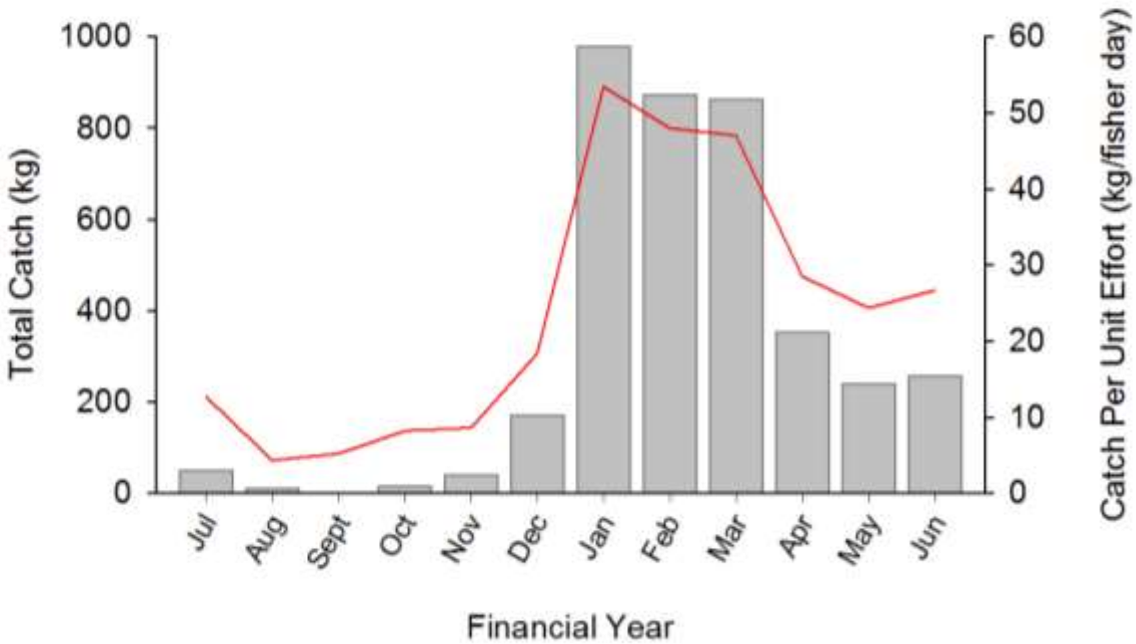


Figure 2.4. Mean monthly commercial catch of blue swimmer crabs per fisher in kilograms (■) and catch per unit effort in kg/fisher day (▬) for the Swan-Canning Estuary (Area 1 of the West Coast Estuarine Managed Fishery) between 1980/81 and 2015/16.

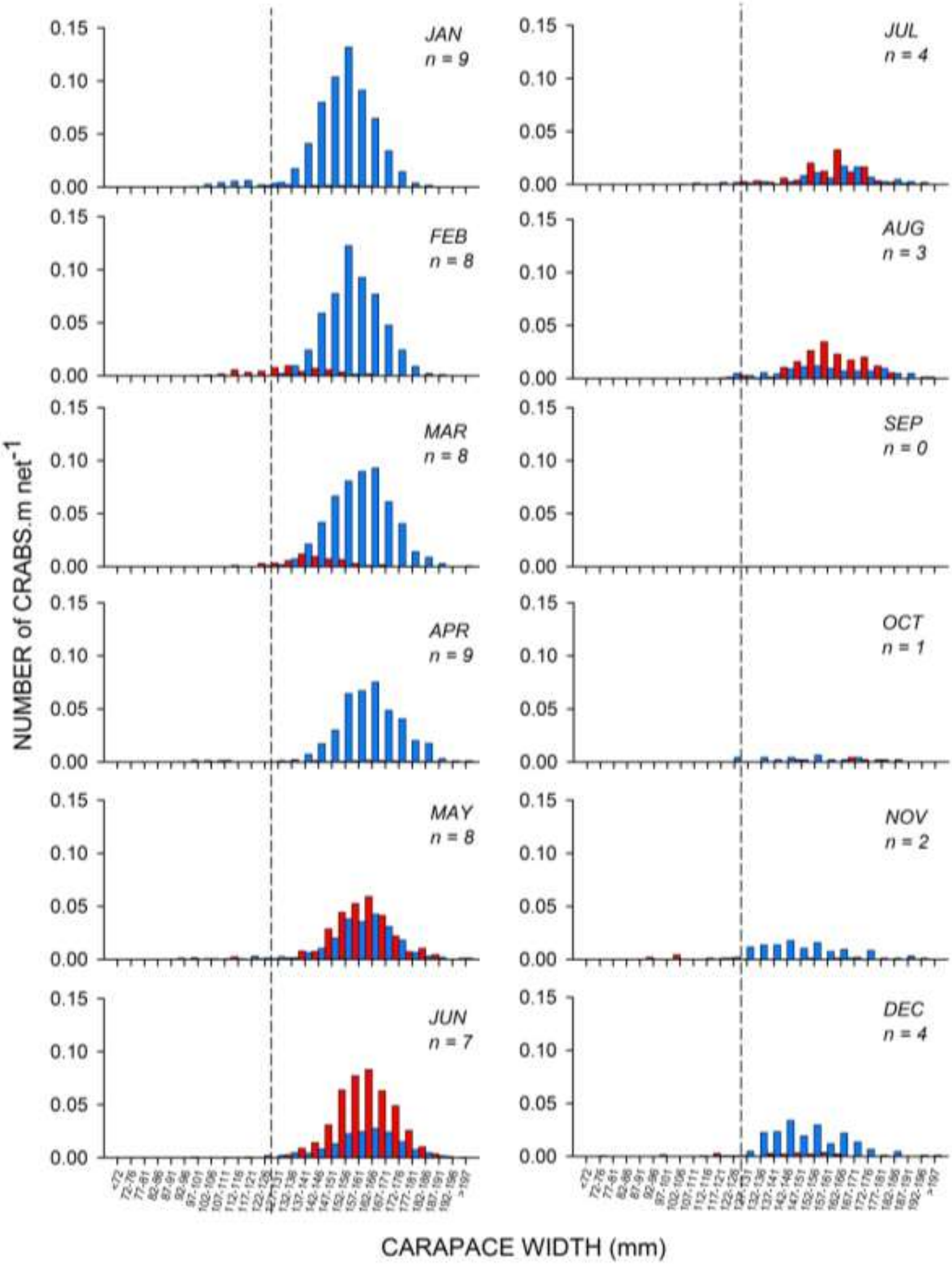


Figure 2.5. Pooled mean length frequency distributions of male (■), female (■), and berried female (■) blue swimmer crabs by month sampled during catch monitoring aboard commercial vessels in Area 1 of the West Coast Estuarine Managed Fishery (Swan-Canning Estuary) between November 2007 and December 2015 inclusive. (- - -) Minimum commercial size limit (127 mm CW).

2.2 The Leschenault Estuary and wider Bunbury area

2.2.1 Physical description

The Leschenault Estuary (LE) is located immediately north of Bunbury in southwest WA (Fig 2.1). The micro-tidal estuary is permanently open to the ocean, and is typical of many estuarine systems in the region. It comprises a large shallow basin that rarely exceeds 2 m in depth, surrounded by a very shallow (≤0.5 m) fringing platform (Potter *et al.*, 2001). The estuary measures 13.5 km in length and 1.5-2.5 km in width, with a short and narrow entrance channel towards the southern end. It runs parallel to the coastline and is separated from the ocean by the Leschenault Peninsula, a narrow system of sand dunes. The estuary substrate consists primarily of silt and sand, covered in areas by large beds of the seagrasses *Ruppia megacarpa* and *Halophila ovalis* (Maegher, 1971). However, a detailed comparative study carried out in 2005 by Semeniuk and Semeniuk (2005) using long-term data (1982–87) identified significant changes in the estuary's ecology with a decline in macrophyte (seagrass and macroalgae) total biomass, with seagrass generally in low abundance and absent within the estuary in some areas compared with previous studies.

Industrial development has significantly changed the LE over the last sixty years. The estuary originally fed into Koombana Bay through the most southwestern entrance, the Leschenault Inlet. Access to the estuary was closed off in an attempt to reduce accumulation of silt within the wider Bunbury Harbour, and allow for the construction of the Bunbury port in 1951. A new artificial entrance in to the estuary, "The Cut", was excavated through the sand dunes opposite the Collie River in 1969 while the Preston River was re-routed to its present course. Further construction work in the 1970s led to the complete isolation of the southern end of the LE from the Leschenault Inlet. Consequently, any water exchange between the estuary and outside marine waters now occurs exclusively through The Cut (Gillibrand *et al*., 2012).

The estuary and surrounding catchment is under increasing pressure from industrial and urban expansion, increasing water demand, and the change and intensification of land use. Land use around the estuary is highly diversified incorporating residential, industrial and agricultural activities. A large proportion of the surrounding catchment is heavily irrigated for dairy farming and horticulture, with the river systems feeding the estuary often of poor water quality (Gillibrand *et al*., 2012). As these river systems flow in through the estuary's basal end, there is poor water mixing towards the estuary's apex in the north.

The estuary water turns hypersaline in the summer months, with increased temperature and evaporation. In contrast, increased rainfall in the winter months significantly lowers salinity levels within the estuary and the increased runoff in the catchment results in high nutrient loading and periods of anoxia and hypoxia (Veale *et al*., 2014, Gillibrand *et al*., 2012). These prolonged fluctuations in temperature, salinity and water quality significantly affect the distribution and movement of resident blue swimmer crab stocks Potter and de Lestang (2000).

The study area of The LE incorporated the estuary, the mouths of the Collie and Preston Rivers, and Bunbury Harbour (Fig 2.6).

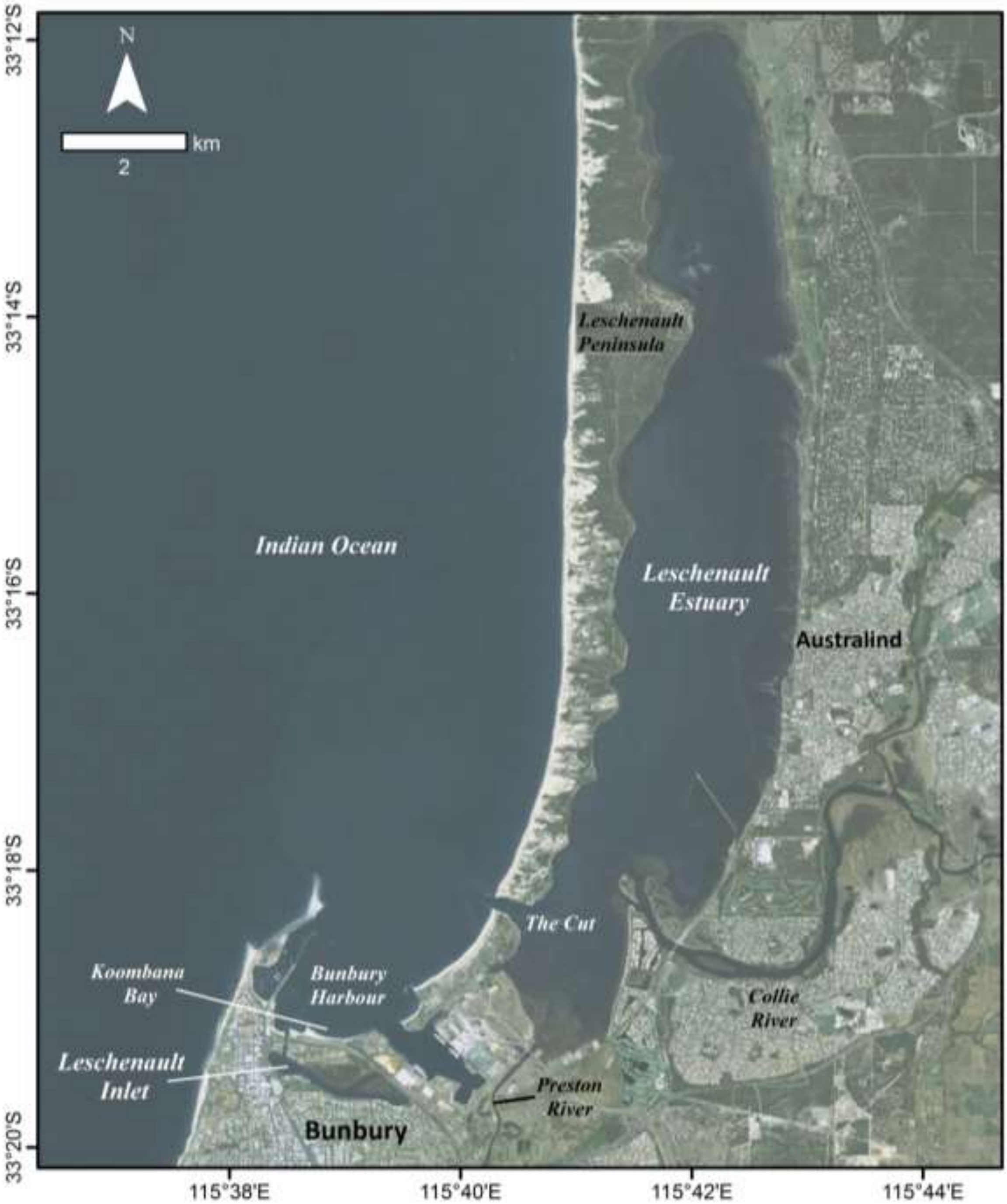


Figure 2.6. Aerial image of the Leschenault Estuary and wider Bunbury area.

2.2.2 Recreational crab fishery

The LE is historically one of the most popular estuaries for recreational fishing in southwest WA, with blue swimmer crabs the most targeted recreational species (Malseed *et al.*, 2000). However, anecdotal evidence from recreational fishers suggests that fish numbers within the estuary, including the blue swimmer crab, have declined since the mid-1990s.

Malseed *et al.* (2000) conducted a 12 month survey of recreational boat-based and shore-based fishing in the Leschenault Estuary in 1998, reporting that around 87% of the recreational effort in the estuary was targeted at blue swimmer crabs, which accounted for 98% of the total recreational catch for the year. The survey produced an estimated total recreational catch of 219,000 blue swimmer crabs, or

45.7 tonnes, with approximately 80% of the retained catch being male. Boat-based fishers accounted for more than 80% of the total catch.

The majority of the recreational crabbing effort in the LE during 1998 occurred over the summer months, accounting for 70% of boat-based fishing and 82% of shore-based fishing. Autumn and spring were the next most popular seasons, with very little crabbing taking place during winter (Malseed *et al.*, 2000). These seasonal fluctuations in crabbing effort and catch rates reflect the changes in water parameters in the estuary through the seasons. Potter and de Lestang (2000) reported crab numbers in the estuary peaking from late spring through summer and into early autumn, when salinities and water temperatures are at their highest. However, numbers of crabs begin to decline from late autumn with the majority leaving the estuary as salinity and water temperature falls.

Subsequent state-wide or west coast bioregion DoF surveys quantifying recreational effort have been conducted in 2005/06 (Sumner *et al.*, 2008), 2011/12 (Ryan *et al.*, 2013) and 2013/14 (Ryan *et al.*, 2015). However, these surveys have not reported the fine-scale spatial resolution necessary to provide estimates of recreational crabbing catch and effort for the LE.

2.2.3 Commercial crab fishery

Commercial fishing has taken place in the LE since the 19th century (Lenanton, 1984), with as many as 21 vessels operating in the fishery at any one time (Potter and de Lestang., 2000). Commercial fishers set gill/haul nets to primarily target a variety of fish species, but also retained blue swimmer crabs. As with most fisheries in southwest WA, crab catches varied notably in line with environmental conditions, ranging from 1.3-9.8 t between 1987/88 and 1997/98 (Fig. 2.7).

A pattern of declining catches through the late 1970s (Fig. 2.7) and increased urban development in the region saw commercial fishing areas, practices and resource-sharing issues increasingly become the subject of community interest. Commercial participation rates began to decline in the early 1980s, primarily in response to the intensifying level of conflict with the recreational fisheries sector (Lenanton, 2003). Various regulatory tools and adjustment mechanisms were applied to modulate the commercial catch, with the number of endorsements to operate in the estuary falling from 18 in 1979 to just six by the end of 1998. A subsequent VFAS introduced in 2000/01 led to the removal of all commercial fishing effort from the LE, with the remaining six fishers surrendering their licences in 2001.

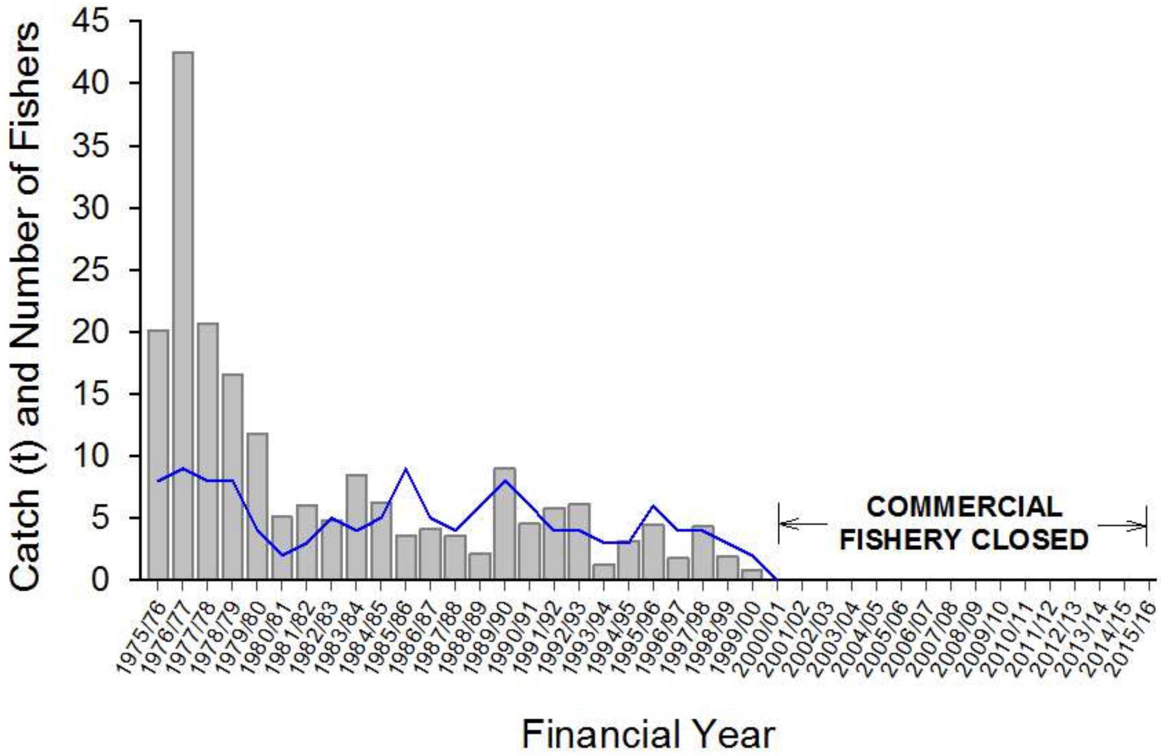


Figure 2.7. Annual commercial catch of blue swimmer crabs in tonnes (■) and number of commercial fishers reporting catches of blue swimmer crabs (----) by financial year for the Leschenault Estuary between 1975/76 and 2015/16.

2.3 Geographe Bay

2.3.1 Physical description

Geographe Bay (GB) is located approximately 250 km south of Perth, and represents the southernmost study area of the three targeted fisheries (Fig. 2.1). The north-facing bay, which marks the southern end of the Swan Coastal Plain, provides a shallow marine environment that is relatively protected from the prevailing south-westerly swell by Cape Naturaliste to the west (Fig. 2.8). It covers an area of approximately 290 nm^2 between the north-west point of Cape Naturaliste and the lighthouse at Bunbury Breakwater (Bellchambers *et al.*, 2006b). The GB seabed forms a shelf that slopes gently seaward to a depth of 18 m around 9 km from shore (Water Authority of Western Australia, 1992). The substrate within the bay is covered by unconsolidated sediments deposited over limestone formations and older clay layers, which are exposed at the surface at various locations (Neil *et al.*, 2009).

Extensive seagrass beds grow in the nearshore sandy substrate, which patchily extend into deeper water as far as sufficient light penetrates to allow photosynthesis. These shallow water areas are dominated by *Posidonia sinuosa*, with *Amphibolis antarctica* found around the edges of *P. sinuosa* meadows and on limestone outcrops (McMahon and Walker, 1998). These seagrass beds provide substantial nursery areas for a variety of finfish and crustacean species within the bay.

Ocean currents influencing GB vary throughout the year. The cool Capes Current flows northward along the Leeuwin-Naturaliste coast and sweeps into GB during summer, while the Leeuwin Current flows southwards further off the coast (Pearce and Pattiaratchi, 1999).

Nine short rivers and major creeks drain the Whicher Range and/or the Swan Coastal Plain and discharge into GB. The more substantial systems are the Capel, Ludlow, Abba and Sabina and Vasse which have head waters in the forested Whicher Range. Smaller streams draining the coastal plain include the Carbanup and Buayanyup Rivers. Many of the creek systems and lower reaches of these rivers and streams have been either entirely or partially modified as part of artificial drainage systems to drain the very low-lying and now cleared Swan Coastal Plain and thus enable its use for dairy farming and other forms of agriculture (Waters and Rivers Commission, 1997). Consequently, the region is facing the stress of excess nutrient loading to the coastal waterways and the adjacent marine ecosystem that leads to highly damaging toxic algal blooms that occur frequently in the fresh and estuarine waters of the region.

The study area for this project spanned approximately 50 km of near-shore waters (≤7 m in depth) along the coast from Peppermint Grove Beach to Meelup within GB, as well as the inland waterway sites of the Wonnerup Estuary, Port Geographe Marina and the Buayanyup Drain (Fig 2.8).

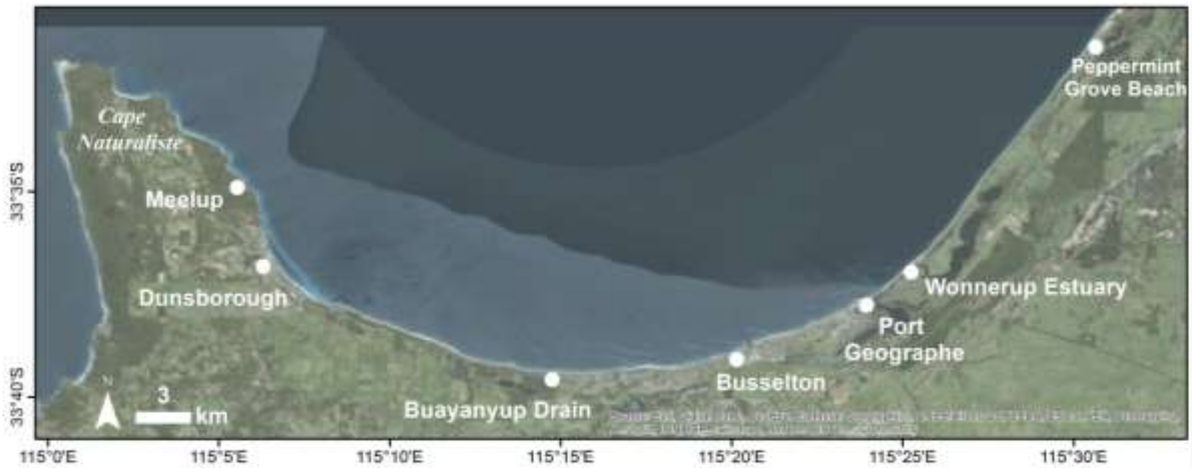


Figure 2.8. Aerial image of Geographe Bay.

2.3.2 Recreational crab fishery

As in most of the embayments and estuaries of southwest WA, fishing for blue swimmer crabs is one of the most popular pastimes for both locals and tourists in GB (Borg and Campbell, 2003). However, the fishery differs from other southwest WA crab fisheries in that most fishing effort, and the highest catch rates, occurs over the winter/spring months between July and November when the catch is predominantly female (Sumner and Malseed, 2004). The fishery is further characterised by crabbing occurring almost exclusively in the waters less than 200 m from shore around the bay (Borg and Campbell, 2003).

DoF surveys quantifying recreational crabbing catch and effort in GB were conducted in 1996/97 and 2000/01. Sumner and Williamson (1999) undertook a creel survey of recreational boat-based fishers on the west coast of WA between Augusta and Kalbarri from September 1996 to August 1997. They reported a boat-based blue swimmer catch from GB of 17.5 t for this period.

Sumner and Malseed (2004) conducted a creel survey to estimate the recreational boat and shore-based blue swimmer crab catch and effort in GB between December 2001 and November 2002. They estimated the crab catch and effort to be 28.6 t from 21,500 fisher days for this period, with the majority (27.0 t from 19,400 fisher days) taken by boat-based fishers. Spring 2002 proved the most popular season for crabbing in GB during the survey, accounting for 54% of the boat-based effort and 52% of shore-based effort. Furthermore, the period from July to November in 2002 contributed 82% of the catch. Female crabs dominated the catch over the surveyed period, comprising 81% of the retained catch and 72% of the released catch. The most popular area for crabbing during the survey was in the vicinity of the Port Geographe Marina, from the Busselton Jetty east to the Wonnerup Estuary (Fig. 2.8).

2.3.3 Commercial crab fishery

Until its closure in 2005, GB was the southernmost commercial blue swimmer crab fishery on the WA coast. While all licenced WA commercial fishers were permitted to set drop nets in the waters of GB, a total of 12 commercial fishers had a demonstrated history of using drop nets in these waters. Furthermore, only six of these fishers identified themselves as genuine crab fishers and landed the majority of the commercial crab catch (Borg and Campbell, 2003).

As with most WA commercial crab fisheries, annual catches in GB varied considerably in line with fishing effort and changes to stock abundance in response to fluctuations in environmental conditions. The annual take of blue swimmer crabs from GB increased from < 2 t in the early 1990s to a peak of 17 t in 1997, before fluctuating between 7-15 t from 1998 to 2004 (Fig. 2.9).

However, a significant increase in both urban development and tourist visitor numbers from the 1980s led to considerable debate over issues associated with commercial and recreational crab fishing in the communities adjacent to GB, and in particular the Busselton area. Despite two DoF surveys that estimated recreational crabbing catch and effort in 1996/97 (Sumner and Williamson, 1999) and 2000/01 (Sumner and Malseed, 2004) indicating otherwise, much of this discussion revolved around the perception that commercial fishers took a large part of the crab resource, leaving little for local recreational fishers and the many tourists who visit the region during holiday periods (Borg and Campbell, 2003).

Following extensive community consultation, temporary management arrangements were introduced for the fishery in May 1999 that:

- prohibited commercial fishing for crabs on weekends, public holidays and school holidays (other than that at the end of term two);
- prohibited commercial gear being in the water from one hour after sunrise to one hour before sunset on all remaining days;
- prohibited commercial crabbing within a scheduled area covering the Busselton Jetty and its surrounding area.

However, these arrangements proved unsatisfactory to some members of the public and the commercial fishing sector. Further consultation, primarily in the form of the Geographe Bay Crab Mediation Group, led to a settlement agreement in December 2002 that ratified the temporary management arrangements and imposed further minor restrictions on both commercial and sectors. Despite this agreement, conflict between the sectors remained unresolved and the commercial fishery was closed in January 2005.

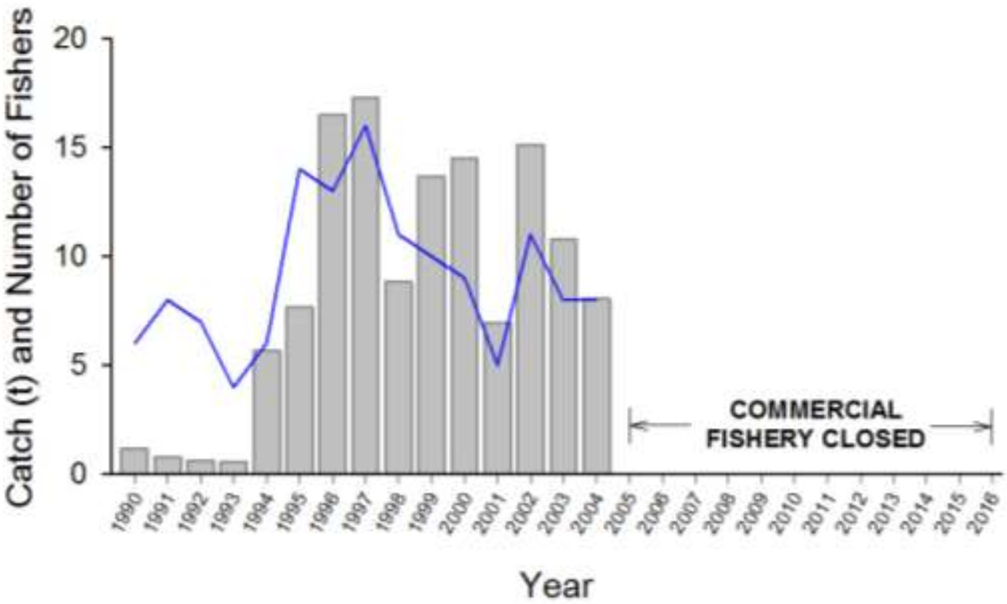


Figure 2.9. Annual commercial catch of blue swimmer crabs in tonnes (■) and number of commercial fishers reporting catches of blue swimmer crabs (----) for Geographe Bay by calendar year between 1990 and 2016.

2.4 Recreational crabbing regulations in Western Australia

Recreational fishing for blue swimmer crabs in Western Australia is managed through a series of input and output controls. As with the commercial sector, the principal management tool employed to sustain an adequate breeding stock involves maintaining minimum size limits well above the size at sexual maturity such that every female crab has at least one spawning season to produce eggs. As the size at sexual maturity for crab stocks in southwest Western Australia ranges from 86.9 – 98 mm CW, the minimum legal size limit is set at 127 mm CW. Further protection is provided to the breeding stock through a ban on keeping berried females, and seasonal closures to both commercial and recreational fishers in some Western Australian fisheries (the Peel-Harvey Estuary, Warnbro Sound and Cockburn Sound).

Restrictions also govern the gear types that can be used to take blue swimmer crabs. Boat or shore-based recreational fishers may use hand-held wire or plastic scoop nets, a blunt wire hook, or a maximum of 10 drop nets, while divers and snorkelers may collect crabs by hand (Fig. 2.10).

Figure 2.10. The primary methods used by recreational blue swimmer crab fishers in Western Australia: a) drop net, b) diving/snorkelling, c) scoop net.

Shore-based recreational crabbers, fishers on non-powered vessels and divers are subject to a possession limit of 20 crabs per fisher per day in all areas of the state other than the West Coast Bioregion (Kalbarri to Augusta), where the limit is 10 crabs per fisher per day (Table 2.1). Boat-based crabbers require a Recreational Fishing from Boat Licence (RFBL) that was introduced in March 2010. The licence entitles fishers to a maximum catch of 20 (west coast bioregion) and 40 crabs (elsewhere in Western Australia) per powered boat per day when there are two or more people on-board holding RFBLs. However, a possession limit of 10 (west coast bioregion) and 20 (elsewhere in Western Australia) crabs per boat per day applies if there is only one person holding a RFBL, regardless of the number of fishers aboard.

Table 2.1. Recreational blue swimmer crabs possession limits per fisher per day for shore-based crabbers, crabbers using non-powered vessels and divers compared to boat-based crabbers in the West Coast Bioregion (WCB) and for the rest of Western Australia (WA).

Shore-based crabbing, non-powered vessels, divers		Boat-based crabbing			
		one licenced crabber aboard		two licenced crabbers aboard	
WCB	Rest of WA	WCB	Rest of WA	WCB	Rest of WA
10	20	10	20	20	40

2.5 Blue swimmer crab biology in southwest Western Australia

The blue swimmer crab, *Portunus armatus* (A. Milne Edwards, 1861) (formerly *Portunus pelagicus* Linnaeus, 1758; Lai *et al.*, 2010) occurs in nearshore, marine embayment and estuarine systems throughout the Indo-West Pacific region (Stephenson, 1962). They live in a wide range of inshore and continental shelf habitats, including sandy, muddy or algal and seagrass habitats, from the intertidal zone to at least 50 m depth (Williams, 1982; Edgar, 1990). The blue swimmer crab's distribution in Western Australia extends along the entire coast, although the majority of commercial and recreational fishing is concentrated in coastal embayments and estuaries between Port Hedland and Geographe Bay (Figure 2.1).

The reproductive cycle of blue swimmer crabs in Western Australia is strongly influenced by water temperature (de Lestang *et al.*, 2003a; Johnston *et al.*, 2011). While spawning and mating occurs all year round in the more tropical waters north from Shark Bay (de Lestang *et al.*, 2003a; Harris *et al.*, 2014), the spawning period in more southern latitudes is restricted to spring/summer as these waters are at the southern extreme of the species' distribution (de Lestang *et al.*, 2010).

Mating occurs in the waters off southwest Western Australia in late austral summer – autumn (January to April), once sexually mature females have finished spawning and recent recruits moult to sexual maturity (Kangas, 2000). Females store the sperm for a number of months over winter, after which increasing water temperatures induce females to extrude and fertilise their eggs, with females becoming ovigerous and spawning between October and January (Penn, 1977; Smith, 1982). Incubation takes 10 to 18 days, depending upon water temperature and the larval phase extends for up to six weeks, with larvae drifting as far as 60 km out to sea, before settling inshore (Kangas, 2000). Rapid growth occurs with increased water temperatures over the summer months during the juvenile phase, with juvenile crabs undergoing their moult to maturity between February and June reaching a size of 70-110 mm CW (Fig. 2.11). Growth is then inhibited as the water temperature in these southern areas declines over the winter months, before the crabs moult to legal size in the coming summer at an age of 14-18 months (Johnston *et al.*, 2011). Most animals in exploited crab stocks will have died either through natural or fishing mortality by the time they are 20 months old (Potter *et al.*, 2001), but can live for three to four years without fishing pressure (Lai *et al.*, 2010).

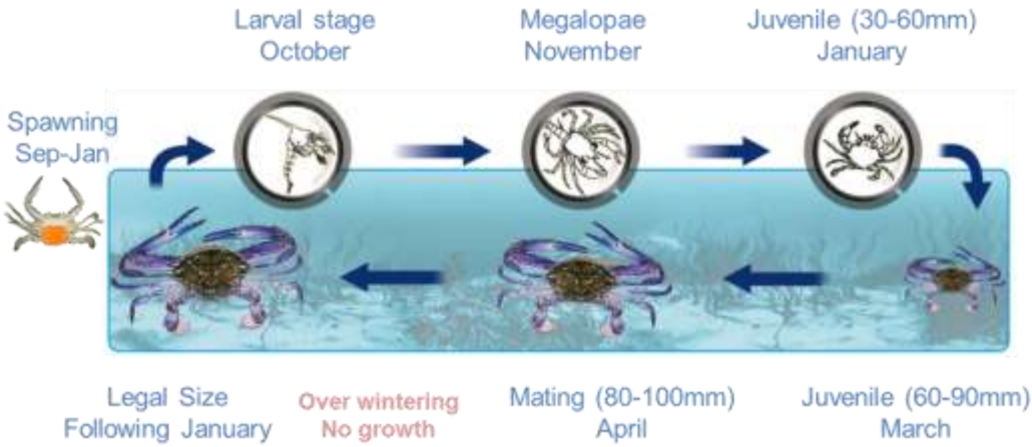


Figure 2.11. The growth cycle over the first 12-15 months of the blue swimmer crab, *Portunus armatus*, in south west Western Australia.

Genetic studies have indicated that populations of blue swimmer crabs separated by distance along the Western Australian coastline are generally independent from other each other, such as Shark Bay, Cockburn Sound and the Peel-Harvey Estuary (Chaplin *et al*., 2001). However, recent research has shown that crab populations in neighbouring habitats, such as Cockburn Sound and its adjacent water bodies of the SCE and Warnbro Sound, are genetically similar suggesting that limited mixing of stocks is occurring between these adjacent water bodies (Chaplin and Sezmis, 2008).

2.6 Study objectives

The SWRCP presented DoF with a valuable opportunity to engage local crabbing communities in developing ongoing, cost-effective programs that could deliver annual information on recreational crabbing and stock dynamics in the iconic recreational blue swimmer crab fisheries of the SCE, LE and GB. The project adopted a Citizen Science approach to foster stewardship of crabber's fisheries, provide a platform for comment on the management of their fishery, and offer hands-on experience in researching their stocks.

The specific objectives of this study aimed to:

1. Establish a Recreational Angler Program in the SCE, LE and GB for targeted recreational crabbers.
2. Develop methods for the ongoing assessment of blue swimmer crab recruitment and breeding stocks in the SCE, LE and GB.
3. Determine the effectiveness of tagging methods to provide information on the movement of blue swimmer crabs that occurs between the SCE, LE and GB and their adjacent marine environments (including Cockburn Sound and Koombana Bay).

3 True Blue Swimmer Supporter Initiative: Recreational Angler Program

D. Harris, D. Johnston, J. Baker, M. Foster and K. Ryan.

Objective: Establish a program for providing recreational crabbing information on the Swan-Canning Estuary, the Leschenault Estuary and wider Bunbury area, and Geographe Bay by implementing a RAP logbook to be completed by targeted recreational fishers.

3.1 Introduction

To understand the dynamics of an exploited fishery and provide for its effective management requires a sound understanding of the rates of exploitation of a fished stock by all sectors that access the resource (Wise and Fletcher, 2013). Accordingly, the Department of Fisheries, Western Australia (DoF) receives considerable information from commercial fishers in Western Australian blue swimmer crab fisheries via statutory monthly catch and effort returns. However, similar information is not readily available for some of the state's recreational fisheries. This information is important as the level of catch and effort from recreational fishing informs a number of management processes, including assessment of fish stocks and resource allocation within the broader context of Ecosystem Based Fisheries Management and Ecologically Sustainable Development (Department of Fisheries, 2012; Fletcher and Santoro, 2015).

Quantifying catch and effort from recreational fishing in Western Australia is particularly challenging given the large coastline (20,781km) and high numbers of recreational fishers (estimated at 711,000 in 2014/15), making it costly and logistically difficult (Department of Fisheries, 2012; Ryan *et al.*, 2015). Consequently, it is difficult to collect sufficient fine scale information from state-wide surveys to quantify catch and effort for localised recreational fisheries. The current state-wide surveys provide estimates of boat-based fishing as fishers are randomly selected from the database of Recreational Fishing from Boat Licence holders, although plans are underway to collect information on shore-based fishing from a sample of fishers randomly selected from the White Pages telephone directory. Henry and Lyle (2003) estimated that 57% of the 2000/01 Western Australian recreational catch was from shore-based fishers, while Ryan *et al.* (2015) suggested that more than 50% of the recreational catch is still likely to be shore-based. Consequently, it is essential to collect information on shore-based fishing activity as well as boat-based fishing, especially if the species of interest has a large shore-based catch.

Daily logbooks maintained by recreational fishers can provide valuable information on fine scale recreational catch and effort, while records of numbers and lengths can be used to monitor catch rates and population structure and inform stock assessments, and subsequently management decisions (Smith *et al.,* 2007). Recreational fishers can be canvassed through publicity directed at fishers that target the species of interest to provide a reasonable sample of boat-based and shore-based fishers. Furthermore, such programs can accommodate multiple fishing methods in addition to line fishing by anglers, including drop net, scoop net and diving/snorkelling. DoF has run a successful Research Angler Program (RAP) since 2004, providing fine-scale recreational catch and effort data across the state over a wide range of species. Data from this program has been used to support the interpretation of analyses and trends in the status of nearshore finfish stocks in south-western Western Australia, particularly for Australian herring, (Smith *et al.*, 2013a) tailor (Smith *et al.*, 2013b), whiting (Brown *et al.*, 2013) and garfish (Smith *et al.*, 2017). RAP data also supports requests for information from internal and external stakeholders and has generated widespread community involvement and support (Wise and Fletcher, 2013).

While recreational angler programs can generate useful recreational fishing information, it is essential that proponents of such programs are aware of the biases that can be introduced into the data from self-selection to the sample and by fisher behaviour (Pollock *et al.*, 1994). For example, fishers may contribute to biases through exaggeration of the number and size of the fish reported, not reporting unsuccessful trips or responding to surveys, or by misinterpreting survey questions and methods (Pollock *et al.*, 1994; Mossindy and Duffy, 2007). Therefore, rigorous oversight of the data collected by these programs is required to ensure non-response errors and avidity bias do not make the data misleading as they can vary markedly over time (Wise and Fletcher, 2013).

While participation in monitoring recreational fishing is voluntary, fishers in the DoF statewide surveys are randomly selected from the Recreational Fishing from Boat Licence database and can "opt out", whereas fishers "opt in" for most logbook programs. This selection influences whether the sample is representative of the population and the ability to weight sample data to determine population estimates (Pollock *et al.*, 1994). Consequently, it is not possible to estimate total catch and effort from the logbook program proposed for this project. However, the data generated will provide useful temporal and spatial trends for researchers and managers on recreational crabbing catch and effort and size composition.

The most successful recreational angler programs tend to cover a single species that inhabit semi-enclosed water bodies such as bays and estuaries (Conron and Bridge, 2004; Tracey *et al.*, 2011). Consequently, the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) represent ideal fisheries for the implementation of a logbook program to collect information on recreational fishing and stock dynamics for the blue swimmer crab, *Portunus armatus*.

3.2 Methods

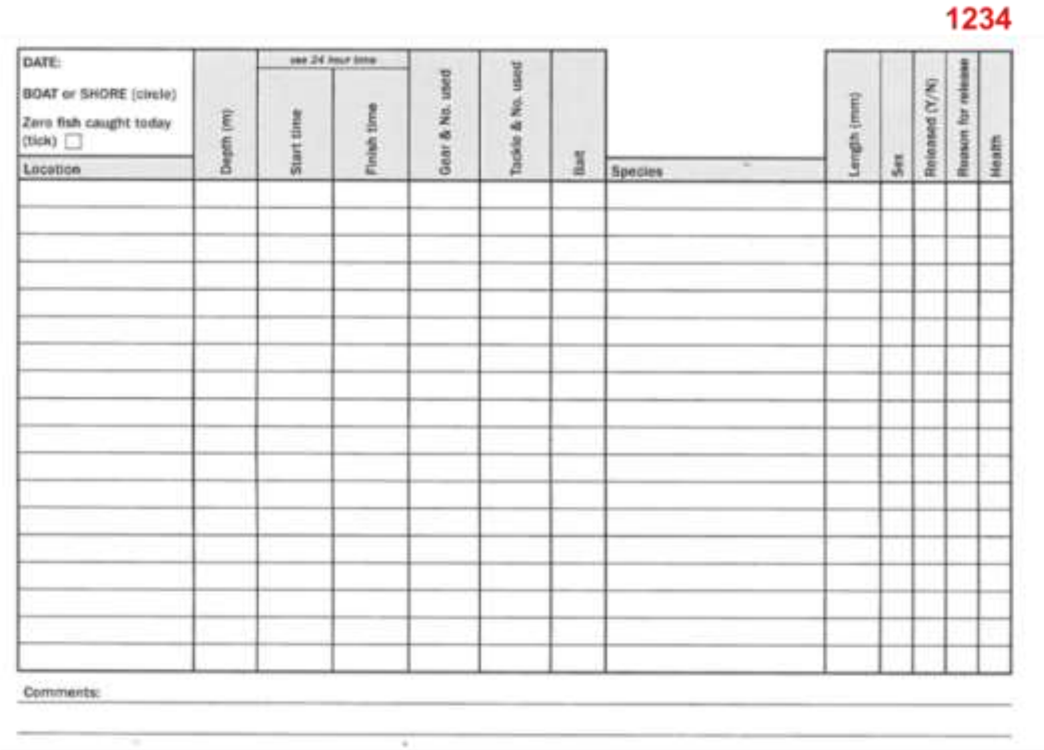
3.2.1 True Blue Swimmer Supporter Initiative: Logbook participants

A target of 70 recreational fishers recording their crabbing activity in each of the SCE, LE and GB was set prior to the commencement of the Southwest Recreational Crabbing Project (SWRCP) in June 2013. Fishers were recruited through advertisement in local newspapers, tackle stores, radio interviews, articles in departmental publications and on the Recfishwest (www.recfishwest.org.au) and DoF websites (www.fish.wa.gov.au). Seminars to welcome fishers to the SWRCP were held in June 2013 at venues near each fishery to: outline the objectives of the project; introduce fishers to the crab research team; issue logbooks and explain how to fill them out; and generate a sense of ownership of the project amongst the local crabbing community.

The RAP logbook developed by DoF was adopted for the recreational angler program component of the SWRCP; the True Blue Swimmer Supporter Initiative. Fishers were issued with a logbook pack, which included: a Recreational Angler Program (RAP) logbook; prepaid return addressed envelopes; vernier callipers; instructions on how to measure *P. armatus*; logbook examples of how to record catch and effort data; a waterproof scribe plate; a blue swimmer crab fact sheet and the current recreational fishing guide. The packs also contained information on the SWRCP, and a t-shirt and calico bag to engender ownership of the project.

Fishers were asked to complete one or more log sheet/s for every fishing trip they undertook. The logbook entries provided information on the location and duration of each fishing trip together with information on catch and effort, and the type of method used (Fig 3.1). The logbook accommodated a variety of different fishing methods including drop netting, scoop netting, and diving. Fishers were asked to document: how many crabs were caught; their sex, size and reproductive state if female (whether they were egg-bearing or not); and whether the crabs were released or retained after being caught during each of fishing trips.

Quantifying effort for recreational fishers using drop nets is problematic in Western Australia due to the difference in bag and possession limits between shore-based and boat-based recreational fishers, and between bioregions (refer to Chapter 2.4 for specific regulations). Consequently, fishers using drop nets were asked to record not only the number of nets they use, but the number of runs (where all the drop nets that has been set are pulled once) they undertake at each location they crab at during a fishing trip. This allowed for an accurate measure of drop net effort and the presentation of an effective catch rate (crabs/drop net pull).


1234

DATE:
BOAT or SHORE (circle)
Zero fish caught today (tick) ☐

Location	Depth (m)	Start time (use 24 hour time)	Finish time	Gear & No. used	Tackle & No. used	Bait	Species	Length (mm)	Sex	Released (Y/N)	Reason for release	Health

Comments:

Figure 3.1. Extract from the Recreational Angler Program (RAP) logbook used in the SWRCP for reporting crabbing activity in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

Fishers were asked to return completed log sheets on a monthly basis. Fishers were contacted after each set of log sheets was received to validate the data and gather further information relating to their crabbing experience and perceptions to the state of the crab stocks in their fishery. Contacting fishers upon receipt of a set of their log sheets allowed researchers to build a rapport with individual participants and validate submitted data. After each log sheet had been validated it was then photocopied and entered into the DoF RAP Microsoft Access database.

3.2.2 Fisher engagement

Annual update seminars were held at venues near each of the fisheries to present fishers with information gathered from each component of the SWRCP. These seminars also provided fishers with an opportunity to provide feedback on the project and anecdotal evidence from the previous fishing season, and to provide comment on the management of their fisheries.

In addition to these seminars, logbook participants were invited to participate in the breeding stock and recruitment surveys and tagging components of the SWRCP. The surveys provided each participant with hands-on experience in the type of field work carried out by DoF, and gave them a better understanding of the aims and objectives of these components of the SWRCP.

3.2.3 Statistical Analysis

As the Primary Sampling Unit for this sample was person-based (i.e. fisher), mean catch rates (measured in number of crabs kept per 10 drop net pulls) for each fishing method were determined by firstly calculating the mean catch rate for each fisher using individual fishing trip data, then calculating the mean catch rate for the sample using the mean catch rate for each fisher. This process allows each fisher to be equally represented in the estimates (i.e. it avoids estimates being over-influenced more by fishers that reported more trips, or less by fishers that reported less trips) and allows the variance around the estimate (in this case standard error) to be calculated appropriately.

Crabbing effort in southwest Western Australian crab fisheries tends to peak from November through the summer months and into autumn the following year. Consequently, annual fishing catch and effort in this study is presented by a modified financial year to accommodate seasonal analysis (e.g. the 2013/14 fishing year covered June 2013 to May 2014 inclusive).

3.3 Results

3.3.1 Participation rates, fishing frequency and demographics

A total of 208 RAP fishers joined the RAP during the three-year period of the study. Almost half (103) of these registered as potential fishers for the SCE, with 43 and 62 fishers registering for the LE and GB, respectively (Table 3.1). However, not all fishers submitted log sheets reporting crabbing activity, with only 43%, 37% and 21% of registered fishers submitting log sheets over the three years of the project in the SCE, LE and GB, respectively.

Table 3.1. A summary of participation rates of SWRCP fishers by fishery and fishing year.

Fishery	Fishing Year	Logbook Participants		Number of Reported Crabbing Trips by Method			
		Total Registered	Submitted log sheets	Drop Net	Scooping	Diving	Other
SCE	2013/14	70	27	135	5	30	0
	2014/15	85	19	194	9	5	4
	2015/16	103	24	167	11	32	0
LE	2013/14	36	12	36	4	0	6
	2014/15	37	6	37	2	0	1
	2015/16	43	4	16	3	0	0
GB	2013/14	53	12	72	1	0	0
	2014/15	57	7	65	0	0	0
	2015/16	62	6	41	6	0	0

Fishing frequency was measured as the mean number of trips reported per year. The majority of fishers reported undertaking between one and five trips per year, accounting for 59%, 72% and 68% of fishers in the SCE, LE and GB, respectively (Fig. 3.2). In contrast, four fishers in the SCE and 2 fishers in GB reported more than 30 trips per year.

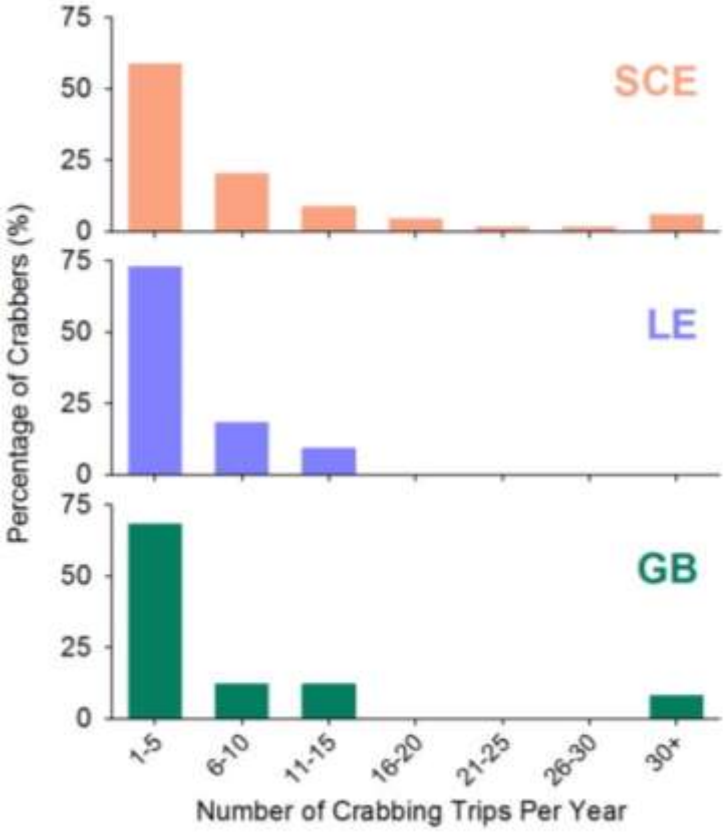


Figure 3.2. The number of trips per year reported by SWRCP RAP fishers in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

All but one of the 103 fishers in the SCE resided in the Perth metropolitan area, with the remaining fisher residing in Mandurah (70 km south of Perth). Similarly, all fishers crabbing in the LE resided in close proximity (>10 km) to the Leschenault Estuary, other than one fisher who resided 15 km away in Boyanup. Likewise, the majority of fishers in GB were local residents of the Busselton/Dunsborough region (78%), with the remaining fishers residing in southwest towns within 50 km of the fishery (Collie, Bunbury and Capel). The majority of recreational fishers were male, representing 98%, 95% and 94% of fishers in the SCE, LE and GB, respectively.

3.3.2 Fishing effort

The majority of trips reported across the three year survey period in all three fisheries were submitted by fishers using drop nets, accounting for 84%, 85% and 92% of all trips in the SCE, LE and GB, respectively (Fig. 3.3). In contrast, fishers using scoop nets accounted for just 4% of reported trips in the SCE and GB, and for 9% of reported trips in the LE. Fishers catching crabs by hand while diving or snorkelling accounted for 11% of reported trips in the SCE, but there was no diving or snorkelling for crabs reported in either the LE or GB. Other methods of catching crabs accounted for 1% in the SCE and 7% in the LE (Fig. 3.3).

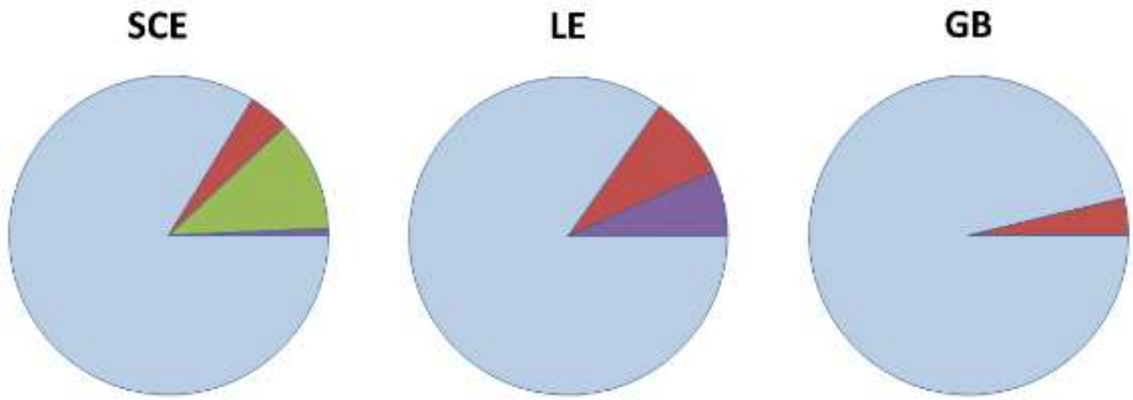


Figure 3.3. Percentage (%) of trips reported by SWRCP fishers using drop nets (■), scoop nets(■), diving or snorkelling (■) or by any other method (■) in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

The majority of reported effort by fishers occurred over summer in both the SCE and LE, with 63% and 67% of trips taking place during this season in each fishery, respectively (Fig. 3.4). In contrast, reported effort in GB was more evenly spread across the year, being highest during spring (35%), followed by summer (29%), winter (22%) and autumn (15%).

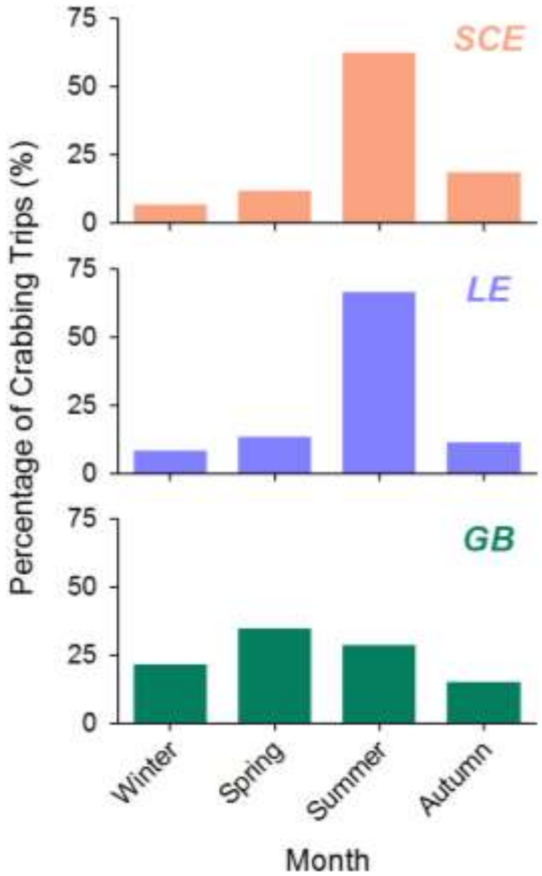


Figure 3.4. The mean annual percentage (%) of trips by season reported by SWRCP fishers in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

The most popular time of day for fishers reporting effort was in the morning. This time period accounted for 39%, 49% and 61% of trip start times in the SCE, LE and GB, respectively (Fig. 3.5). There was also a significant amount of fishing that occurred in the early mornings in the SCE and to a lesser extent in the LE, with 29% and 21% of trips commencing before 6am in each fishery, respectively.

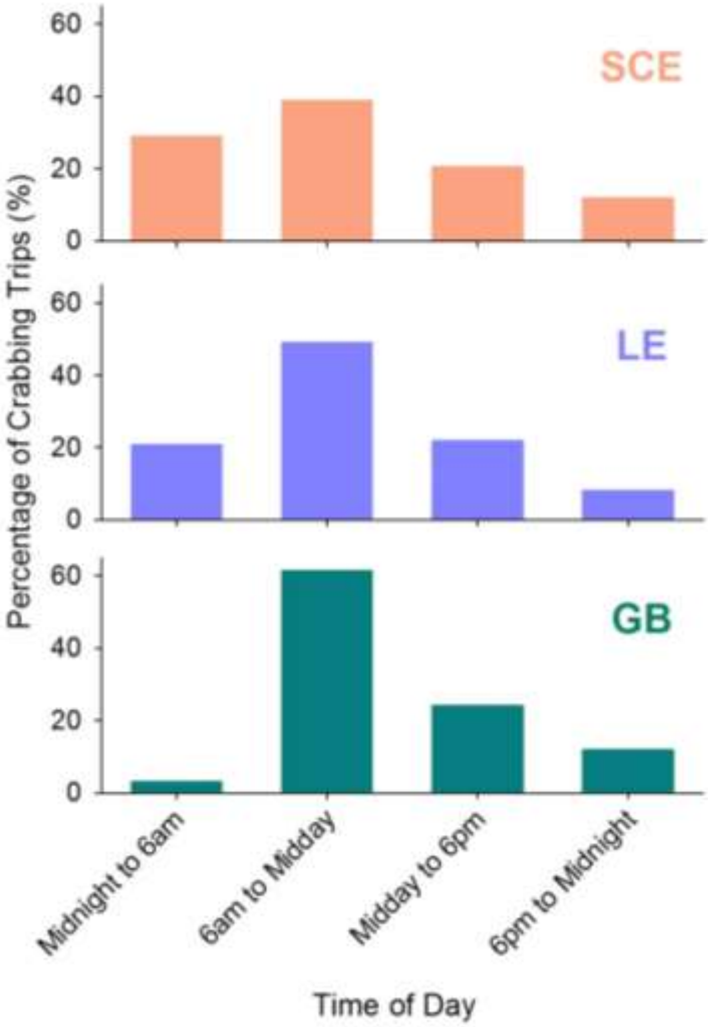


Figure 3.5. The mean annual percentage (%) of start times of trips by six hour block reported by SWRCP fishers in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

Effort by fishers in the SCE was reasonably uniform across the week, ranging from 11% of trips occurring on Mondays to 18% on Saturdays (Fig. 3.6). Saturday was the most popular day amongst fishers in the LE (27%), with the rest of the week ranging from 8% on Thursdays to 16% on Sundays. Saturdays were also marginally more popular in GB (21%), with the next most commonly fished day being Friday (18%) down to 8% of trips occurring on Tuesday (Fig. 3.6).

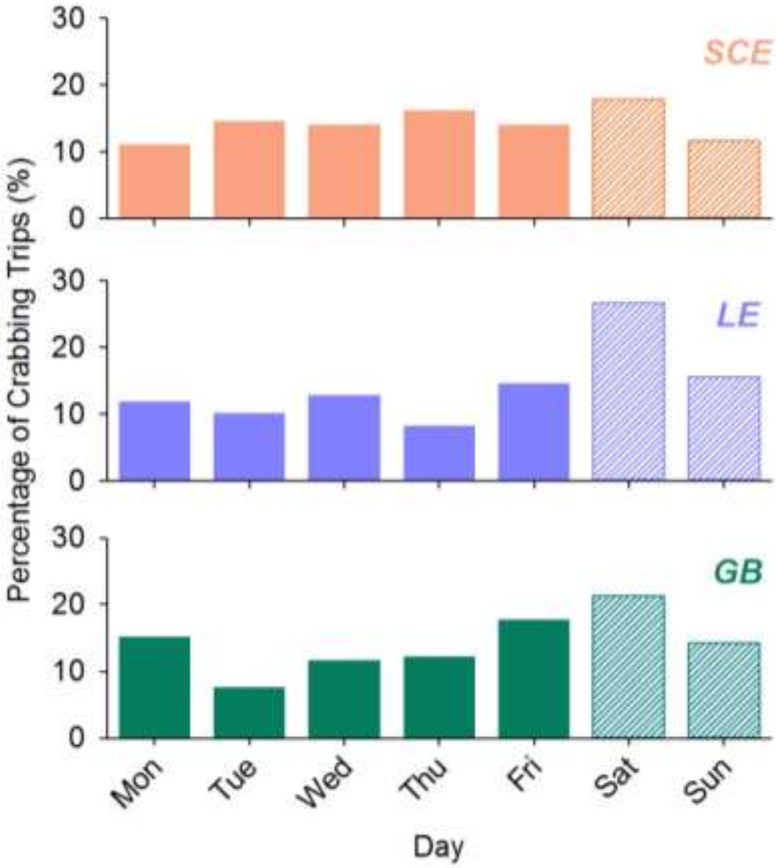


Figure 3.6. Mean annual percentage (%) of trips on individual weekdays (solid bars) and weekend days (diagonal bars) reported by SWRCP fishers in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

Virtually all of the effort reported in the SCE during winter and spring over the three year period occurred in the lower reaches, downstream from Point Walter (Fig. 3.7). While fishing in this section of the SCE continued to be reported over summer and autumn, fishing effort during these seasons extended up the Swan River as far as Maylands, and up the Canning River as far as the Kent St Weir.

Reported effort in the LE during winter tended to focus on the sheltered oceanic waters of Bunbury Harbour, with minimal fishing undertaken in either the Collie River or the Leschenault Estuary (Fig. 3.7). However, effort was more widely reported in the Estuary and Collie River during the remaining seasons. Boat-based fishing in GB over winter occurred in a near-shore stretch of the bay from the Abbey Beach boat ramp in the west to just east of the mouth of the Wonnerup Estuary. Shore-based fishing was reported from the Busselton Jetty and within the Port Geographe marina (Fig. 3.7). Effort over spring extended west to Dunsborough, before contracting to the region around, and within, the Port Geographe Marina during summer and autumn.

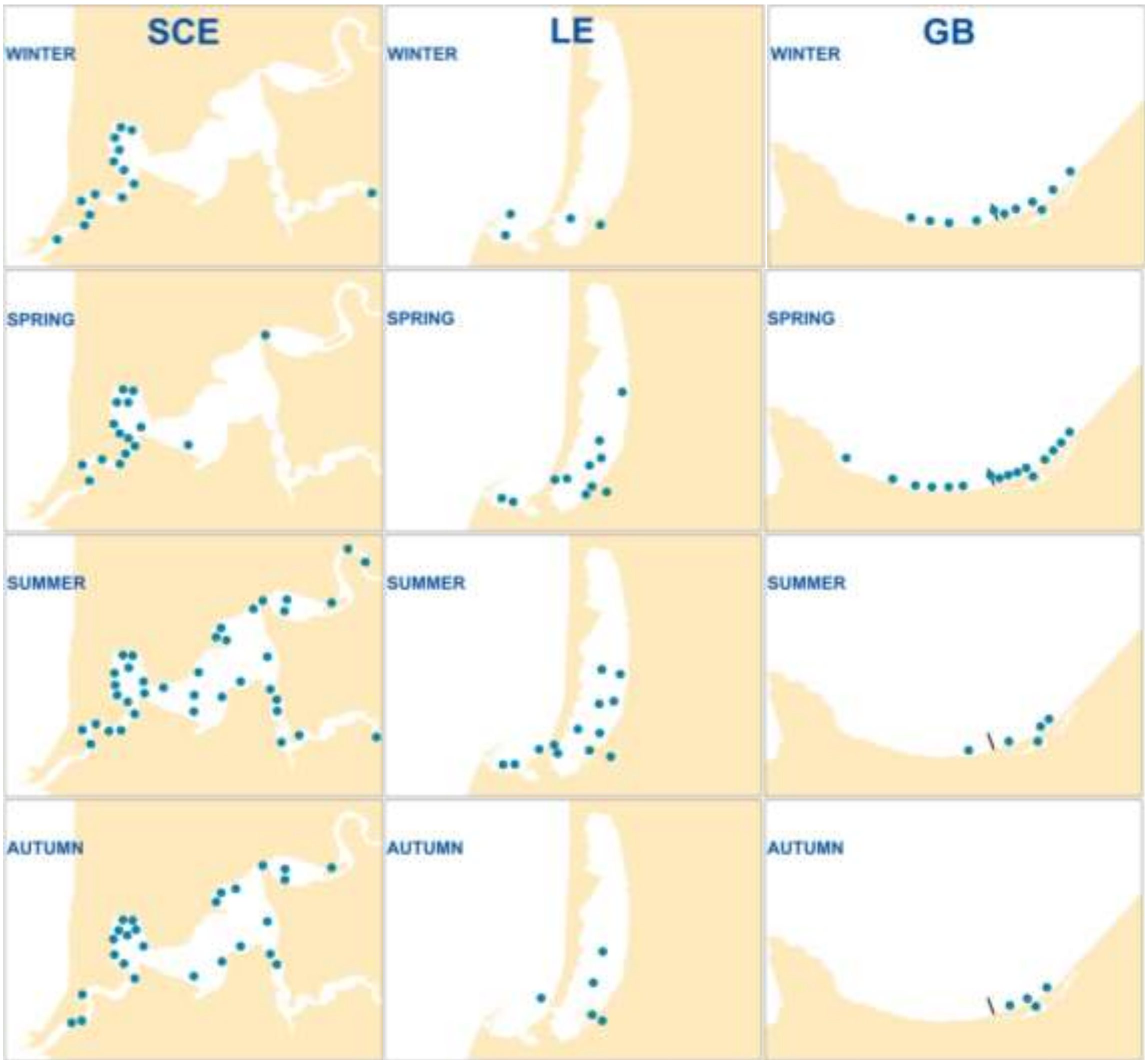


Figure 3.7. Generalised crabbing locations by season for SWRCP fishers in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

3.3.3 Boat vs shore fishing

Most of the effort reported in each fishery was undertaken by boat-based fishers, particularly in the SCE and LE. Fishers in the SCE reported a total of 564 boat-based trips over three years, compared with 87 shore-based trips (Table 3.2). A similar scenario occurred in the LE, with 86 boat-based trips compared with 18 shore-based trips. In contrast, fishers in GB reported 105 boat-based trips and 86 shore-based trips.

Table 3.2. Catch and effort statistics for SWRCP fishers reporting boat-based and shore-based trips in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

		BOAT-BASED				SHORE-BASED			
	FISHING	No. of	No. of	CATCH		No. of	No. of	CATCH	
FISHERY	YEAR	FISHERS	TRIPS	KEPT	RELEASED	FISHERS	TRIPS	KEPT	RELEASED
	2013/14	23	154	1133	319	5	32	184	24
SC	2014/15	16	213	2008	555	3	13	30	9
	2015/16	21	197	1694	593	5	42	217	169
	2013/14	10	36	265	971	4	12	5	150
LE	2014/15	5	40	375	953	2	4	9	29
	2015/16	5	20	118	815	1	2	16	2
	2013/14	10	43	362	582	5	33	154	190
GB	2014/15	7	30	250	537	2	36	76	277
	2015/16	6	32	327	678	2	17	29	124

3.3.4 Catch by method

Fishing with drop nets was the dominant method used by fishers in all three fisheries in each year of the project. On average, drop nets accounted for 90%, 96% and 98% of crabs (kept and released) caught each year in the SCE, LE and GB, respectively (Fig. 3.8). Diving or snorkelling was the second most popular method in the SCE (7%), while a small amount of scoop netting (2-3%) occurring in all three fisheries.

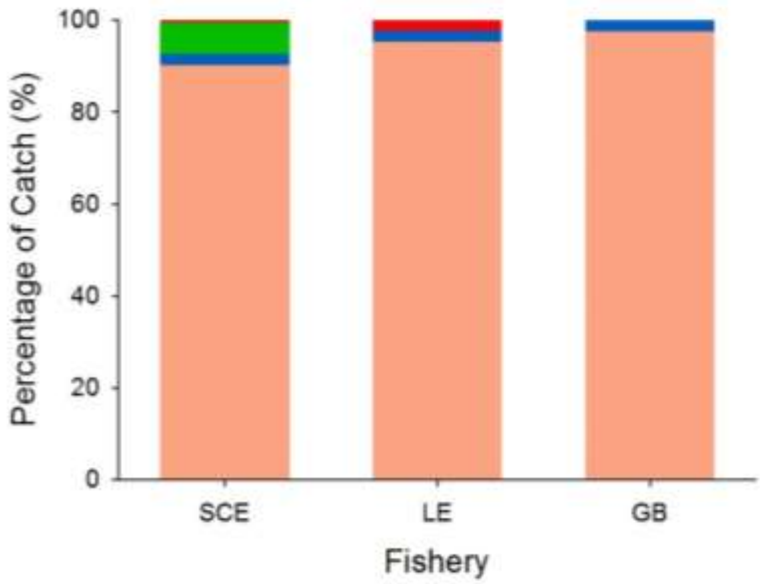


Figure 3.8. Mean annual percentage (%) of the total catch caught by drop net (■), scoop net (■), snorkelling/diving (■) and all other methods (■) for SWRCP fishers the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

Approximately three quarters of crabs caught by fishers in the SCE over the three years were kept, with the remainder released because they were either undersize (19%), berried (2%) or the fisher had already achieved their bag limit (<1%) (Fig. 3.9).

By contrast, most of the crabs captured in the LE and GB over the three year period were released, with only 22% and 33% of crabs kept in the LE and GB, respectively (Fig. 3.9). Three quarters of the crabs in the LE and more than half of the crabs in GB were released because they were undersize (i.e. CW less than 127 mm), while 9% of the crabs caught in GB had to be returned because they were berried.

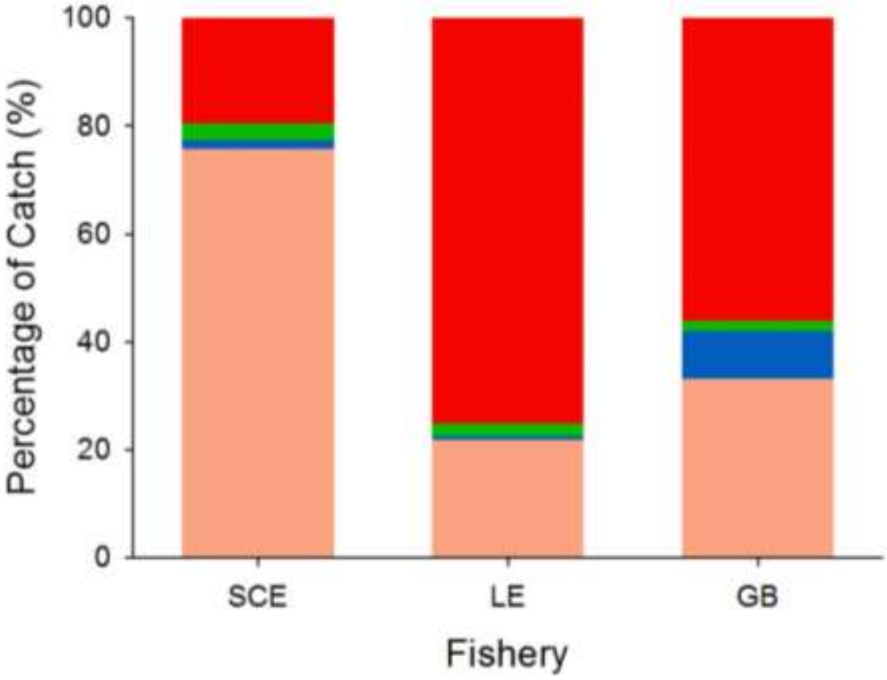


Figure 3.9. Mean annual percentage (%) of the total catch that was kept (■), or released [berried (■), undersize (■) or for any other reason (■)] by SWRCP fishers in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

3.3.5 Drop net catch and effort

Fishers in the SCE reported 135, 194 and 167 trips using drop nets in 2013/14, 2014/15 and 2015/16, respectively (Table 3.3). The mean annual catch rate (crabs kept per 10 drop net pulls) for fishers using drop nets in the SCE across the three years of the SWRCP, increasing marginally from 1.6 in 2013/14 to 1.7 in 2014/15 before falling to 1.3 in 2015/16 (Table 3.3, Fig. 3.10). However, these variations were not statistically significant.

Drop net catch rates were generally higher and more variable in the LE and GB than in the SCE. Fishers in the LE reported 36, 37 and 16 trips using drop nets in 2013/14, 2014/15 and 2015/16, respectively. The catch rate of kept crabs caught by drop net fishers in the LE almost doubled from 1.7 in 2013/14 to 3.0 in 2014/15, before falling to 1.4 in 2015/16 as most of the crabs caught were undersize (Table 3.3, Fig. 3.10).

Fishers in GB reported 72, 65 and 41 trips using drop nets in 2013/14, 2014/15 and 2015/16, respectively. The mean annual drop net catch rate in GB for 2013/14 was noticeably higher than in the following two years, with fishers keeping 2.9 crabs for every 10 drop nets pulled. However, the catch rate then declined in 2014/15 and 2015/16 to 2.0 and 1.9, respectively (Table 3.3, Fig. 3.10).

Table 3.3. Catch and effort statistics for SWRCP fishers using drop nets in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

Fishery	Year	Number of Drop net Crabbing Trips	Drop Net Catch (numbers of crabs) Kept Male	Kept Female	Released Male	Released Female	Kept Drop Net Catch Rate (no crabs kept/ 10 drop net pulls) Catch Rate	Standard Error
SCE	2013/14	135	1088	25	219	96	1.6	0.12
	2014/15	194	1936	40	451	97	1.7	0.08
	2015/16	167	1668	17	484	109	1.3	0.08
LE	2013/14	36	180	85	703	312	1.7	0.15
	2014/15	37	320	60	707	249	3.0	0.71
	2015/16	16	104	6	594	97	1.4	0.19
GB	2013/14	72	91	425	207	549	2.9	0.32
	2014/15	65	69	240	388	440	2.0	0.33
	2015/16	41	79	254	219	531	1.9	0.25

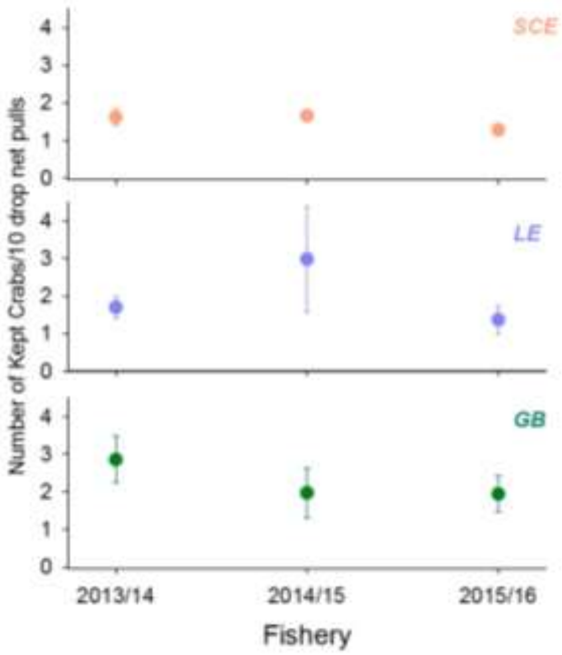


Figure 3.10. Mean annual drop net catch rates (kept crabs per10 drop net pulls) for SWRCP fishers in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive. 95% confidence intervals are included.

Mean seasonal drop net catch rates (crabs kept per 10 drop net pulls) in the SCE were consistent across the 2013/14 and 2015/16 fishing years. During 2013/14, catch rates ranged from 0.8 (±0.12) in winter, increasing to 1.0 (±0.38) in spring, 1.7 (±0.31) in summer and peaking at 1.9 (±0.54) in autumn (Fig. 3.11). A similar pattern was evident in 2015/16, with mean seasonal catch rates ranging from 0.8 – 1.4 crabs kept per 10 drop net pulls. However, there was a slight variation to this trend during the 2014/15 fishing year. While the mean catch rates reported for spring, summer and autumn (0.7-1.7) were consistent with previous years, there was an uncharacteristically high mean catch rate of 3.1 (±1.49) recorded over winter (Fig. 3.11). This resulted from a small number of trips (4) over this period, with one fisher reporting unusually high catch rates on two occasions for this time of year.

Mean seasonal drop net catch rates in the LE were consistent across most of 2013/14, with 1.9 crabs kept per 10 drop nets pulls recorded for winter, spring and summer of that year, before declining to 1.1 (±0.33) in autumn (Fig. 3.11). Seasonal catch rates of kept crabs were noticeably higher and more variable in 2014/15, increasing from 2.0 in winter to 3.1 in spring based on returns from a single fisher. The mean catch rate was 3.2 (±1.7) in summer, before again declining to 2.0 (±0.75) in autumn. Mean catch rates were again consistent between spring (1.4 ±0.77) and summer (1.3 ±0.34) during 2015/16. However, no effort was reported by fishers for either winter or autumn in this year.

Mean seasonal catch rates in GB were more variable across the year than the SCE or LE, being consistently higher in winter and spring and lower in summer and autumn. In 2013/14, the mean catch rate increased from 3.0 (±1.10) in winter to a peak of 4.4 (±1.66) in spring, before declining to 2.1 (±0.46) and 1.8 (±0.89) in summer and autumn, respectively (Fig. 3.11). A similar pattern of seasonality was evident in GB in 2014/15 and 2015/16. During 2014/15, the mean seasonal catch rates increased from 2.8 (±1.73) during winter to 3.0 (±1.62) over spring. The catch rate then declined to 1.1 (±0.27) in summer before increasing to 1.5 (±0.83) in autumn. Similarly, the catch rate in 2015/16 rose from 2.2 (±1.22) in winter to 2.4 (±0.70) in spring, fell to 0.9 (±0.35) over summer and then increased to 1.7 (±0.00) in autumn (Fig. 3.11).

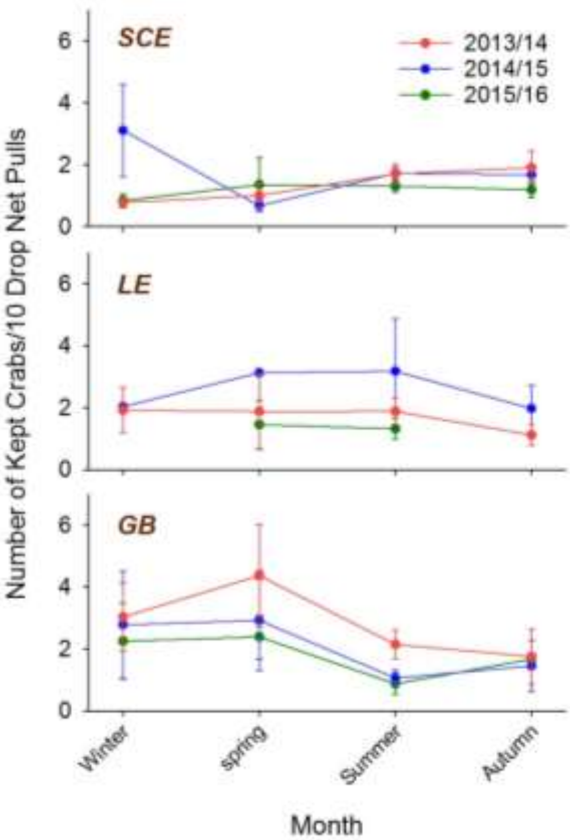


Figure 3.11. Mean seasonal drop net catch rates (crabs kept per 10 drop net pulls) for SWRCP fishers in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive. 95% confidence intervals are included.

The catch from SWRCP fishers in the SCE and LE was dominated by male crabs, accounting for 94% and 76% of the mean annual catch in each fishery, respectively. The male crabs from the SCE were notable for their large size, with over 82% above the minimum recreational size limit of 127 mm CW (Fig. 3.12). In contrast, the male crabs caught in the LE were considerably smaller than in the SCE, with three quarters of the male catch below the minimum size limit (Figure 3.12).

In contrast, the catch from SWRCP fishers in GB was predominantly female. Female crabs represented 70% of the total catch and included a considerable number of berried females, which were largely absent from catches in SCE and LE (Fig. 3.12).

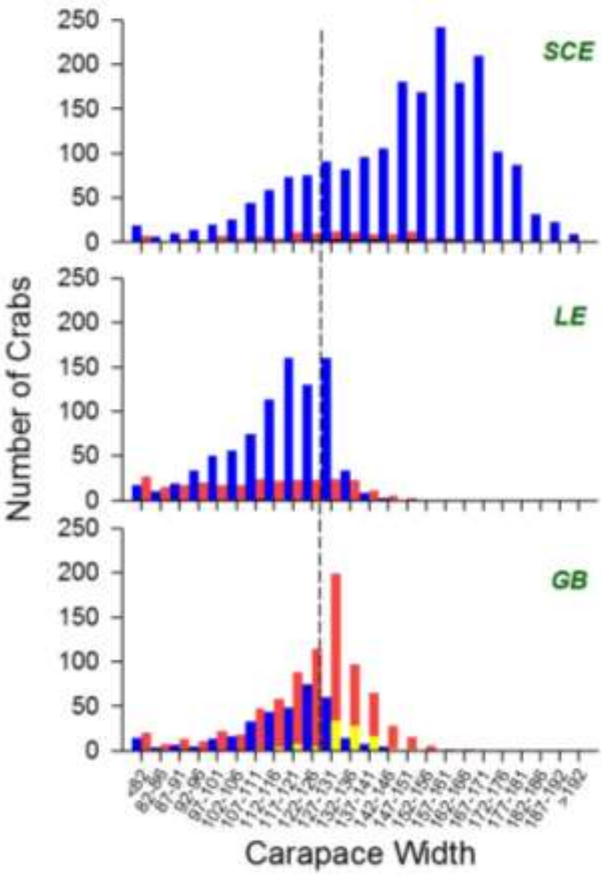


Figure 3.12. Mean annual pooled length frequency distributions of male (■) and non-berried female (■) and berried female (■) blue swimmer crabs caught by SWRCP fishers using drop nets in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive. (Vertical dashed line indicates the recreational size limit of 127 mm CW).

Minimal fishing in the SCE occurred over winter and spring, with mean catches during this period composed mainly of undersized male crabs (Fig. 3.13). In contrast, there was a substantial increase in the number and size of male crabs caught in summer and autumn.

Fishers in the LE also undertook minimal crabbing during winter and spring (Fig. 3.13). Winter fishing was restricted to the near-shore oceanic waters of Bunbury Harbour (Fig. 3.7), where the catch was predominantly female (Fig. 3.13). Fishing extending into the Leschenault Estuary over the spring months (Fig. 3.7), with catches during this period characterised by undersize male crabs. Peak effort in the LE occurred over the summer months, with the catch again dominated by undersize male crabs (Fig. 3.13).

Catches reported by fishers in GB during winter and spring were predominantly female, with undersize male crabs and a substantial number of berried females also caught in spring (Fig. 3.13). Catches in summer in GB were characterised by equal numbers of undersize male and female crabs.

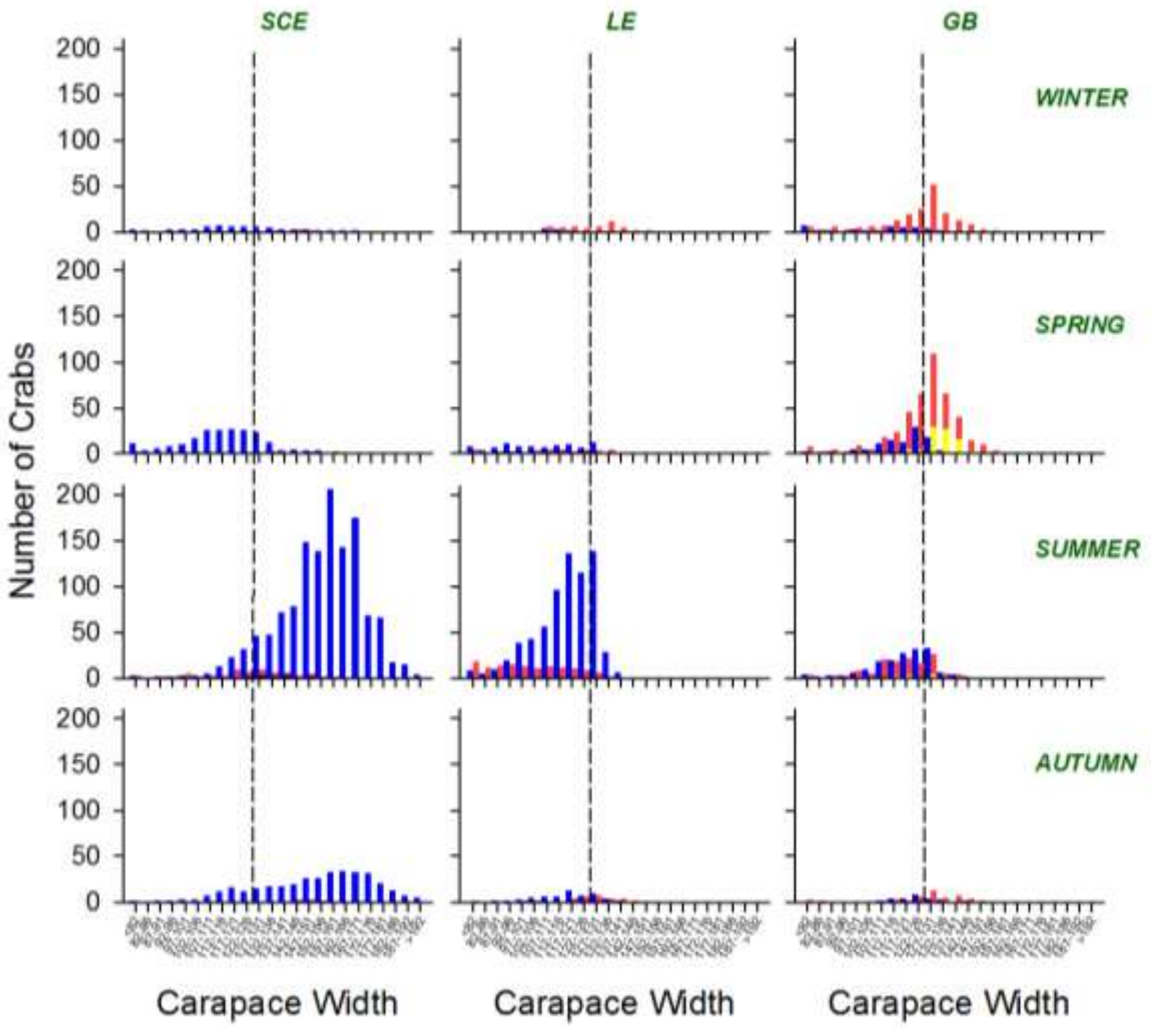


Figure 3.13. Mean seasonal pooled length frequency distributions of male (■) and non-berried female (■) and berried female (■) blue swimmer crabs caught by SWRCP fishers using drop nets in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive. (vertical dashed line indicates the recreational size limit of 127mmCW).

3.3.6 Other crabbing methods

While drop netting was by far the most common form of recreational fishing in the SWRCP, several other methods were used to catch crabs. Diving was the second most popular method in the SCE, accounting for 11% of reported trips over the three years. A total of 30, 5 and 32 diving trips were reported in the 2013/14, 2014/15 and 2015/16 fishing seasons, respectively (Table 3.4). There was also a small amount of scoop netting, while several crabs were caught by a SCE fisher dab netting for king prawns in 2014/15 (Table 3.4).

A small amount of scoop netting took place in the LE (9 trips) and GB (6 trips) over the three years (Table 3.4). Fishing also occurred in the LE using a set net, with crabs caught as a bycatch while targeting mullet.

Table 3.4. Catch and effort statistics for SWRCP fishers using methods other than drop nets in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive.

		SCOOP NET						DIVING						ALL OTHER METHODS					
				Total Catch (# crabs)						Total Catch (# crabs)						Total Catch (# crabs)			
				Kept		Released				Kept		Released				Kept		Released	
Fishery	Year	Fishers	Trips	M	F	M	F	Fishers	Trips	M	F	M	F	Fishers	Trips	M	F	M	F
SCE	2013/14	1	5	3	18	2	0	3	30	113	60	12	9	0	-	-	-	-	-
	2014/15	2	9	6	10	0	7	2	5	7	10	2	0	1	4	19	0	2	4
	2015/16	2	13	5	30	10	139	4	32	153	42	1	5	0	-	-	-	-	-
LE	2013/14	2	4	5	0	15	8	0	-	-	-	-	-	2	6	0	0	61	22
	2014/15	2	2	4	0	15	7	0	-	-	-	-	-	1	1	0	0	1	0
	2015/16	1	3	24	0	4	0	0	-	-	-	-	-	0	-	-	-	-	-
GB	2013/14	1	1	0	0	3	4	0	-	-	-	-	-	0	-	-	-	-	-
	2014/15	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-
	2015/16	1	6	1	20	4	46	0	-	-	-	-	-	0	-	-	-	-	-

Most of the crabs caught by SWRCP fishers using scoop nets in the SCE and GB were female. In contrast, scoop netters in the LE caught mainly male crabs (Fig. 3.14). Divers in the SCE caught a mix of male and female crabs, with very few undersize crabs taken (Fig. 3.15).

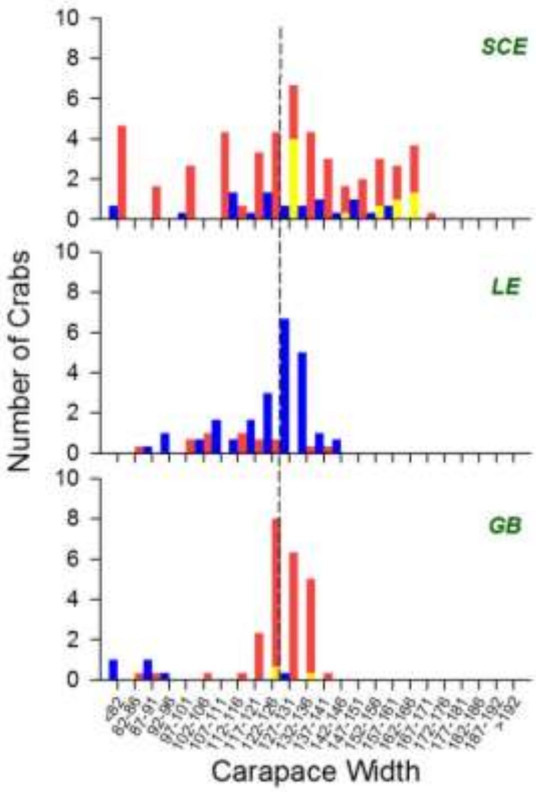


Figure 3.14. Mean annual pooled length frequency distributions of male (■) and non-berried female (■) and berried female (■) blue swimmer crabs captured by SWRCP fishers using scoop nets in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive. (vertical dashed line indicates the recreational size limit of 127mmCW).

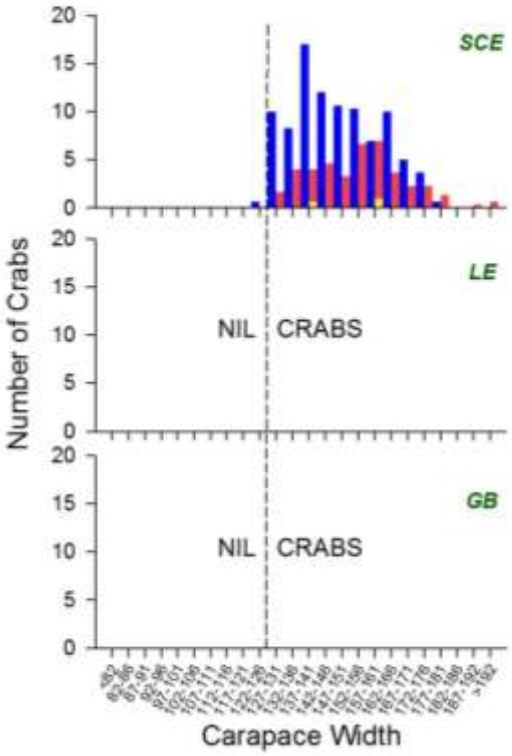


Figure 3.15. Mean annual pooled length frequency distributions of male ( ) and non-berried female ( ) and berried female ( ) blue swimmer crabs captured by SWRCP fishers diving/snorkelling in the Swan-Canning Estuary (SCE), Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) between June 2013 and May 2016 inclusive. (vertical dashed line indicates the recreational size limit of 127mmCW).

3.4 Discussion

A successful Recreational Angler Program (RAP) was established during the SWRCP in the three recreationally important crab fisheries of the SCE, LE and GB. The generated data provided useful temporal and spatial information on recreational catch and effort and catch composition, which met the expectations of the local communities and was consistent with literature on the respective crab stocks. The program has built on the success of the existing Department of Fisheries, Western Australia (DoF) RAP, refining efficiencies in data collection/validation and providing targeted information on recreational crabbing to support existing data which primarily covered finfish species.

Participation rates, submission rates and avidity

The target of attracting 70 recreational fishers to the RAP for each fishery was exceeded in the SCE. The positive perception of the project in this fishery saw an additional 33 fishers joining the program after we had stopped actively engaging potential participants. In contrast, despite comprehensive publicity we attracted 43 fishers in the LE and 62 in GB. This is possibly a reflection of the substantial differences in population, and subsequent numbers of recreational fishers, between the Perth metropolitan area and the regional centres around the LE and GB. Furthermore, the reduced numbers in these two fisheries may have been influenced by the somewhat transitory nature of fishing in these areas, with GB in particular being a popular tourist destination.

Submission rates from fishers were consistent with those reported for similar recreational surveys. A total of 44% of SCE fishers submitted records during the SWRCP, compared with 37% in the LE and

21% in GB. Tracey *et al.* (2011) reported 44% of targeted fishers engaged with a pilot recreational angler program in Tasmania submitting fishing records, despite the project recruiting just 50 highly avid fishers. Bray and Schramm (2001) reported a return rate of 19% from 1,153 volunteer fishers who returned at least one recorded trip that was usable for data analysis in a 1995 angler diary program targeting sport fishes in waters throughout Mississippi, USA.

Despite significant effort to maintain fisher enthusiasm, declining log sheet submission rates were experienced in each of the fisheries. This was especially noticeable after the first year of the program. This attrition was overcome to an extent with additional fishers joining the program as it progressed. This decline is common in recreational angler programs and highlights the difficulty researchers have in maintaining involvement from volunteer recreational fishers. Tracey *et al*. (2011) reported a similar decline over the course of a pilot recreational angler project in Tasmania. Bridge and Conron (2010) reported an increase in submission rates over the first 6 years of a recreational angler program conducted in Victoria between 1996/97 and 2005/06, before a noticeable decline over the final three years of the project.

To foster higher submission rates and maintain an ongoing rapport, all fishers who did not submit catch records during a year were contacted to determine if they still wished to remain part of the program. While there was a 10% annual attrition rate, the majority of those who did not submit indicated a strong preference to remain with the program. Reasons for non-submission included not being able to fish, lost logbooks at which point they were issued with a new book, and not crabbing anymore but enjoying being kept in touch with how the program was evolving and the information that was being collected.

Although the process of contacting fishers on each occasion a set of log sheets was received was resource intensive, it was considered an extremely successful and beneficial part of the program. The contact allowed researchers to validate fisher's data, elicit missing information, and reinforce the correct way to record fishing activity. Consequently, the quality of submitted data improved markedly as the program progressed. This contact also allowed researchers to gain valuable anecdotal evidence on the performance of the fishery which complemented the log sheet data. The response from fishers when contacted was overwhelmingly positive as they: recognized that their data had been received, was considered valuable and would be used; felt a valued part of the program; appreciated the effort of researchers and enjoyed the personal interaction; and felt they had a platform to discuss the management of their fishery.

Fisher avidity is widely recognised as having the potential to introduce significant bias to the data generated through voluntary RAPs, with a core group of dedicated fishers providing the bulk of information (Tracey *et al*., 2011; Ryan *et al*., 2013). The potential for this bias was evident in this RAP, with two fishers accounting for a third of the effort in the SCE, and two fishers accounting for over half the effort in the LE and GB. Consequently, this bias needs to be considered when interpreting the logbook data, particularly in the LE and GB where the number of fishers submitting log sheets was low. However, it should be noted that these highly avid fishers are likely to have the greatest impact on crab stocks (Tracey *et al*., 2011).

Boat-based fishing reported by SWRCP fishers exceeded shore-based fishing, accounting for 87%, 83% and 55% of effort in the SCE, LE and GB respectively. This level of boat-based effort was comparable with estimates from previous recreational crabbing surveys conducted in these fisheries. Malseed and Sumner (2001) undertook a roving creel survey on recreational crabbing using the bus-route method in the SCE in 1998/99 and reported boat-based fishing to account for 91% of the total effort over that period. Similarly, roving creel surveys in the LE in 1998 (Malseed *et al*., 2000) and

GB in 2001/02 (Sumner and Malseed, 2004) estimated boat-based fishing accounted for 86% of effort in both fisheries over the respective periods.

Drop netting was the dominant method employed by SWRCP fishers, accounting for 84%, 85% and 92% of crabbing trips in the SCE, LE and GB, respectively. These results compare favourably with integrated state-wide surveys of boat-based recreational fishing in Western Australia (Ryan *et al.,* 2013; Ryan *et al*., 2015) that estimated drop netting accounted for 99% of boat-based crab catch across the state in both 2011/12 (Ryan *et al*., 2013) and 2013/14 (Ryan *et al.*, 2015).

Analysis of the methods used by recreational fishers reporting tag recaptures during field tagging surveys provided a useful insight into the overall proportions of the different crabbing methods used by the wider fishing community in the SCE, LE and GB. Fishers using drop nets accounted for 62% and 56% of reported recaptures in the first and second field tagging surveys, respectively, with a third of this activity shore-based. In contrast, only 35% of reported recaptures during the first field survey in GB were from fishers using drop nets compared with 54% using scoop nets. However, very few shore-based drop net or scoop net fishers were registered with the SWRCP RAP. Consequently, the variance in fishing methods of RAP fishers was not necessarily representative of that occurring in the wider fisheries and this must be considered when interpreting the results. Given that initiating contact with some fisher groups (e.g. shore-based drop netters) can be difficult, interaction with fishers reporting tag recaptures proved particularly effective in connecting with these sectors. Therefore, tagging surveys may be worth consideration as a method for attracting a more diverse range of potential fishers in any new RAP.

Recreational catch and effort

Clear temporal and spatial patterns were evident in the catch and effort reported by SWRCP fishers. Most effort in the SCE occurred over summer and autumn, with fishing taking place throughout much of the estuary. The catch was almost exclusively male, and distinctive by the very large size of crabs caught (mean carapace width ~153 mm CW). This pattern changed considerably during winter and spring. Substantial modifications to the upstream catchment areas have reduced historic water flow levels into both the Swan and Canning Rivers. However, winter rains entering the estuary through these regions still have a significant impact on water quality by lowering salinity and oxygen levels in the shallow upper and middle reaches to below those preferred by blue swimmer crabs. Consequently, crabs in these upper and middle regions move downstream from Point Resolution to deeper waters (to 20 m) nearer the mouth of the estuary where haloclines (resulting from fresh water flowing over denser salt water) preserve marine conditions in the lower depths and allow crab stocks to remain within the estuary all year round. Consequently, reported effort in the SCE during winter and spring was largely confined to these lower reaches. The catch during this period was predominantly composed of large female and undersize male crabs as the stock of large male crabs was fished down over the summer and autumn.

The unusually large size of crabs captured over the summer and autumn months in the SCE is consistent with a previous recreational survey conducted in 1998/99 by Malseed and Sumner (2001). They reported the recreational crab catch to be dominated by male crabs, with a relatively even distribution from the legal size of 127 mm CW up to 173 mm CW, and as big as 194 mm CW. However, it is possible that this sex ratio is biased towards male crabs as the survey sampled only crabs retained by recreational fishers and there is a preference amongst recreational fishers for large male crabs and a desire to help conserve the breeding stock by returning females. The large size of crabs from the recreational catch in the SCE is also consistent with the commercial catch history in this fishery. Johnston *et al.* (2011) reported the mean carapace widths of male crabs captured during

December commercial monitoring surveys in the SCE to be 154 mm CW, increasing to 160 mm CW by April. This is a much larger size than crabs captured in any of the other southwest Western Australian fisheries where DoF sampling is conducted. Johnston *et al*. (2011) reported the mean carapace width of male crabs captured during December commercial monitoring surveys in CS between 1999 and 2006 being 131mm CW, increasing to 136 mm CW by March before decreasing to 129 mm CW in July as fishing pressure removed larger animals from the stock. Similarly, the mean carapace width of male crabs captured during December commercial monitoring surveys in the Peel-Harvey Estuary between 2007 and 2011 was ~129 mm CW. The mean carapace width then increased to ~135 mm CW by April before declining to ~126 mm CW, again largely as a result of commercial and recreational fishing pressure removing larger animals from the estuary stock (Johnston *et al*., 2014).

A similar pattern of catch and effort to the SCE was reported by fishers in the LE, although there was a considerable difference in the size of crabs caught. The majority of effort in the LE occurred over summer, largely centred within the Leschenault Estuary where the catch was almost exclusively male. However, the crabs caught in the LE over this period were notably smaller (mean carapace width ~123 mm CW) than in other southwest Western Australian fisheries, with most having to be released as they were under the legal recreational size limit of 127 mm CW. A small amount of crabbing also occurred in the near-shore marine waters of Bunbury Harbour, with the catch a mix of male and female crabs. Crabbing effort continued in the estuary into the autumn months, until winter rains flowing into the shallow water body rapidly lowered salinity levels to below those preferred by blue swimmer crabs and the crab stock moved out of the estuary to more marine waters. The movement of crab stocks from the estuary is also influenced by declining water temperatures in the shallow water body. Consequently, crabbing effort over the winter months and into spring was centred on the near-shore marine waters of Bunbury Harbour. As is the case with most southwest Western Australian crab fisheries, the recreational catch during this period was largely female with about half the catch over the legal size limit. Crabbing effort remained focussed on these near-shore marine waters until the winter rains receded and salinity levels and water temperatures in the estuary returned to levels acceptable to blue swimmer crabs and some of the stock returned to the estuarine habitat. This spatial pattern of crab movement in the LE mirrors that described by Potter and de Lestang (2000), who reported that numbers of crabs in the estuary fell dramatically in the winter months due to declining water temperatures and salinities. They also noted an appreciable increase in the number of crabs in Koombana Bay and Bunbury Harbour, indicating that the estuarine crabs had emigrated to the alternative habitats provided by this embayment. Meagher (1971) also concluded that temperature differences between the estuary and fringing embayment causes crabs to emigrate from the estuary in autumn and return the following spring.

In contrast to both the SCE and LE, crabbing effort reported by fishers in GB was more evenly spread throughout the year with a peak in activity from September to January. The catch during this peak period was predominantly female. This is consistent with other southwest Western Australian crab fisheries, such as Cockburn Sound and the Peel-Harvey Estuary, where the commercial catches are largely female during the winter/spring period (Johnston *et al*., 2011, Johnston *et al*., 2014). As with the LE, a large proportion of the reported catch in GB had to be released because the crabs were under the legal size limit. However, there were also a significant number of female crabs that had to be returned during the spring months because they were berried. This is consistent with a study conducted in Geographe Bay by Bellchambers *et al*. (2005), which identified the spring months to be the peak spawning period in GB. Furthermore, this result is consistent with the peak spawning period identified in other southwest Western Australian fisheries (Kangas, 2000, de Lestang *et al*., 2003a; Johnston *et al*., 2011). While female crabs dominated the reported catch from fishers over winter and spring, the catch over summer was composed equally of male and female crabs. Spatially, effort extended from Dunsborough in the west through to Forrest Beach in the east with most activity between the Busselton Jetty and Wonnerup Estuary (Fig. 2.8). This effort occurred exclusively in the shallow nearshore waters around the bay, less than 200 m from the water's edge.

Quantifying effort for recreational fishers using drop nets is problematic in Western Australia due to the difference in bag and possession limits between shore-based and boat-based recreational fishers, and between bioregions (refer to Chapter 2.4 for specific regulations). Consequently, previous studies have been restricted to general catch rate information of crabs per boat per hour or fishing trip. To refine this catch rate, SWRCP fishers using drop nets were asked to record not only the number of nets they use, but the number of runs (where all the drop nets that has been set are pulled once) they undertake at each location they crab at during a fishing trip. This allowed for a more accurate measure of drop net effort and the presentation of an effective catch rate (crabs/drop net pull) and is recommended for future recreational surveys involving crab species.

The information generated by the RAP has proved valuable for DoF managers currently undertaking a review into crab stocks in southwest Western Australian fisheries. However, it is important to recognise the limitations of this dataset. The data presented reflects the catch and effort of SWRCP fishers that submitted log sheets, and does not necessarily provide an accurate representation of overall recreational crabbing in these fisheries. Therefore, it cannot be used to generate total recreational catch estimates for each fishery. Nor is the three-year time series generated by this study sufficient to determine the trends exhibited in the data. So DoF will maintain the RAP to monitor these fisheries into the future, with consideration given to incorporating the important recreational crab fisheries of Cockburn Sound and the Peel-Harvey Estuary.

4 Fishery-independent monitoring program: breeding stock and recruitment surveys

D. Harris, D. Johnston, J. Baker, M. Foster and A. Denham.

Objective: To develop methods for the ongoing assessment of blue swimmer crab breeding stock and recruitment in the Swan-Canning Estuary, Leschenault Estuary and wider Bunbury area, and Geographe Bay.

4.1 Introduction

Fisheries stock assessment involves the use of statistical analyses to understand the dynamics of exploited fisheries. These assessments make quantitative predictions about the reactions of fish populations to alternative management choices that aim to ensure sustainable production of fish stocks over time, through regulatory actions that promote the economic and social well-being of the fishers and industries that access the resource (Hilborn and Walters, 1992). DoF scientists utilise such stock assessments to develop harvest strategies that establish clear performance levels and associated management actions designed to achieve the agreed objectives for a particular fish resource, and the relevant fishery sectors that access that resource (Department of Fisheries, 2015).

Fishery-independent estimates of abundance form the cornerstone of rigorous stock assessments, providing valuable and comparatively unbiased measures of relative abundance, rates of population change, and size and sex composition. Because these measures are obtained through scientific sampling within an experimental design, they are less subject to the often confounding factors and biases that complicate the interpretation of fishery-dependent indices of stock status (Rago, 2005). However, fishery-independent research surveys are traditionally resource intensive and researchers are often forced to rationalise the biological parameters they can afford to measure. The relationship between the breeding stock and the subsequent strength of recruitment into a fishery is considered by many fisheries scientists to be the most important component of a biological stock assessment (Hillborn and Walters, 1992). Consequently, we have endeavoured to develop cost-effective methods that provide annual data to quantify the state of the breeding stock, and the strength of subsequent recruitment from the previous year's spawn, for the crab stocks from each of the three target fisheries during this project.

While mature female crabs spawn all year round in tropical waters (Harris *et al*., 2014; Zairion *et al*., 2015), the cooler waters experienced during the winter months in southwest Western Australia result in an abbreviated spawning season from September to January (Johnston *et al*., 2011; Johnston *et al*., 2014). Spawned larvae in these regions grow rapidly as the water temperature increases over the summer months, reaching 60-90 mm CW some 4-6 months later when they recruit to the fishery (Johnston *et al*., 2011, Johnston *et al*., 2014).

A number of fishery-independent surveys monitoring breeding stock and recruitment levels in southwest Western Australian crab fisheries have been conducted since the 1980s, including studies on the Peel-Harvey Estuary (Potter *et al*., 1983; de Lestang, 2002; Johnston *et al*., 2014), Cockburn Sound (de Lestang, 2002; Bellchambers *et al.,* 2006a, Johnston *et al*., 2011), the Leschenault Estuary and Koombana Bay (de Lestang, 2002) and Geographe Bay (Bellchambers *et al*., 2006b). However, there have not been any fishery-independent studies conducted on blue swimmer crabs in the SCE. Consequently, the only data available for the ongoing assessment of the crab stock in this fishery has been commercial fishers' monthly catch and effort (CAES) returns (since 1977) and monthly monitoring trips aboard commercial vessels sampling the day's catch (since 2007). While these data provide a base index of abundance and information on the size and sex of the commercial catch, they cannot be used to assess breeding stock or recruitment levels.

This chapter presents cost-effective surveys designed to provide data to generate annual indices quantifying the state of the blue swimmer crab breeding stock, and strength of subsequent recruitment, in the SCE, LE and GB.

4.2 Methods

4.2.1 Breeding stock surveys

4.2.1.1 Survey design

Monthly breeding stock surveys to sample sexually mature (SCE: ≥ 93 mm CW; LE: ≥ 94 mm CW; GB: ≥ 92 mm CW) and egg bearing female *P. armatus* were conducted over the peak period of the spawning season in southwest Western Australian crab fisheries (October and November) in each year of the SWRCP. As the shallow nature of LE prevented demersal otter trawling, research hourglass traps covered with 2" mesh were deployed to sample sexually mature female crabs in each of the three fisheries.

Three research hourglass traps were deployed for a 24-hour soak time at each of 15 sites within each fishery (Fig. 4.1 – 4.3, Table 1 in Appendix). Individual traps were baited with yellow-eye mullet (*Aldrichetta forsteri*) contained inside a perforated PVC bait tube measuring 55 mm diameter x 250 mm and sealed with end-caps joined using a length of shock cord. The traps were set 100 m apart along a transect at each site. Each trap was identifiable by a clearly labelled Department of Fisheries, Western Australia (DoF) float. The research traps measured approximately 115 cm diameter and 50 cm in height when extended (Fig. 4.4). The galvanised steel basal ring was connected to the pneumatic upper ring via two-inch mesh that tapered in towards the midline where entry gaps were located. Unlike commercial traps, there were no escape gaps so juvenile and sub-adult crabs were more likely to be retained along with adults. The traps were emptied into an ice-slurry for 60 seconds upon retrieval to subdue the crabs. Carapace width (CW), sex, and shell condition (hard or soft carapace) were recorded for all crabs captured, along with the state of maturity and egg development of female crabs. The catch was then returned to the water as close to the retrieval location as practicable.

Breeding stock sites sampled within the SCE and LE were identified after consultation with local commercial crab fishers and DoF staff. Within GB, thirteen of the fifteen sample sites were selected based on analysis of data collected by Bellchambers *et al.* (2006b), with the additional two sites chosen on advice from local DoF staff.

Figure 4.1. Breeding stock survey sites (●) within the Swan-Canning Estuary sampled using research hourglass traps during the SWRCP.

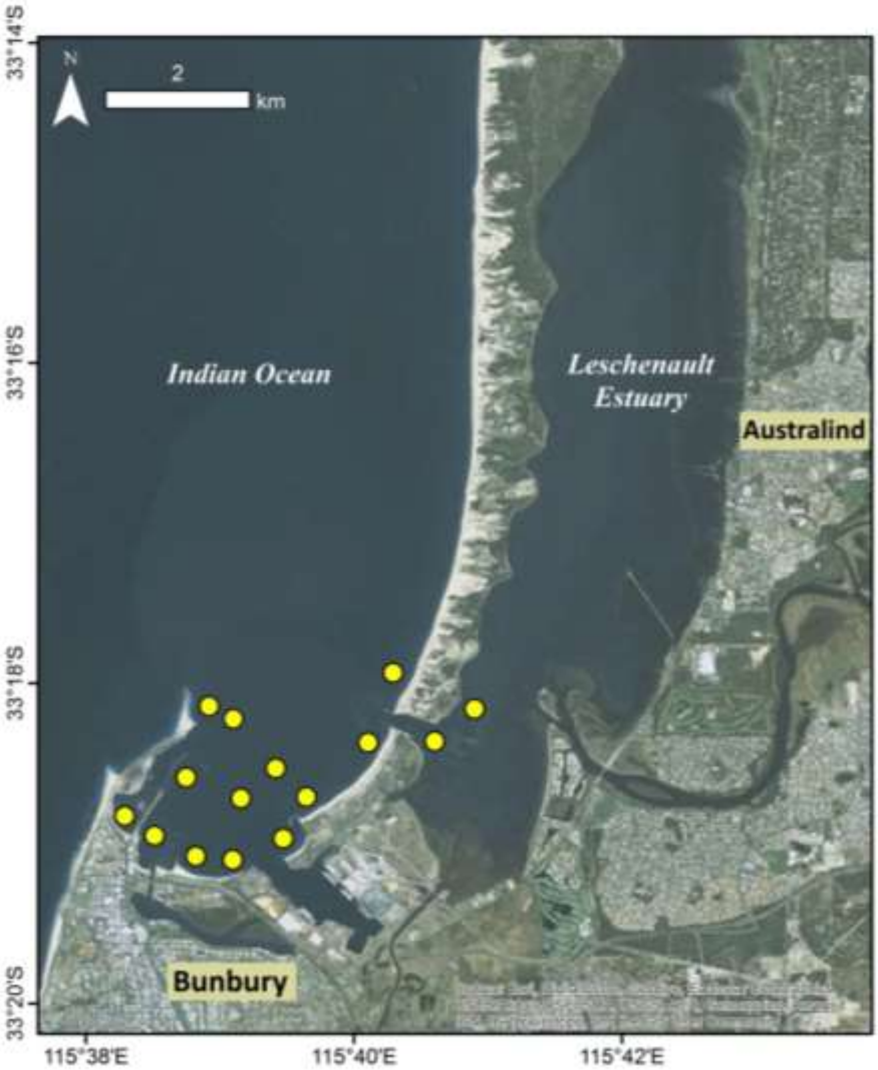


Figure 4.2. Breeding stock survey sites (●) within the Leschenault Estuary sampled using research hourglass traps during the SWRCP.

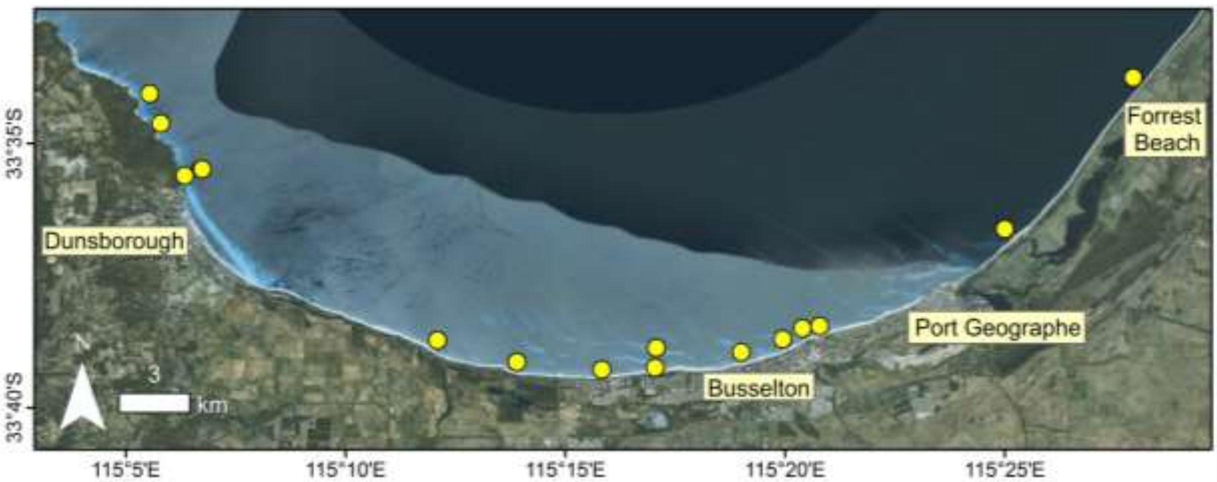


Figure 4.3. Breeding stock survey sites (●) within Geographe Bay sampled using research hourglass traps during the SWRCP.

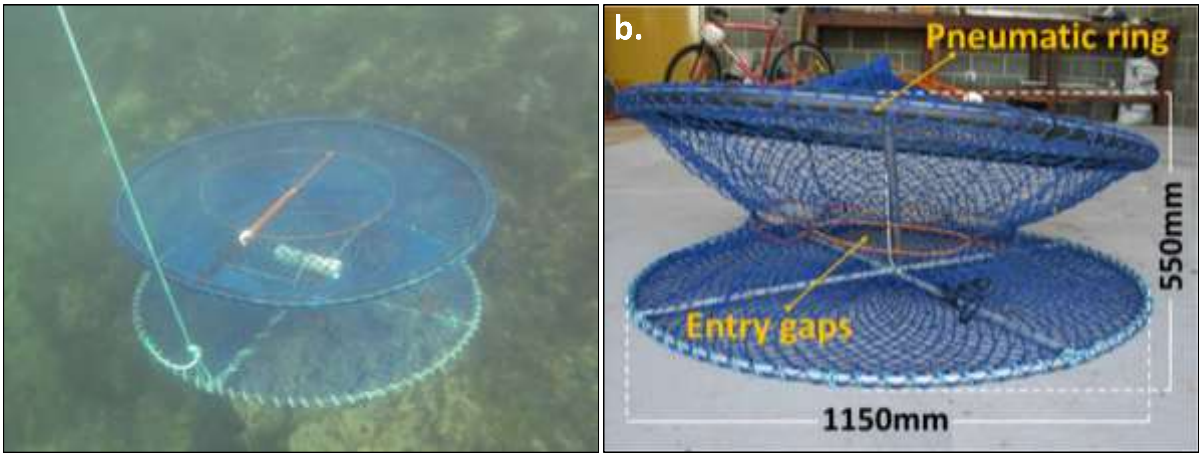


Figure 4.4. (a) A baited research hourglass trap deployed underwater, illustrating the buoyant pneumatic ring extending the trap whilst submerged. (b) Research hourglass trap dimensions.

4.2.1.2. Statistical analysis

Catch rates of sexually mature female crabs by number and weight in the SCE, LE and GB were calculated at each sampling site for each sampling year and month. The probability of sexual maturity of each individual female crab, based on carapace width, was used to calculate the number of sexually mature female crabs in each sample:

$$p = \frac{1}{1 + \exp\left(\frac{L - L_{50}}{a}\right)} \tag{1}$$

where L_{50} is the size at 50% maturity for each fishery (SCE: L_{50} = 93.8 *mm*; LE: L_{50} = 94.7 *mm*; GB: L_{50} = 92.5 *mm*; unpublished data, de Lestang, 2016), and a is the corresponding slope parameter of the logistic function used to model size-at-maturity for each fishery (SCE: a = -3.58; LE: a = -4.32; GB: a = -4.55; unpublished data, de Lestang, 2016). The distribution of catch rates of sexually mature female crabs, by number and weight, in a given year (over two sampling months and multiple sampling sites) was then used to produce a mean annual catch rate and its associated 95% confidence limits.

The breeding potential of female crab stocks in the SCE, LE and GB was determined by applying batch fecundity and batch frequency models in order to calculate catch rates of eggs per traplift as an index of egg production (EPI). These calculations took into account the size of captured sexually mature female crabs, as there is a direct relationship between size and spawning potential with larger females producing more eggs per batch, and more batches of eggs per spawning season (de Lestang, 2003).

Each female crab captured during October and November breeding stock surveys was assigned a total potential egg production based on a batch fecundity (E, number of eggs x 1000) to carapace width (L) relationship (unpublished data, Foster and Hesp, 2016):

$$E = 1.017\exp(-6.909)L^{2.837}(1000) = 1.016L^{2.837} \tag{2}$$

where 1.017 is the bias correction factor calculated as $\exp(\sigma^2/2)$ (Beauchamp and Olson, 1973) to adjust for the mean estimate calculated in log space. A batch frequency (N) to carapace width (L)

relationship (modified from de Lestang, 2003) was used to adjust the number of eggs by the number of expected batches to estimate the total fecundity for a crab of given carapace width:

$$N = 1 + \frac{2}{1 + \exp\left(-\ln(19)\frac{L - 120.97}{134.77 - 120.97}\right)} \quad (3)$$

The batch frequency-carapace width relationship was modified from that of de Lestang *et. al.* (2003) by adjusting for the change in size at maturity for crabs in Cockburn Sound from de Lestang ($L_{50} = 86.4mm$) which was previously used as a proxy for all crabs from southwest WA crab fisheries, to the revised 2016 analyses for each individual fishery (SCE: L_{50} = 93.8 *mm*; LE: L_{50} = 94.7 *mm*; GB: L_{50} = 92.5 *mm*; unpublished data, de Lestang, 2016).

The probability of sexual maturity of each individual crab (See Eq (1) above) was used to calculate the number of sexually mature female crabs of given carapace width which had the potential to produce eggs. The probability of sexual maturity at length, batch fecundity at length and batch frequency at length relationships were used to calculate the number of eggs for each individual crab in the sample, which were then aggregated to calculate the number of eggs for each site. The number of eggs and the associated number of pots was then used to calculate the annual potential egg catch rates (eggs per potlift) at each site in a given sampling month and year for each of the three fisheries. The distribution of catch rates in a given year (over two sampling months and multiple sampling sites) was then used to produce a mean annual catch rate and its associated 95% confidence limits.

4.2.2 Recruitment Surveys

Recruitment surveys to sample sub-adult (≤110 mm CW) *P. armatus* were conducted over the peak period of crab recruitment in southwest Western Australia (March to May) in the SCE, LE and GB during each year of the SWRCP. As sub-adult blue swimmer crabs tend to inhabit shallow, near-shore areas of marine embayments and estuaries, beach seining was the preferred method for sampling recruits during this study.

4.2.2.1 Swan-Canning Estuary

During the 2014 and 2015 recruitment surveys in the SCE, a 21.5m beach seine was used to sample sub-adult blue swimmer crab stocks in shallow (≤1.5 m), nearshore waters fringing the Swan and Canning Rivers. The seine net consisted of two 10 m wings of 9 mm mesh and a 1.5 m bunt composed of 3 mm mesh (Fig. 4.5) and was manually towed along three replicate 30 m transects at each site location. Sampling commenced thirty minutes after sunset. The length of each seine was standardised by using four marker posts with lights attached secured vertically in the sand adjacent to the shoreline; two posts lined up at the beginning of each transect and two at the end separated by 30 m lengths of rope (Fig. 4.6). The seine net would be towed out in line with the beginning marker posts such that the nearshore end of the seine net was 10 m from shore. At the end of the thirty metres, the two operators closed the net before returning to shore by bringing both ends of the net together causing the net to form a teardrop shape. Each transect was standardised at 30 m along the shore from the previous, with exception of the Bicton site in the SCE as the sampling area available at this site was only long enough to perform one seine. At the end of each drag the crab catch was emptied into an ice slurry with all other bycatch returned immediately to the water. The CW, sex, state of maturity and shell condition of captured crabs were measured and recorded before returning the crabs to the water.

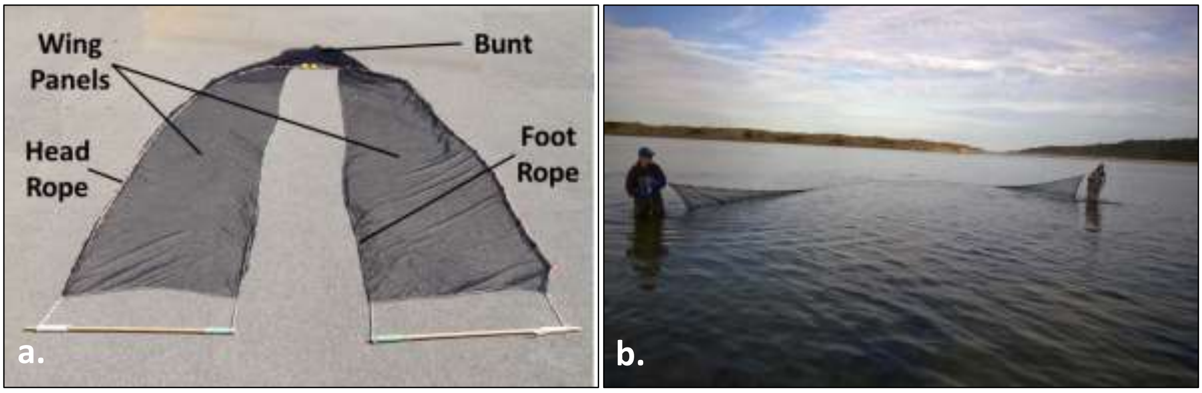


Figure 4.5. (a) The 21.5 m beach seine used for recruitment stock surveys during the SWRCP. (b) The seine net being towed by two operators.

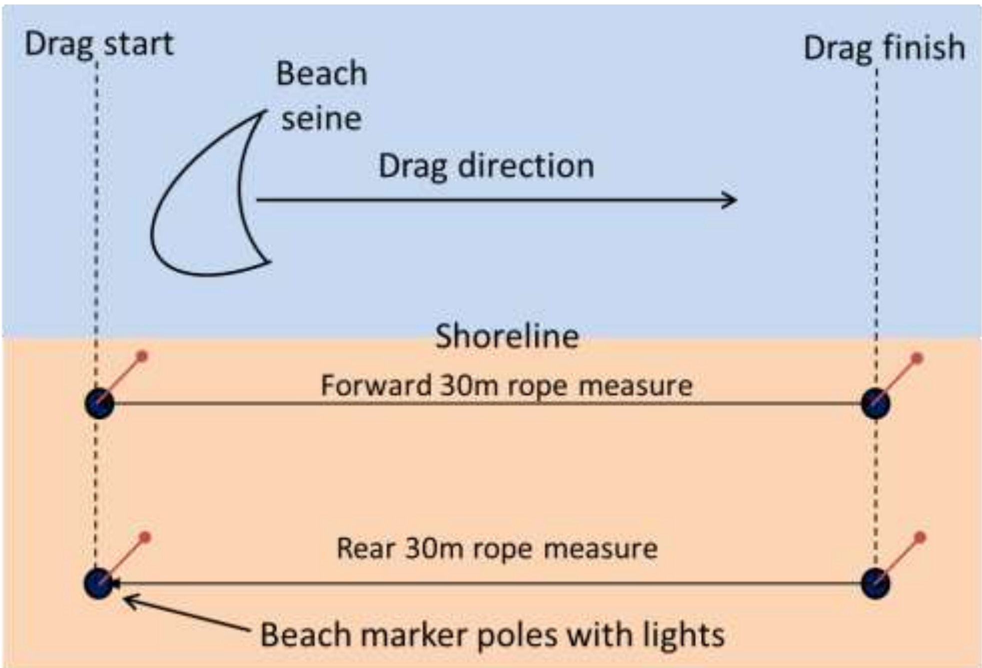


Figure 4.6. A schematic representation of a seine net transect on the shoreline of each sample site.

Twelve sites were sampled in the SCE during the March and April 2014 recruitment surveys, from Gilbert Fraser Reserve in North Fremantle upstream to the Como shoreline on the Swan River, and the Gentilli Way boat ramp on the Canning River (Fig. 4.7). However, few sub-adult crabs were captured in seines during these two months, so the survey was repeated in May to minimise the likelihood of missing a later recruitment pulse. In addition, research hourglass traps with 2" mesh were trialled during the May survey to sample a variety of depths to 5 m at recruitment sites in the lower reaches of the SCE. However, very few sub-adult crabs were captured in the traps so this method was not pursued in this fishery.

Due to the lack of sub-adult crabs in seines at sites upstream from Bicton during sampling in 2014, the 2015 survey was refined to the three sites that produced notable quantities of sub-adult crabs in the previous year (Fig. 4.7). However, very few sub-adult crabs were again caught in seines during the March and April surveys, so sampling in 2015 was extended to May and June.

Despite few sub-adult crabs being captured on any of the recruitment surveys undertaken during 2015, trawl sampling carried out by James Tweedley from Murdoch University (*pers. comm.*), together with consultation with SWRCP logbook participants, in particular those diving, suggested sub-adult stocks were present in large numbers in the lower reaches of the river at depths between 5-20 m at this time. As a consequence, otter trawling was trialled across 11 site locations in the SCE in March and April during 2016 recruitment surveys (Fig. 4.7). The site locations spanned upstream from East Fremantle through to Dalkeith and were selected to sample a variety of different depths ranging from ~5m. – 20m. The sites were selected based on a previous study by Jenkins *et al.* (2015), consultation with the SCE logbook diarists, and analysis of SWRCP tagging survey data. The trawl comprised a two-fathom trawl net with 25 mm mesh in the wings and 9 mm in the cod-end (Fig. 4.8). Ten millimetre ground chains were attached to a foot-rope that kept the net on the bottom during the trawl. A net efficiency factor of 0.67 is applied to account for the effective spread of the net on the estuary bed (Harris *et al.*, 2014). Trawling commenced each night thirty-minutes after sunset, with the trawl towed at 2.7 knots for 500m. At the end of each shot the trawl net was retrieved and all crabs were emptied into an ice slurry before being measured, recorded and returned to the water.

Figure 4.7. Recruitment survey sites within the Swan-Canning Estuary sampled using a beach seine in 2014 (●), a beach seine in 2014 and 2015 (●), and by otter trawl in 2016 (●).

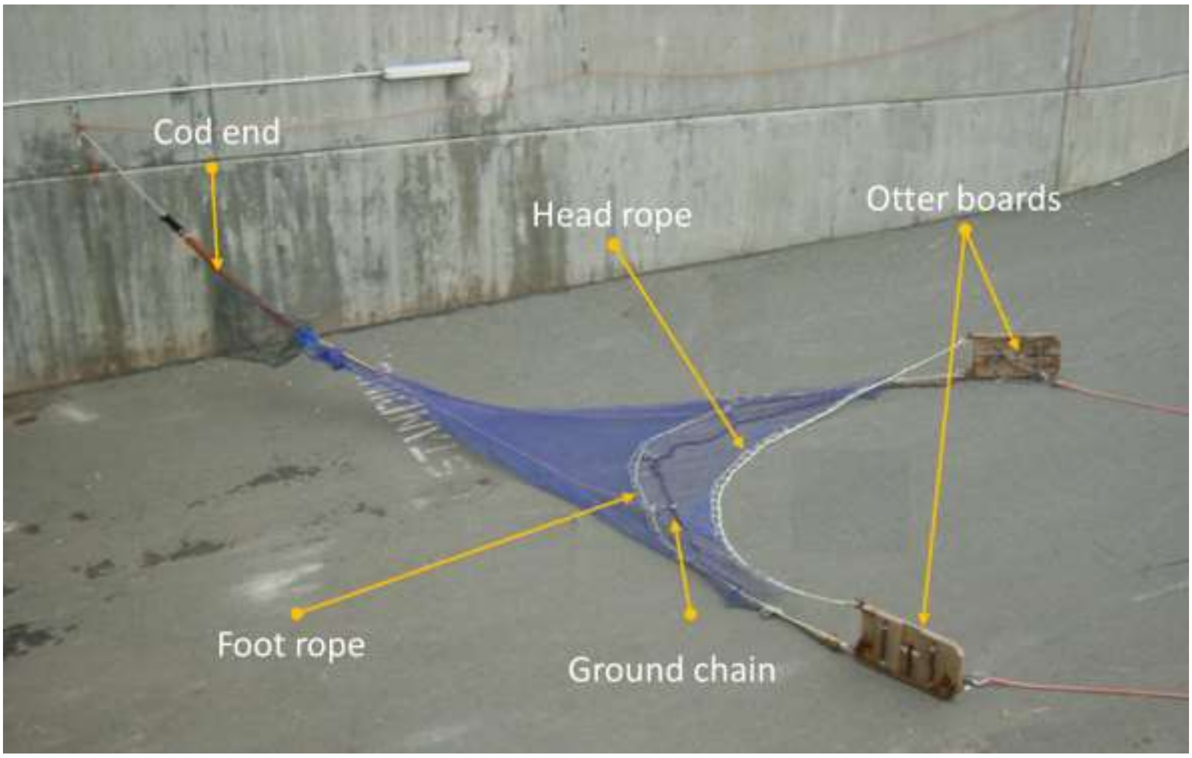


Figure 4.8. Extended otter trawl net and otter boards used during recruitment surveys in the Swan-Canning Estuary and Geographe Bay.

4.2.2.2. Leschenault Estuary and wider Bunbury area

Beach seining was employed for sampling sub-adult blue swimmer crabs during recruitment surveys in the LE over each year of the SWRCP. Three site locations within the Leschenault Estuary were selected based on previous studies (Potter and De Lestang, 2000; Veale *et al*., 2014), while the fourth site in Casuarina Harbour was selected after consultation with local DoF personnel (Fig. 4.9).

The months of March and April were sampled in each of the three years of the project. However, the March 2015 sample was severely affected by unseasonably high tides and so the survey was repeated in May of this year. Seining methods replicated that used in the SCE.

Figure 4.9. Recruitment survey sites (●) within the Leschenault Estuary sampled using a beach seine during the SWRCP.

4.2.2.3. Geographe Bay

Seine net sampling replicating the methods described in section 4.2.1 was conducted at four sites around GB in March and April 2014 (Fig. 4.10). However, very few sub-adult crabs were captured during these surveys and the sampling was repeated in June to minimise the likelihood of missing a late recruitment pulse. However, the beach seine sites at Toby's Inlet and the mouth of the Queen Elizabeth Drain were inaccessible due to banks of weed on the beach. To further explore the spatial extent of sub-adult crab stocks, research hourglass traps covered in 2" mesh (Fig. 4.4) and box traps covered in 1" mesh (Fig. 4.11) were trialled in near-shore marine waters to 5m depth along GB, along with the inland waterways of Toby's Inlet, the Buayanyup River drain, the Port Geographe Marina and the Wonnerup Estuary (Fig. 4.10).

As beach seining was not successful in capturing sub-adult crabs in GB during 2014, and the seining sites were subject to constraints with seasonal variation in accessibility and beach profile, this method was deemed unsuitable for recruitment surveys in this fishery. Consequently, three 2" mesh research hourglass traps were employed to sample sub-adult crabs during March and April 2015 recruitment surveys at each of six sites in near-shore marine waters to depths of 5m, from Siesta Park east to Forrest Beach (Fig. 4.10). Site selection was based on analysis of data from a previous trap survey in GB by Bellchambers *et al.* (2006b). Three traps were also deployed at each of three sites in each of the inland waterways of the Wonnerup Estuary, Port Geographe Marina, and Buayanyup Drain (Fig

4.10). Trapping methods replicated that described in Section 4.2.1. However, while quantities of mature crabs were captured in the March and April surveys, very few of the target sub-adults appeared in the catch. So the sampling was repeated in May and June 2015 to minimise the likelihood of missing a late recruitment pulse.

Although reasonable quantities of mature crabs were captured in the research hourglass traps during the 2015 recruitment surveys, very few of the target sub-adults appeared in the catch so this method was also deemed unsuitable for recruitment surveys in this fishery. Consequently, otter trawling was employed during March and April 2016 recruitment surveys in GB. Eight sites were selected across GB based on analysis of data from a previous trawl survey conducted in GB by Bellchambers *et al.* (2006b), spanning east from Broadwater to the mouth of the Wonnerup Estuary (Fig. 4.10). Trawling methods replicated that described in Section 4.3.1.

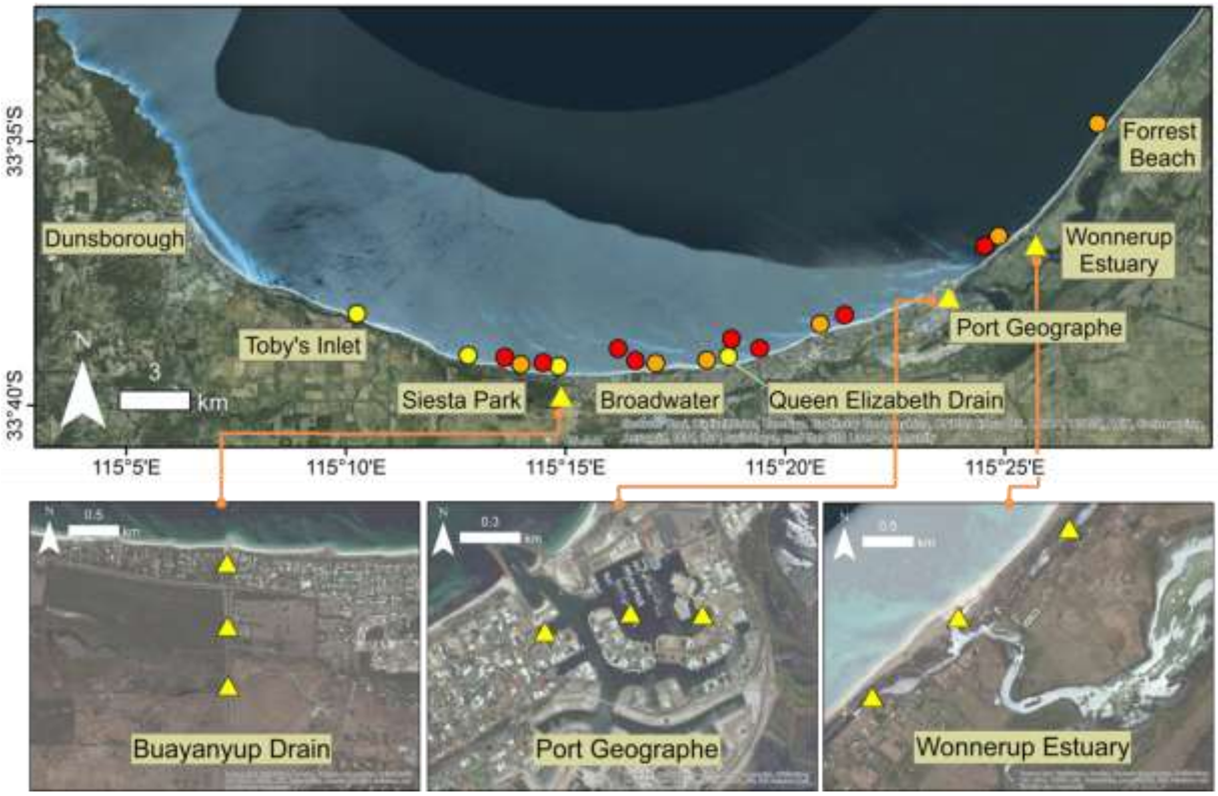


Figure 4.10. Recruitment survey sites in Geographe Bay for the beach seine sampling carried out in 2014 (●), research hourglass trapping undertaken at the nearshore (●) and inshore (▲) site locations in 2015, and the otter trawl site locations sampled in 2016 (●).

Figure 4.11. A box trap covered in one inch mesh trialled in near-shore marine waters and inland waterways of GB during June 2014.

4.3 Results

4.3.1 Breeding stock surveys

Sexually mature (SCE: ≥ 93 mm CW; LE: ≥ 94 mm CW; GB: ≥ 92 mm CW) female blue swimmer crabs were captured during all surveys conducted in each of the three fisheries sampled as part of the SWRCP between 2013 and 2015.

While similar numbers of sexually mature female crabs were caught in traps at sites in the LE and GB, markedly fewer crabs were captured in traps in the SCE (Fig. 4.12). However, the mature female crabs in this fishery were noticeably larger in size than those in either LE or GB.

Two distinct cohorts of female crabs were evident in the length frequency distributions for each year in the SCE, a 0+ cohort and a cohort most likely comprising of 1+ and 2+ animals (Fig. 4.12). There also appears to be divergent 0+ and 1+ cohorts in the distributions from the LE sampled in 2013 and 2014, although this separation was not so apparent in the 2015 distribution. A similar pattern was evident in GB, with two discernible cohorts in 2013, but not in 2014 or 2015 (Fig. 4.12).

Mean annual catch rates of sexually mature female crabs were not significantly different in the SCE over the three years of the project, increasing marginally from 3.0 crabs/traplift in 2013 to 3.4 and 3.7 crabs/traplift in 2014 and 2015, respectively (Fig. 4.13). In contrast, there was a slight reduction in catch rates of sexually mature females in the LE, from 7.3 crabs/traplift in 2013 to 6.0 and 5.4 crabs/traplift in 2014 and 2015, respectively. However, overlapping confidence intervals suggest that the catch rates for the LE over the three years were not statistically significantly different from one another. A more noticeable decline was evident in GB, with the catch rate of sexually mature female crabs falling from 10.6 crabs/traplift in 2013 to 8.1 and 5.6 crabs/traplift in 2014 and 2015, respectively, with the decline in catch rates between 2013 to 2015 of statistical significance (Fig. 4.13).

Inter-annual variations in breeding potential within each fishery were very similar to the catch rates of sexually mature female crabs. Mean annual catch rates of the number of eggs per traplift were relatively consistent in the SCE over the three years of the project, falling slightly from 10.6 million eggs/traplift in 2013 to 9.4 million eggs/traplift in 2014 before increasing to 13.0 million eggs/traplift in 2015 (Fig.4.14). There was a slight decline in the annual breeding potential in the LE from 14.5 million eggs/traplift in 2013 to 10.4 million eggs/traplift in 2014, but it remained stable at 10.5 million eggs/traplift in 2015. A more evident decline was recorded over the three year period for GB, with the breeding potential falling from 24.0 million eggs/traplift in 2013 to 17.3 million and 13.3 million eggs/traplift in 2014 and 2015, respectively (Fig. 4.14).

There was a slight increase in the mean proportion of berried female crabs in breeding stock surveys in the SCE over the three years of the SWRCP, from 28.0% of female crabs in 2013, to 30.1% and 33.0% of crabs in 2014 and 2015, respectively (Fig. 4.15). However, following a noticeable increase in the proportion in the LE from 21.5% in 2013 to 34.1% in 2014, the proportion of berried females in surveys fell to 24.9% in 2015. A similar trend was evident in surveys in GB, with an initial increase in the proportion of berried females from 28.9% in 2013 to 39.1% in 2014, followed by a decline to 21.5% in 2015 (Fig. 4.15).

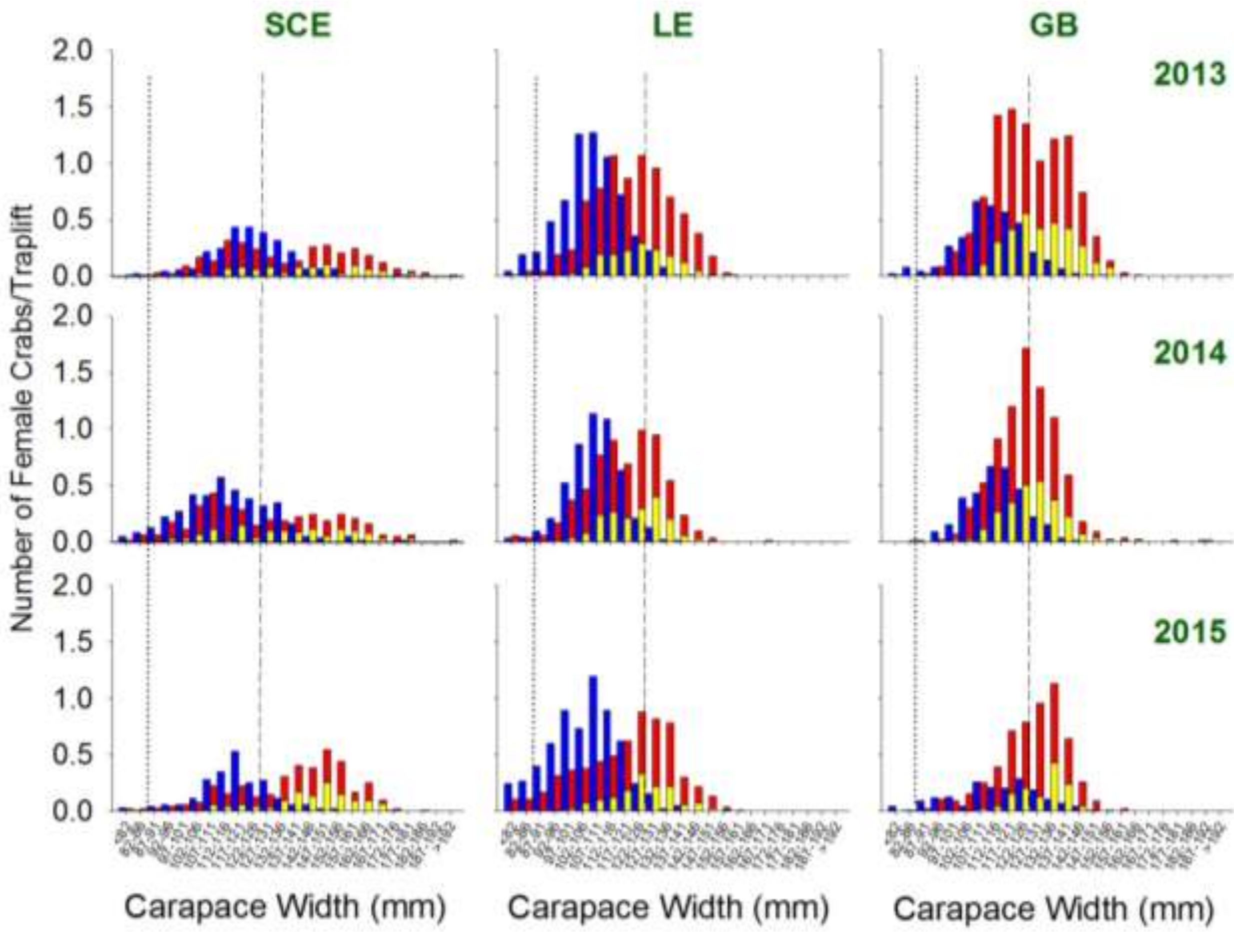


Figure 4.12. Mean pooled length frequency distributions of male ( ), female non berried ( ) and ovigerous ( ) blue swimmer crabs captured in hourglass traps during breeding stock surveys in the Swan-Canning Estuary, the Leschenault Estuary and wider Bunbury area, and Geographe Bay in October and November 2013-15. ---- recreational size limit (127 mm CW); ⋯⋯ mean size at sexual maturity (SCE: ≥ 93 mm CW; LE: ≥ 94 mm CW; GB: ≥ 92 mm CW).

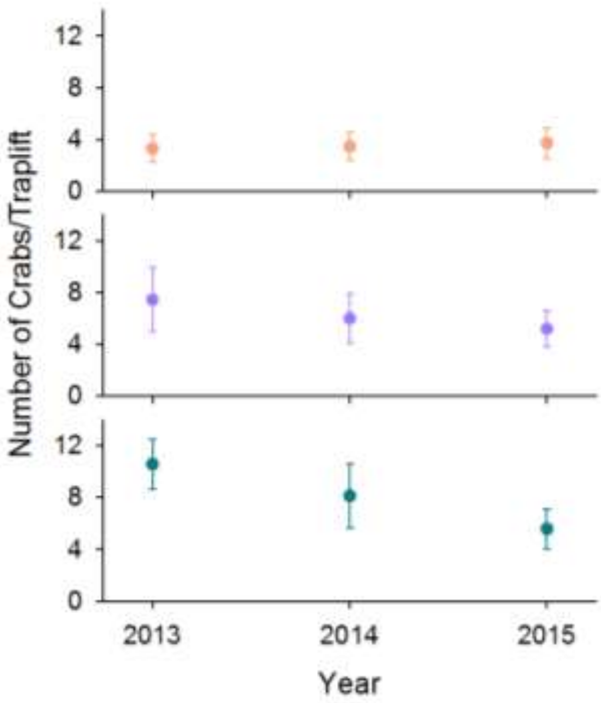


Figure 4.13. Mean annual catch rates (numbers of crabs/traplift) of sexually mature (SCE: ≥ 93 mm CW; LE: ≥ 94 mm CW; GB: ≥ 92 mm CW) female blue swimmer crabs captured in research hourglass traps during breeding stock surveys in the Swan-Canning Estuary (●), the Leschenault Estuary and wider Bunbury area (●), and Geographe Bay (●) between 2013 and 2015. 95% confidence limits presented.

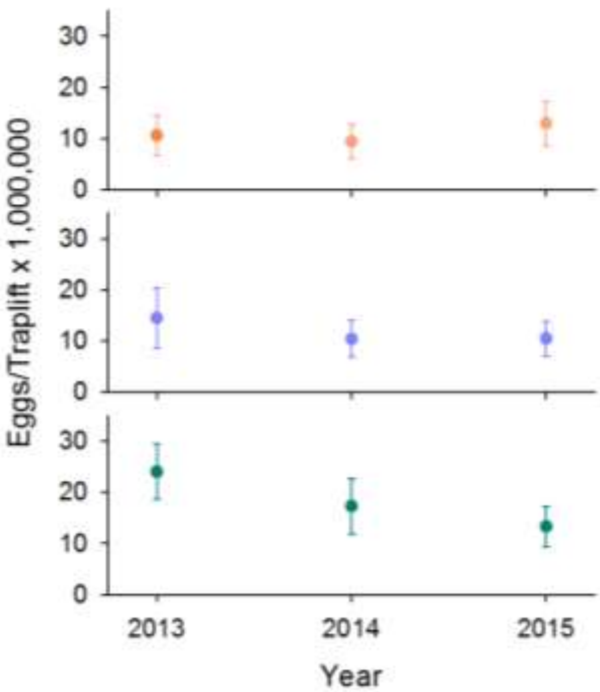


Figure 4.14. Mean annual catch rates (numbers of eggs/traplift) of breeding stock potential generated from breeding stock surveys in the Swan-Canning Estuary (●), the Leschenault Estuary and wider Bunbury area (●), and Geographe Bay (●) between 2013 and 2015. 95% confidence limits presented.

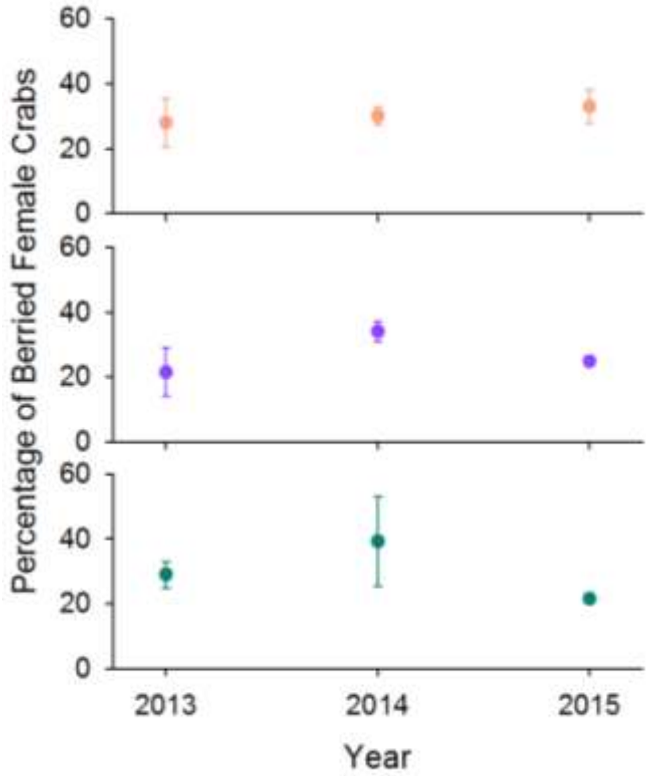


Figure 4.15. Mean percentages of female blue swimmer crabs that were bearing eggs captured in hourglass traps during breeding stock surveys in the Swan-Canning Estuary (●), the Leschenault Estuary and wider Bunbury area (●) and Geographe Bay (●) between 2013 and 2015. Standard error presented.

While sexually mature female crabs were captured at all 15 sites sampled during breeding stock surveys in the SCE between 2013 and 2015, highest catch rates (averaged over month and year) were consistently encountered in the very lower reaches of the Estuary downstream from Bicton (Fig. 4.16).

Sexually mature female crabs were also captured at all 15 sites sampled during breeding stock surveys in the LE between 2013 and 2015. Catch rates (averaged over month and year) were relatively consistent across sites throughout Bunbury Harbour, with a noticeable increase in catch rate at the two most oceanic sites between the end of the harbour breakwater and the shipping channel (Fig. 4.17).

Likewise, sexually mature female crabs were captured at all 15 sites sampled during breeding stock surveys in GB between 2013 and 2015. Catch rates (averaged over month and year) were relatively consistent across sites west of the Busselton Jetty, with a noticeable increase in catch rates at sites east of the jetty (Fig. 4.18).

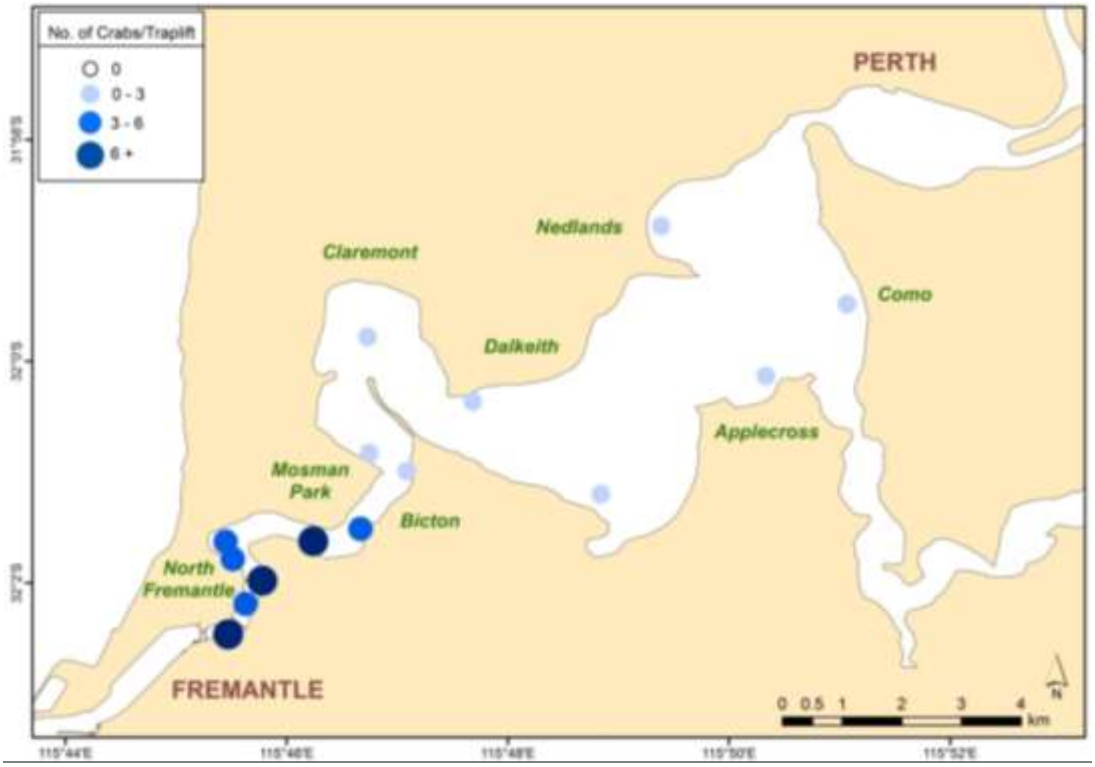


Figure 4.16. Mean catch rates of sexually mature female blue swimmer crabs (crabs/traplift) by site (averaged over year and month) captured using research hourglass traps at 15 sites in the SCE during the months of October and November between 2013 and 2015.

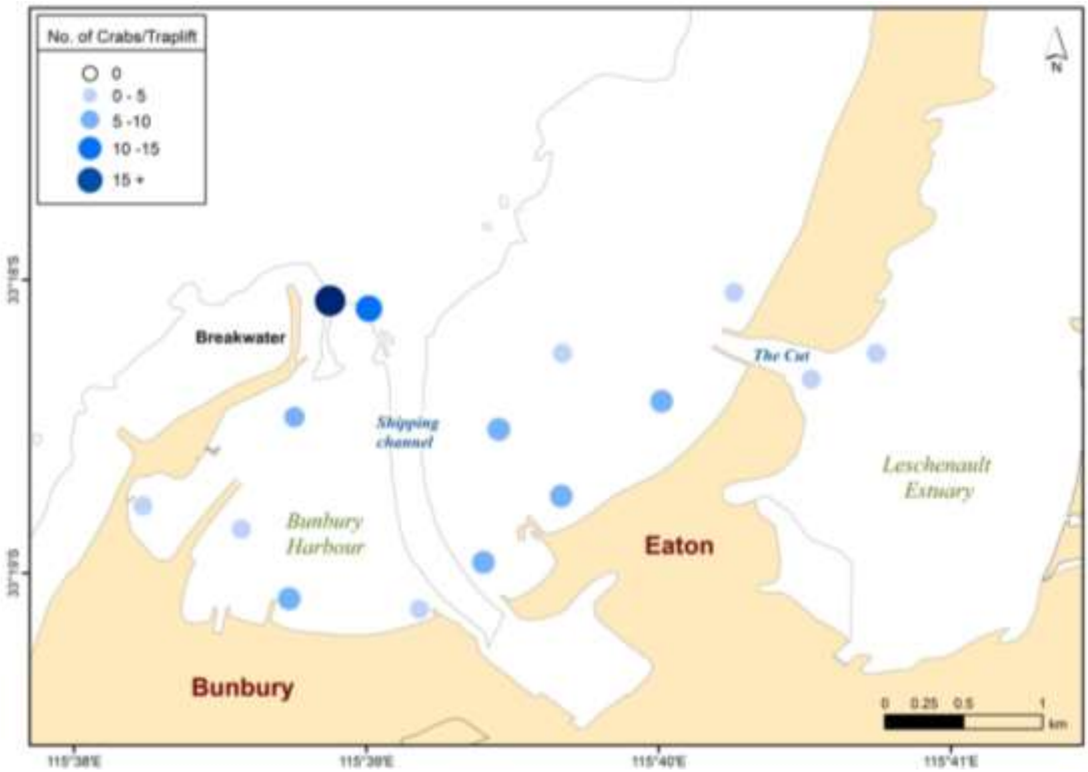


Figure 4.17. Mean catch rates of sexually mature female blue swimmer crabs (crabs/traplift) by site (averaged over year and month) captured using research hourglass traps at 15 sites in the LE during the months of October and November between 2013 and 2015.

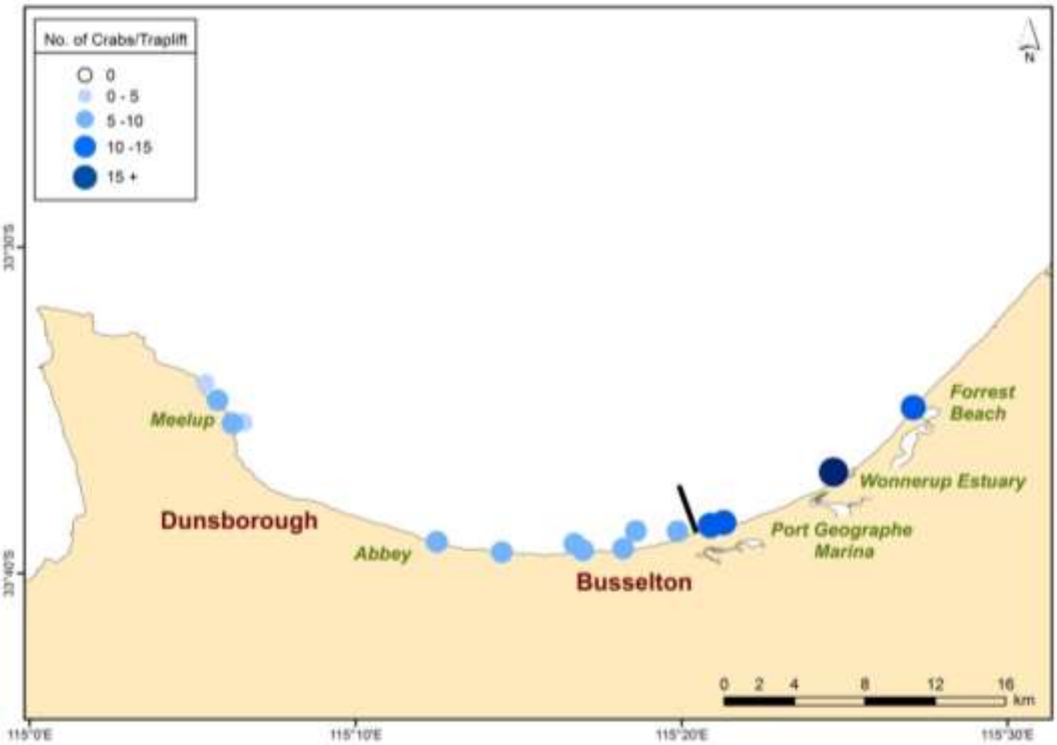


Figure 4.18. Mean catch rates of sexually mature female blue swimmer crabs (crabs/traplift) by site (averaged over year and month) captured using research hourglass traps at 15 sites in GB during the months of October and November between 2013 and 2015.

4.3.2 Recruitment surveys

Swan-Canning Estuary

Sampling for sub-adult (≤110 mm CW) blue swimmer crabs in the SCE using the preferred method of dragging a 21.5m beach seine through the shallow (≤1.5m) waters fringing the lower reaches of the Swan and Canning Rivers proved unsuccessful. While a small number of sub-adult crabs were captured in seines during the 2014 March survey in the very lower reaches of the Swan River, very few sub-adults were captured upstream from Bicton (Figs 4.19, 4.20). Sub-adult numbers increased in seines at the lower sites in April, but were again largely absent at upstream sites. Consequently, only the 4 sites downstream from Claremont were sampled when further seining was undertaken in the SCE in May 2014, to provide a comparison with various styles of traps and mesh size trialled in the SCE to determine if trapping was a suitable alternative method for sampling sub-adult crabs in GB. A substantial increase in the numbers of sub-adults was evident in seines during the May survey in the three sites downstream from Bicton (Figs 4.19, 4.20).

The substantial increase in sub-adult numbers in seines in the lower reaches of the SCE between March and May 2014 suggested a temporal influence, with March being too early in the season for sub-adults to be recruiting to the fishery. Therefore, sampling in 2015 did not commence until April. Furthermore, seining was restricted to the three sites downstream from Bicton that had produced reasonable quantities of sub-adults in 2014. However, very few crabs were captured at any of these sites in April or May 2015 (Fig. 4.20). Despite testing any temporal influence by extending sampling into June and July, there was still a lack of crabs captures in seines at any site. Consequently, it was determined that beach seining was not a suitable method for sampling sub-adult crabs to develop an index of the strength of recruitment to the SCE crab stock.

While sub-adult crabs were scarce in the near-shore shallows during 2015, divers registered with the SWRCP logbook program reported seeing large numbers of sub-adult crabs in waters deeper than 6 m in the lower reaches of the SCE. This information corresponded with preliminary results from a trawl survey targeting the western school prawn, *Metapenaeus dalli*, being conducted in the SCE by Murdoch University. Therefore, demersal otter trawling was trialled as a method for sample sub-adult crabs in the SCE during 2016, with initial surveys proving highly successful. Sub-adult crabs were present in all trawls during both March and April, with particularly high numbers captured on the shallow banks (≤4m) in North Fremantle and on Karrakatta Bank (≤2m) near Claremont (Figs 4.19, 4.208).

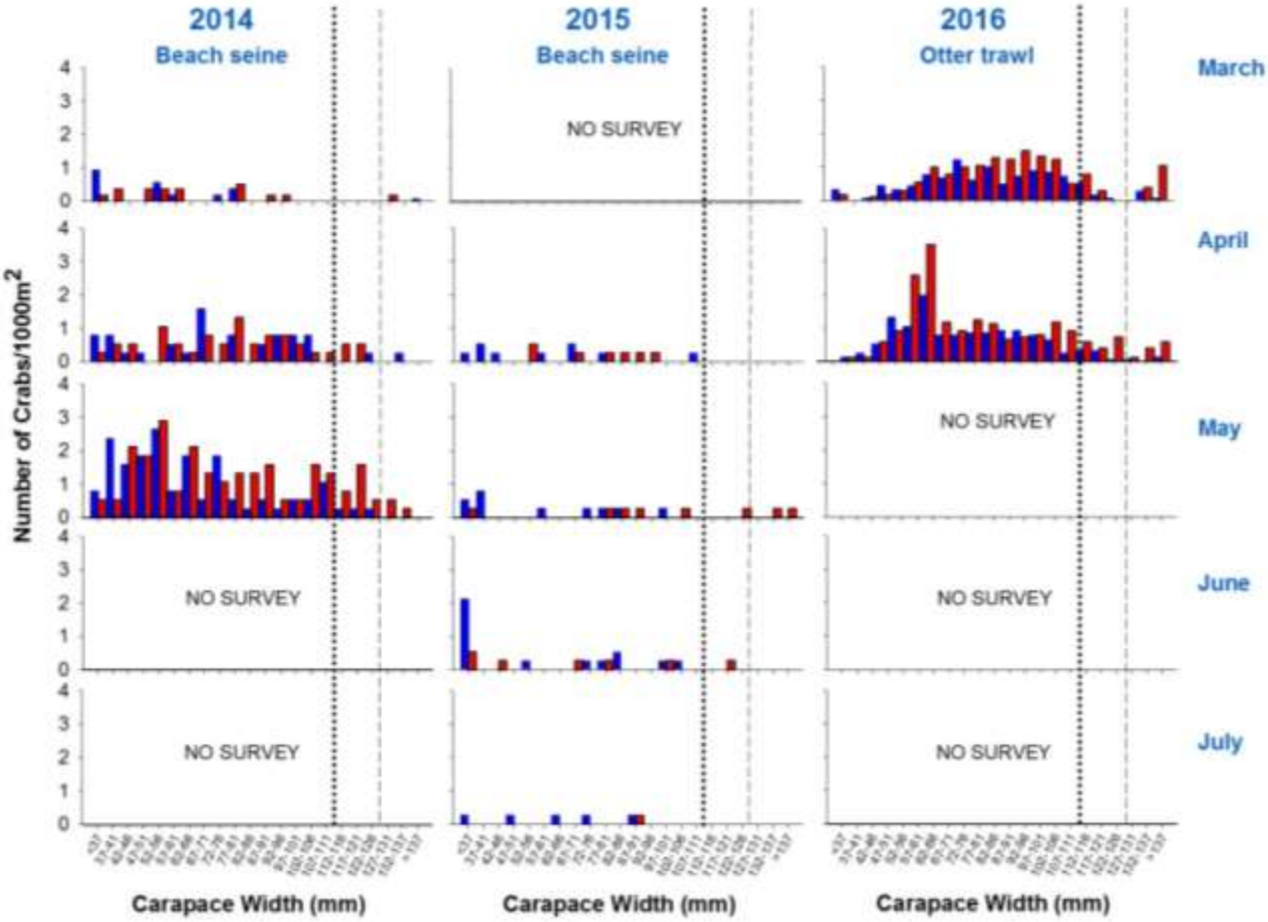


Figure 4.19. Monthly length frequency distributions of male (█) and female (█) blue swimmer crabs captured by either beach seine (2014 and 2015) or otter trawl (2016) during recruitment surveys in the Swan-Canning Estuary. ---- recreational size limit (127 mm CW); ······ recruit cutoff (110 mm CW).

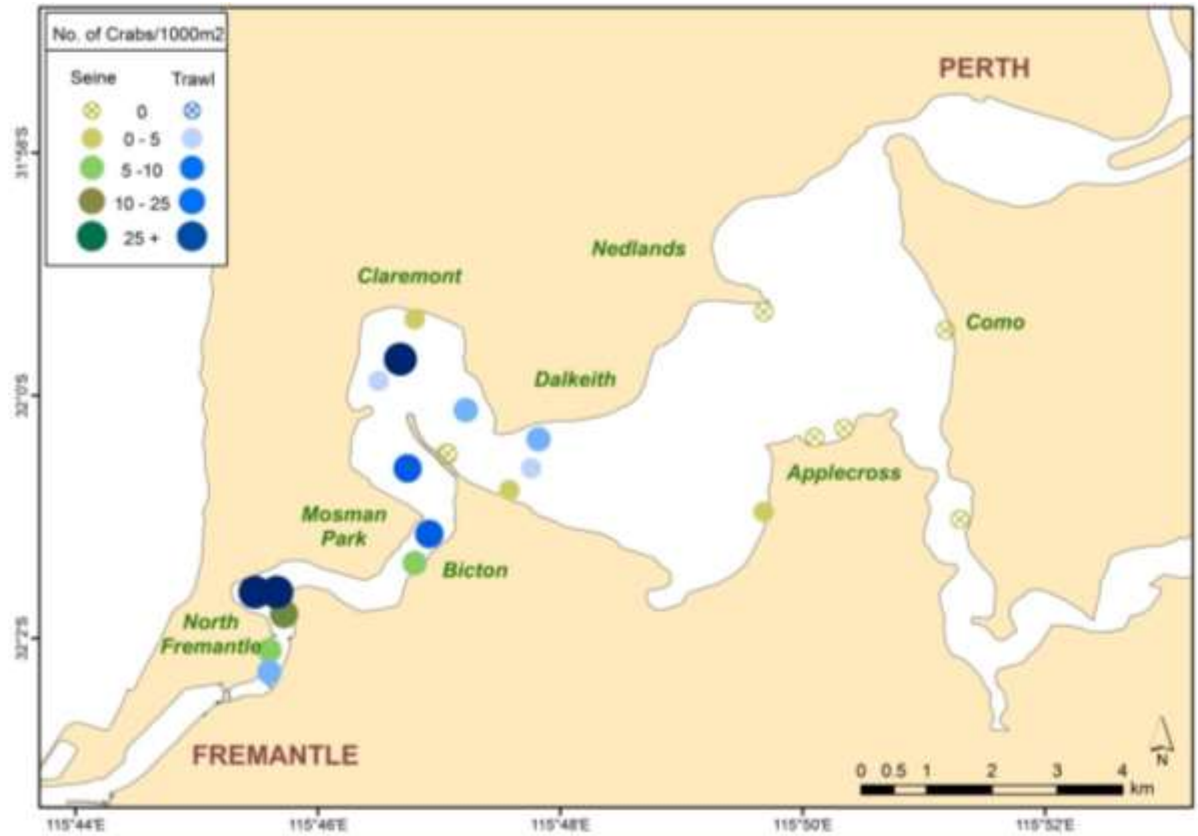


Figure 4.20. Mean annual catch rates showing the spatial distribution of sub-adult (<=110 mm CW) blue swimmer crabs sampled by beach seine (green circles) and otter trawl (blue circles) in SCE during the months of March and April between 2013 and 2015.

Leschenault Estuary and wider Bunbury area

Male and female sub-adult (≤110 mm CW) blue swimmer crabs were captured during all surveys conducted using the 21.5m beach seine in the LE between 2014 and 2016 (Fig. 4.21). A single cohort of sub-adults with a mean carapace width of around 100 mm CW was evident in the sample from March 2014, with a small number of crabs captured in the 30-70 mm CW range (Fig. 4.21). In contrast, two distinct cohorts could be distinguished in the length frequency distribution from the pooled April sample; a cohort of equal numbers of male and female sub-adult crabs with a mean carapace width of ~70mm and a separate cohort of predominantly female crabs with a mean of around 110 mm CW (Fig. 4.21).

The March 2015 survey was affected by adverse weather, with extreme high tides impacting on all seined sites and rendering the Australind Boat Ramp site inaccessible. A similar distribution was evident in the April 2015 sample as the previous year, with a cohort of similar numbers of male and female sub-adult crabs with a mean carapace width of ~60-70mm and a separate cohort of predominantly female crabs with a mean of around 100 mm CW (Fig. 4.21). As the March survey was weather-affected, a third recruitment was conducted for 2015 in May. The cohort of smaller animals was again evident, with a slight increase in mean carapace width to around 75mm. However, there was little evidence of the second cohort with the larger carapace width.

A cohort of equal numbers of male and female sub-adult crabs with a mean carapace width of ~70 mm was evident in the March 2016 distribution. A second male cohort with a mean of ~95 mm CW and female cohort with a mean of ~115mm CW could also be distinguished (Fig. 4.21). As with the previous two years, a cohort of smaller crabs (50-90 mm CW) was captured during seining in April 2016.

Highest catch rates of sub-adult crabs were caught in the fringing waters 300 m north of the Australind Boat Ramp, with a mean catch rate over the three years of the SWRCP of 80.2 sub-adult crabs/1000m^2 seined (SE: 8.5 crabs/1000m^2 seined) (Fig. 4.22). The next most abundant site was Casuarina Harbour (54.2 crabs/1000m^2 seined; SE: 8.5), followed by Pelican Point and Balmoral sites which had similar mean catch rates of 22.4 (SE: 5.1) and 20.9 (SE: 16.8) sub-adult crabs/1000m^2 seined, respectively (Fig. 4.22).

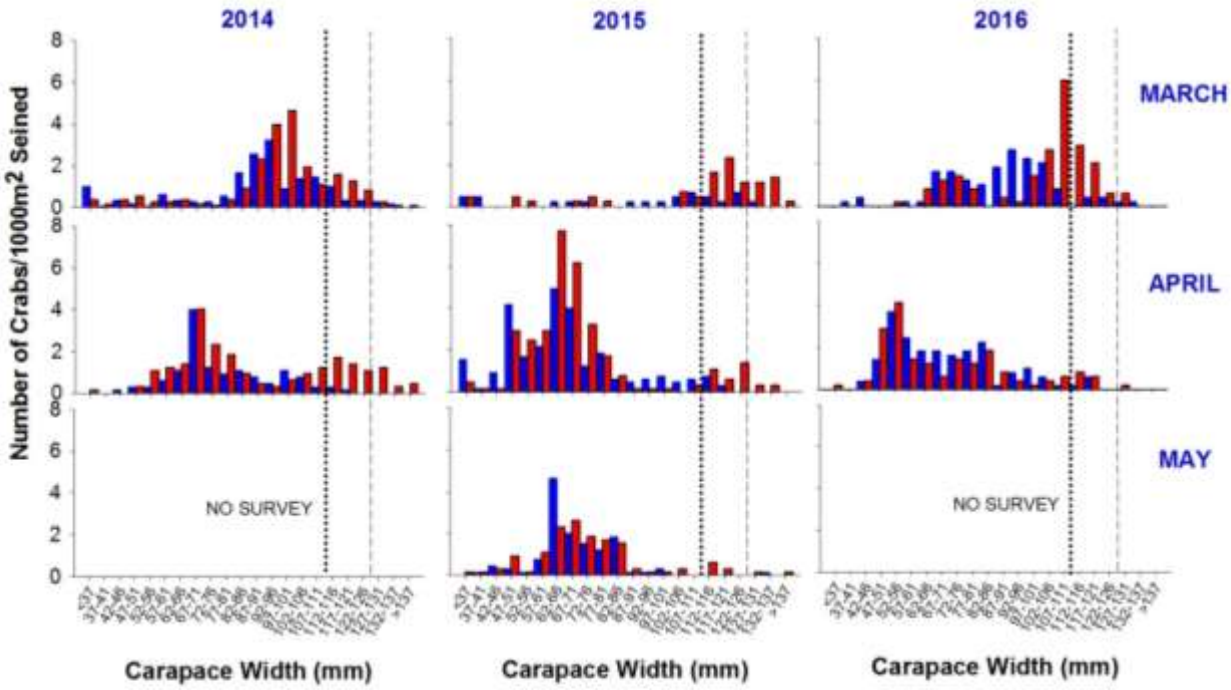


Figure 4.21. Monthly length frequency distributions of male (■) and female (■) blue swimmer crabs captured by 21.5m beach seine during recruitment surveys in the Leschenault Estuary and wider Bunbury area. ---- recreational size limit (127 mm CW); ⋯⋯ recruit cutoff (110 mm CW).

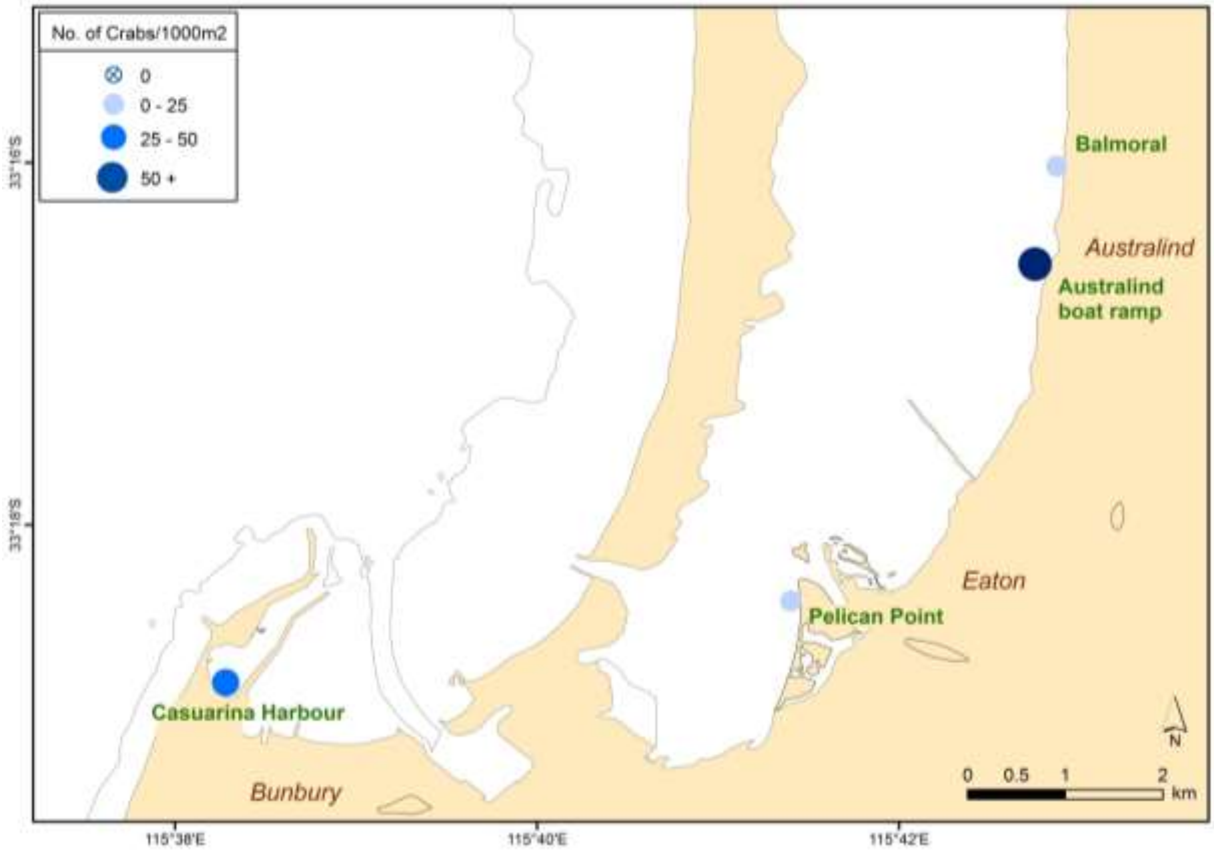


Figure 4.22. Mean annual catch rates of sub-adult (<=110 mm CW) blue swimmer crabs sampled by beach seine at 4 sites in LE during the months of March and April between 2013 and 2015.

Geographe Bay

Three different methods; a 21.5m beach seine, small mesh research hourglass traps and a demersal otter trawl; were trialled for sampling sub-adult blue swimmer crabs in GB over the three years of the SWRCP, with all three methods proving unsuccessful (Fig. 4.23).

Dragging a 21.5 m beach seine through the shallow (≤1.5m) waters fringing GB was the preferred method for sampling sub-adults in this fishery, and was trialled in March and April 2014. However, very few blue swimmer crabs were captured in the seines during both surveys (Fig. 4.23).

Through consultation with former commercial crabbers in the fishery, SWRCP logbook participants from GB, and local DoF regional staff, it was suggested that the near-shore seagrass beds and inland waterways of GB might present potential nursery areas for sub-adult crabs. As neither of these habitats could be sampled with a seine net, small mesh research hourglass traps were trialled during 2015 recruitment surveys in these areas. However, although more crabs were captured in the traps than with the beach seine, there were very few sub-adults in the sample. The surveys were extended by two months to include May and June to examine whether crabs had yet to reach a size where they recruit to the fishery. But despite more mature females appearing in the traps, there were still very few sub-adult crabs (Fig. 4.23).

Given the selectivity of traps against catching sub-adult crabs, demersal otter trawling was trialled during 2016 surveys having proved successful in the SCE. However, very few crabs, and almost no sub-adults, were captured in the either of the trawl surveys in March and April of this year (Fig. 4.23).

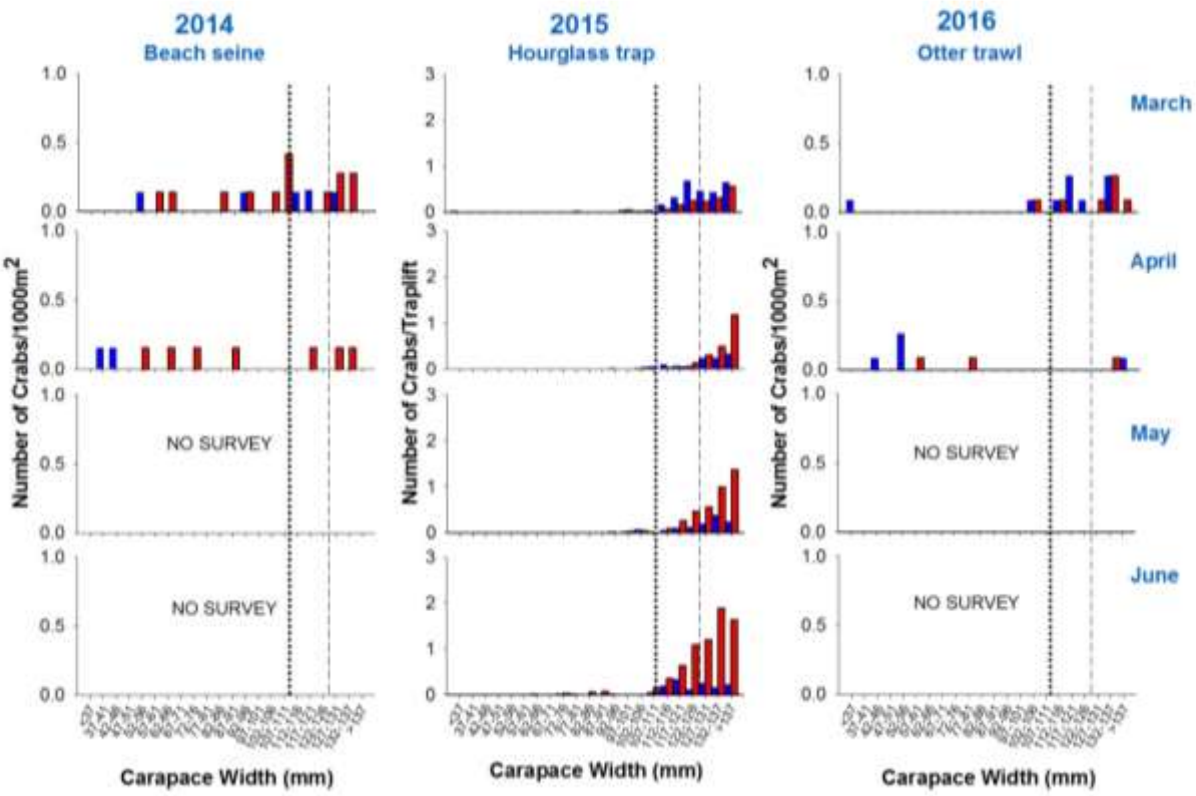


Figure 4.23. Monthly length frequency distributions of male (■) and female (■) blue swimmer crabs captured by either beach seine (2014), research hourglass traps (2015) or otter trawl (2016) during recruitment surveys in Geographe Bay. ---- recreational size limit (127 mm CW); ⋯⋯ recruit cutoff (110 mm CW).

4.3.3 SWRCP fisher participation in sampling surveys

SWRCP Recreational fishers were keen to contribute to the fishery independent survey work undertaken in the SCE, LE and GB, with a total of 26 fishers joining DoF researchers during the recruitment and breeding stock surveys over the three years of the project (Figs 4.24, 4.25).

Figure 4.24. DoF research staff and SWRCP fishers undertaking juvenile recruitment sampling at Pelican Point in the Leschenault Estuary during the South West Recreational Crabbing Project.

Figure 4.25. DoF research staff and SWRCP fishers undertaking breeding stock surveys during the South West Recreational Crabbing Project.

4.4 Discussion

Breeding stock surveys

The deployment of small mesh (2”) hourglass traps was found to be an effective method for the ongoing assessment of blue swimmer crab breeding stocks in each of the three fisheries surveyed during the SWRCP. Significant quantities of sexually mature and berried female crabs were captured in surveys during all months and years sampled in the SCE, LE and GB. This indicates that this method can provide a reliable index of breeding stock potential that can inform a future harvest strategy, as has been the case in the other southwest Western Australian crab fisheries of Cockburn Sound and the Peel-Harvey Estuary (Johnston *et al.*, 2011; Johnston *et al.*, 2014).

The selectivity of crab traps has been well documented. Bellchambers and de Lestang (2005) concluded that hourglass crab traps tend to select against sub-adult and female crabs, as blue swimmer crabs have a size-dependent social hierarchy with larger males tending to dominate. Therefore, they recommended either beach seining or otter trawling as preferred methods for sampling blue swimmer crab stocks. However, this behavioural influence is less likely to be a factor during October and November in southwest Western Australian crab fisheries, as stocks of large male crabs have been depleted due to the fishing pressure of the previous summer and autumn (Figs 3.13, 4.10). Furthermore, neither beach seining nor otter trawling were suitable methods for sampling sexually mature female crabs in each of the fisheries covered by this project. Sexually mature female crabs in southwest Western Australian fisheries tend to inhabit deeper waters (≥5m) at this time of year, influenced by water temperature and salinity levels. Consequently, beach seining is unsuitable as it cannot be used at such depths. While trawling was possible in the SCE, it was considered problematic in the LE and GB. Both Department of Fisheries, Western Australia (DoF) personnel and commercial and recreational crab fishers advised against trawling in Bunbury Harbour (the marine embayment outside the Leschenault Estuary and habitat for sexually mature female crabs in this fishery), due to limited areas suitable for trawling in this location which would compromise the spatial integrity of the sampling design. Furthermore, previous trawling conducted by Bellchambers *et al*. (2006b) in GB over winter and spring proved unsuccessful, as the high energy nature of this marine environment during this period means that the bay is subject to large amounts of benthic drift weed that makes trawling unviable.

Trap mesh size has also been found to have a significant effect on the catch rate of legal and sub-legal crabs. Guillory and Prejean (1997) reported that there was an inverse relationship between mesh size and the retention of sub-adult crabs, with increased mesh size leading to higher catches of adult crabs but lower catches of sub-adult crabs. Consequently, 2” mesh was used to cover the traps in this study which resulted in the retention of more sub-adult crabs and so sampled a wider distribution of the crab stock than would have been captured using traps with commercial size mesh (3½-4” mesh).

Therefore, we have concluded that while small mesh hourglass traps may have some bias in selecting against juvenile blue swimmer crabs, as well as female crabs during the summer months, they provide for an acceptable measure of breeding stock abundance during the peak spawning period in each of the three fisheries covered by this study.

Mean annual catch rates of sexually mature female crabs in the SCE were consistent across the three years of sampling, while a slight decline was evident in the mean annual catch rate of sexually mature female crabs in the LE. However, this variation was not statistically significant. In contrast, a notable decline was experienced in mean annual catch rates of sexually mature females in GB with the reduction in catch rates between 2013 and 2015 of statistical significance. However, given the relatively short three-year time series of the data, it is not possible to determine if this represents a declining trend in the crab stocks in this fishery, or more a return to normal levels of stock abundance after a higher than average catch rate in 2013. Anecdotal evidence from registered diarists and DoF personnel suggests that the 2013/14 recreational crabbing season in GB was one of the most successful in the previous decade, lending weight to the argument that crab stock levels may have subsequently returned to more normal levels. There was a statistically significant reduction in catch rates of sexually mature female crabs from October to November each year in GB, most likely in response to fishing pressure as the spring months represent the peak crabbing period in this fishery.

The optimal measurement of a spawning stock is the numbers of eggs spawned, preferably estimated from the average fecundity at age/size and the proportion of each age/size (Haddon, 2011). Sexually mature female crabs captured in the SCE were consistently larger in size than crabs sampled in either the LE or GB, and in any of the southwest Western Australian crab fisheries where DoF conducts monitoring programs. Blue swimmer crab fecundity is proportionate to size, with larger animals producing more eggs per batch and more batches per spawning season (de Lestang *et al.*, 2003a). So while the mean annual catch rates of sexually mature female crabs were higher in the LE and GB than in the SCE, the breeding potential of the respective stocks was more comparable. The consistently larger size of crabs captured during breeding stock surveys in SCE than encountered in other southwest Western Australian fisheries was mirrored in commercial catches (refer to Chapter 3 discussion for description).

The catch rate of sexually mature female crabs provides a relative index of the size of the potential breeding stock, and the catch rate of the numbers of eggs per trap the spawning potential of that stock. However, to be of value both of these parameters assumes that crabs will spawn according to their normal spawning cycles in terms of egg batch frequency and fecundity. The proportion of ovigerous female crabs in samples from breeding stock surveys can provide important information to assess this assumption. The proportion of berried females in samples from SWRCP breeding stock surveys were within expected ranges in all three fisheries sampled. The proportion in the SCE was consistent over the three years, and while they were more varied in the LE and GB, they were still within expected ranges for southwest Western Australian crab fisheries.

Highest numbers of sexually mature female crabs in the SCE were consistently encountered in the lower reaches of the Swan River, downstream from Bicton. Prior to this project, the blue swimmer crab stock in the SCE was assumed to function like other estuarine systems in southwest Western Australia, with all crabs flushed out of the estuary by winter rains that led to declining salinities as in the Peel-Harvey Estuary (Johnston *et al.*, 2014) and the Leschenault Estuary (Potter and de Lestang, 2000). This synopsis was supported by commercial catches in the estuary, with the majority of catches occurring over the summer months before catch rates declined into winter and fishing ceased as predominantly occurs with commercial fishing effort in the Peel-Harvey Estuary (Johnston *et al.*, 2014). Consequently, Smith (2006) had concluded that the main source of recruitment to SCE was the breeding stock in the nearshore marine embayment of Cockburn Sound. The tagging component of the SWRCP demonstrated that sexually mature females do leave the estuary for nearshore marine waters, with several mature female crabs tagged in the SCE being recaptured in Owen Anchorage and Cockburn Sound. However while it is clear that some of the breeding stock leaves the estuary, a significant portion remains in these lower reaches of the Swan River. Weekly water quality data from the Department of Water demonstrated that benthic salinity levels in the middle and upper reaches of the Swan and Canning Rivers fell below 20 ppt (refer to Figure 5.26 in Chapter 5) during the winter months and into spring which is below levels preferred by blue swimmer crabs (Rome *et al.*, 2005; Romano and Zeng, 2006). However, while the surface salinity levels in the lower reaches of the Swan

River also dropped below these levels during this period, the deeper waters (≥10m) in this stretch results in haloclines as far upstream as Point Resolution. This stratification of fresh water over the heavier salt water maintains marine salinity levels (30-35 ppt) in the lower depths where crabs tend to reside and so provides suitable conditions for crabs to remain in these lower reaches all year round. Given reasonably high proportions of berried females in October and November trap catches, it is clear that this stock contributes to recruitment within the Estuary. This hypothesis is further supported by the spatial abundance of juvenile crabs (≤110 mm CW) sampled during the SWRCP. The greatest abundance of this size class was caught by both seine and trawl in waters downstream from Point Resolution. As this spatial pattern closely matches the spatial abundance of berried females, it is reasonable to conclude that the breeding stock in this area contributes to the juvenile recruitment in this fishery.

In contrast with the SCE, the spatial distribution of sexually mature and berried females in the LE reflected the almost complete flushing of crab stocks out of the shallow (≤3m depth) Leschenault Estuary into the surrounding marine waters as winter rains lowered salinity levels to below that tolerated by blue swimmer crabs within the estuary. Consequently, very few sexually mature female crabs were captured in the sites within the Estuary compared to those in the permanently marine waters of Koombana Bay and Bunbury Harbour. This trend is consistent with a study undertaken by Potter and de Lestang (2000) between 1996 and 1998, which observed the highest numbers of ovigerous females to be in this area and that it represented the primary spawning grounds. Highest catch rates of sexually mature female crabs in the LE were encountered at the two breeding stock sites between the seaward end of the shipping channel into Bunbury Port and the outer Bunbury Harbour breakwater (Fig. 4.15). This spatial abundance is consistent with anecdotal evidence from the LE diarists registered with the logbook program. The reasons for the high catches in this region are not readily apparent from the data collected during this project, but most likely are a result of food availability and favourable benthic habitat.

Catch rates of sexually mature female crabs were relatively consistent across the 15 breeding stock sites sampled in GB compared with the SCE and LE. This is most likely because GB is an open embayment and subject to minimal rainfall runoff during the winter months, so salinity levels remain relatively consistent throughout the bay all year round. While catch rates were comparatively consistent across breeding stock sites, numbers of sexually mature female crabs were highest towards the eastern end of the bay, at sites east of Busselton Jetty. While the limited temporal and spatial scale of the surveys prevented conclusions to be drawn, a hypothesis popular with GB diarists in the logbook program was that crabs migrate eastwards along the coast towards Bunbury. This hypothesis is supported by the movement of a 127mm CW male crab that was tagged at Broadwater in October 2014 as part of the SWRCP tagging program, and was recaptured 10 weeks later off Peppermint Grove Beach, 30km around the coast towards Bunbury.

Recruitment surveys

Beach seining was found to be an effective method for the ongoing assessment of blue swimmer crab recruitment in the LE. Significant quantities of sub-adult male and female crabs were captured in recruitment surveys during all months and years, indicating that this method can provide a reliable index of the strength of recruitment in this fishery. Equal numbers of male and female crabs were represented in recruitment survey samples of sub-adult cohorts, whereas female crabs tended to dominate the adult cohorts. Of interest were the consistent changes in mean cohort size between months in the LE, most noticeably at the sites within the Leschenault Estuary. The primary cohort in the samples from March surveys tended to range from 80-110 mm CW. It is possible that this cohort contains the earliest recruits from the most recent spawning season, combined with later recruits from the spawning season before that. However, the main cohort in the April/May samples tended to be in the 50-90 mm CW range, suggesting they were spawned during the most recent spawning season. This implies that more than one pulse of juvenile crabs recruits into this fishery over the summer and autumn months, with recruiting cohorts migrating through the estuary and possibly into the outside marine environment.

However, while beach seining was found to be an effective method for the ongoing assessment of blue swimmer crab recruitment in the LE, this was not the case in either the SCE or GB. Despite sampling near-shore waters extensively in the SCE as far up stream as the Como foreshore in the Swan River and Gentilli Way boat ramp in the Canning River during the 2014 recruitment surveys, sub-adult crabs were only caught at three sites (Bicton, Zephyrs and Gilbert Fraser Reserve) in the very lower reaches of the Swan River. Furthermore, significant quantities of sub-adults didn't appear in seining samples until the May survey in that year. Consequently, recruitment seining was restricted to these three sites in 2015 but very few sub-adult crabs were caught despite sampling continuing through until July of that year. Otter trawling was trialled in the SCE during 2016 and was considerably more successful, with quantities of sub-adult crabs captured during all surveys in both March and April. As with the beach seining, highest abundances of sub-adult crabs tended to be captured in trawls downstream from Point Resolution. Particularly high catch rates were recorded in the shallow (≤4 m) waters on the bank in the middle of Rocky Bay and around the Swan Yacht Club in North Fremantle, and Karrakatta Bank in Freshwater Bay. Moreover, catch rates from the North Fremantle sites represented some of the highest historical densities of sub-adult crabs recorded by the Crab Research section in any of the southwest Western Australian crab fisheries where juvenile trawl programs have been conducted. Therefore, otter trawling is considered the most appropriate method for sampling the strength of sub-adult abundance in the SCE and will be the preferred method for future recruitment surveys in this fishery.

Despite Geographe Bay being fringed by sandy beach along most of its shoreline, there were very few locations around the bay that were suitable for seining using the method employed in this project. Furthermore, the high energy nature of the Naturaliste-Leeuwin coast meant that the shoreline of the bay was subject to considerable erosion and sand movement at various times of the year. Four sites were identified that were accessible and offered a sufficient stretch of sand to accommodate three 30 m seines. However, very few sub-adult crabs were captured during seining surveys in 2014 and it was clear that the limited area available to seine would not produce a viable index of recruitment. Although hourglass crab traps tend to select against juvenile and sub-adult crabs, small (2") mesh traps were trialled in GB as an alternative to beach seining in 2015 as they retain more sub-adult crabs than commercial mesh size. Furthermore, they provided the opportunity to sample some of the inland waterways around GB that could have proved to be nursery areas for blue swimmer crabs in this fishery, such as Toby's Inlet, the Buayanyup Drain, the Port Geographe Marina, and the Wonnerup Estuary (Fig. 4.10). However, while the traps caught reasonable quantities of mature crabs there were very few sub-adult crabs present in the trap samples. Consequently, otter trawling was trialled as a potential method during recruitment surveys in 2016, but again very few sub-adult crabs were present in the trawl samples. Furthermore, the net was often fouled by benthic drift weed rendering most trawls inoperable. Additional research will need to go into determining the locations of nursey areas for blue swimmer crab stocks in GB, and appropriate methods for sampling these areas.

Future surveys

This project has developed suitable and cost-effective methods for the ongoing assessment of blue swimmer crab breeding stocks in the SCE, LE and GB, and the strength of recruitment in the SCE and LE. However, the three-year time series generated by this study is not currently sufficient to determine the trends exhibited in the data. Therefore, DoF intends to continue the breeding stock surveys on an annual basis to compile the long term datasets that will inform harvest strategies for monitoring these fisheries into the future. The breeding stock surveys have identified the most appropriate locations to sample sexually mature females in each fishery, allowing for the surveys to be refined from 15 sites in each fishery to 10 sites in the SCE and 8 sites in both the LE and GB. This introduces further cost efficiencies as the SCE survey can be undertaken by two researchers rather than three, while the LE and GB surveys can be completed together in two days rather than three days. The recruitment trawl surveys in the SCE will also be maintained due to its close proximity to Perth resulting in minimal cost.

5 Tagging surveys

D. Harris, D. Johnston, J. Baker and S. de Lestang

Objective: Determine the effectiveness of tagging methods to provide information on the movement of blue swimmer crabs that occurs within and between the Swan-Canning Estuary, the Leschenault Estuary and wider Bunbury area, and Geographe Bay, and their adjacent marine environments.

5.1 Introduction

Capture-mark-recapture techniques are useful for obtaining information on fish migration and movements, as well as the dynamics of an exploited fish population such as abundance, survival, reproduction, and recruitment (Thorsteinsson, 2002, González-Vincente *et al.*, 2012). Most fish species are comparatively easy to tag over much of their life history, given the nature of their longitudinal growth. Likewise, many invertebrates, such as the western rock lobster, *Panulirus cygnus*, can be effectively marked for long-term tag retention as they have large areas of exposed muscle tissue where T-bar tags can be inserted that will allow the animal to moult while retaining the tag. Furthermore, there are some crab species that offer opportunities for tagging over the longer term, such as the crystal crab, *Chaceon albus*. This species has particularly wide carapace suture lines, so a T-bar tag can be inserted into the muscle between the suture line and will remain attached when the carapace splits as the animal moults (Melville-Smith *et al.*, 2007).

The long term marking of blue swimmer crabs represents a significantly more difficult challenge as they moult their entire carapace leaving nothing on which to anchor a tag. They have particularly tight suture lines so the insertion of a conventional T-bar tag runs the risk of disrupting vital organs. Several studies have attempted to mark blue swimmer crabs using T-bar tags with variable success (Potter *et al*., 1991; Potter *et al*., 2001; McPherson, 2002). However, McPherson produced the most promising results using a modified T-bar tag with an extended barrel and shortened filament such that a few millimetres of the barrel resided in the animal. In addition, Bellchambers and de Lestang (*pers. comm.*) trialled cryogenic marking using liquefied nitrogen to scar the carapace of *P. armatus* so that the mark was apparent on the animal's new carapace after ecdysis. However, the technique was not considered successful as the application process proved cumbersome, the post-moult mark tended to be indistinct and it was difficult to label large numbers of crabs individually.

As a consequence, crab researchers have employed a variety of temporary tagging techniques when undertaking mark and recapture surveys. Examples of these include glue-on tags attached to the dorsal carapace of *P. armatus* (Bellchambers *et al*., 2005), vinyl tags attached by constrictor knot to the rear appendage of the male Dungeness crab, *Metacarcinus magister* (Hildenbrand *et al.*, 2011), strap tags across the back and lateral spines of the blue crab, *Callinectes sapidus* (Fischler and Walburg, 1962; Turner *et al.*, 2003; Lambert *et al.*, 2006), epoxy-resin based paint on the dorsal carapace of the edible crab, *Cancer pagarus* (Bell *et al.*, 2003) and using button tags on horseshoe crabs, *Limulus Polyphemus* (Smith *et al.*, 2006). However, these temporary techniques present limitations on the type of data that can be collected. For example, it is not possible to collect information on growth, while information collected on movement is limited to one inter-moult period in a crab's life.

Technological advances have delivered a suite of new tagging methods that provide potential opportunities for the long term tagging of *P. armatus*, including coded wire tags, Passive Integrated Transponder (PIT) tags and microtags. These tools tend to be biologically inert, have minimal impact on growth or movement and are subject to very low rates of tag loss and infection (McMahon *et al.*, 2011; Smyth and Nebel, 2013). However, these types of tags are identified in recaptured animals by means of radio frequency induction, metal detectors or magnetic devices. Consequently, they are not suitable for field surveys where recreational fishers are expected to account for the majority of tag recaptures.

Marking with compounds that leave chemical signatures, such as Alizarin, Oxytetracycline, Calcein and Visable Implant Elastomer, is also becoming increasingly popular for tagging animals over an extended period of their lifecycle. These techniques are relatively inexpensive and easy to apply, while offering high tag retention and visibility, and minimal effects on growth and survival (Simon, 2007; Zhu *et al.*, 2015). However, they usually function by leaving internal signatures in ossicles or other body parts that require dissection of the animal, which again makes these techniques unsuitable for studies reliant on recaptures by recreational or commercial fishers. Furthermore, it would not be possible to individually mark sufficient quantities of crabs to ascertain fine scale movement, nor growth parameters.

The primary objective of this component of the Southwest Recreational Crabbing Project (SWRCP) was to determine the effectiveness of tagging methods in providing information on the movement of blue swimmer crabs within the SCE, LE and GB and their adjacent marine environments. A field survey using short-term glue-on tags was initially undertaken to assess the suitability of these fisheries for mark and recapture studies. While the survey was successful, the limitations of the glue-on tag were apparent as recaptures ceased to be reported after the tag was lost over the peak moulting period. Investigations were then undertaken to develop a longer-term technique for marking blue swimmer crabs. Following a comprehensive literature review, it was determined to persist with and further develop the Hallprint TBF-1 fine anchor T-bar tag used by McPherson (2002) as no other suitable alternative was apparent. Two aquarium trials examined the retention rate of the T-bar tag across a moult without adversely impacting the animal, while a second field survey in the SCE was conducted to determine the effectiveness of the tag in providing information on the movement of blue swimmer crabs within the estuary.

The main objective has been split into three sub-objectives:

Objective 1: Examine the suitability of the FloyTag polyvinyl glue-on tag (GT) as a short-term marker to investigate movement of *P. armatus* within the SCE, LE and GB and their adjacent marine environments.

Objective 2: To test whether a T-bar tag (Hallprint TBF-1 fine anchor T-bar tag (ST) and Hallprint TBF-1 Micro fine anchor T-bar tag (MT)) could be retained by *P. armatus* during a moult without adversely impacting the animal.

Objective 3: Examine the suitability of the MT as a long-term marker to investigate movement of *P. armatus* within the SCE.

5.2 Methods

5.2.1 First field survey: short-term marker (GT)

Survey regime

Monthly tagging surveys in the SCE, Owen Anchorage (OA) and Cockburn Sound (CS) were conducted between September and December 2014, with SCE sites replicating the breeding stock survey sites. Opportunistic tagging also took place during the November 2014 breeding stock surveys in the LE and GB.

The sampling methodology employed during SWRCP breeding stock surveys was replicated during the tagging surveys, with three research hourglass traps deployed for a 24-hour soak time at 15 sites within each study area (Figs 5.1, 5.2 and 5.3). Traps set at sites in the SCE, OA and LE that were likely to be affected by tidal and/or swell movement were weighted with 3 kg lengths of chain.

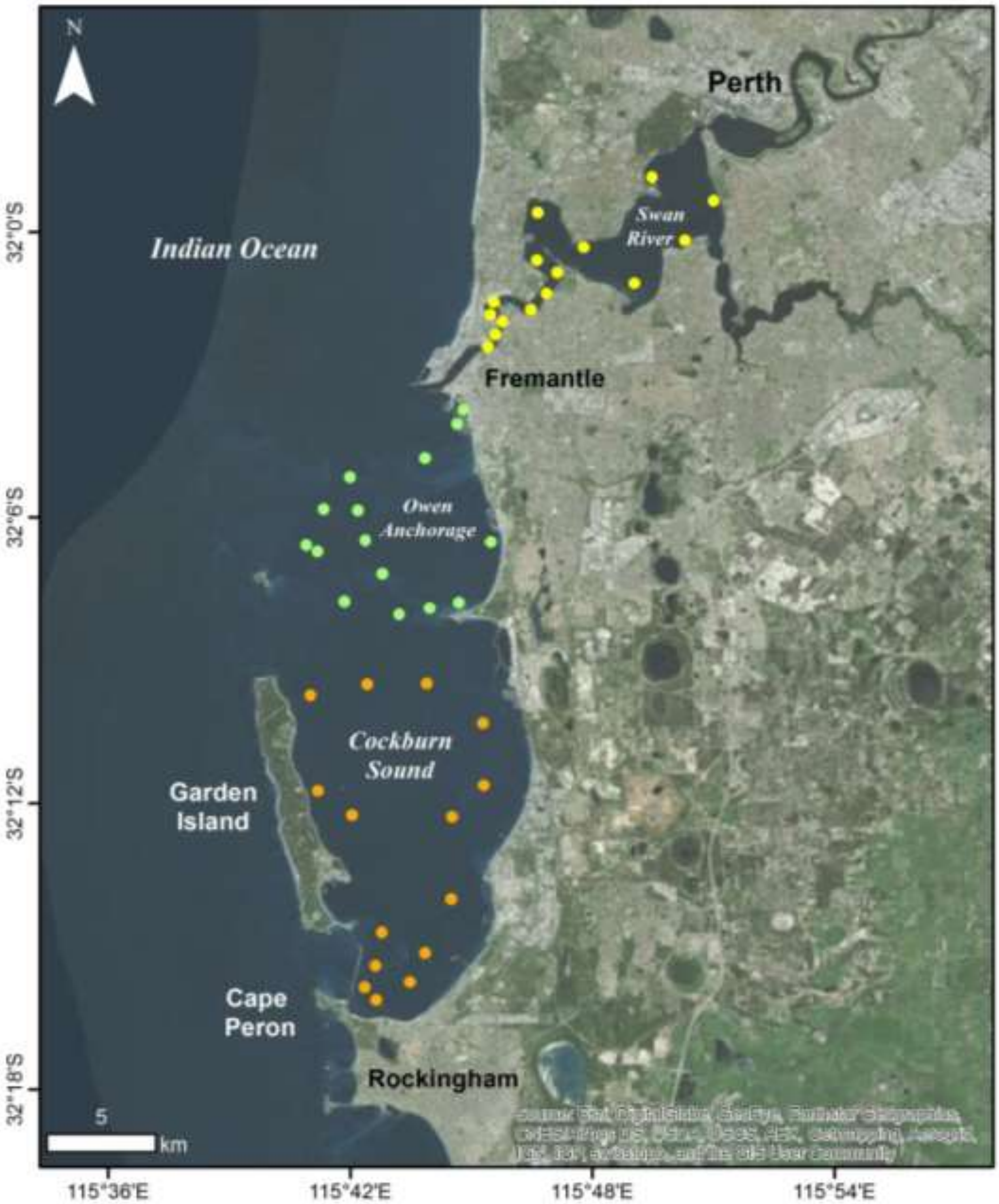


Fig 5.1. Tagging sites sampled in the Swan-Canning Estuary (●), Owen Anchorage (●) and Cockburn Sound (●) during the first field survey between September and December 2014.

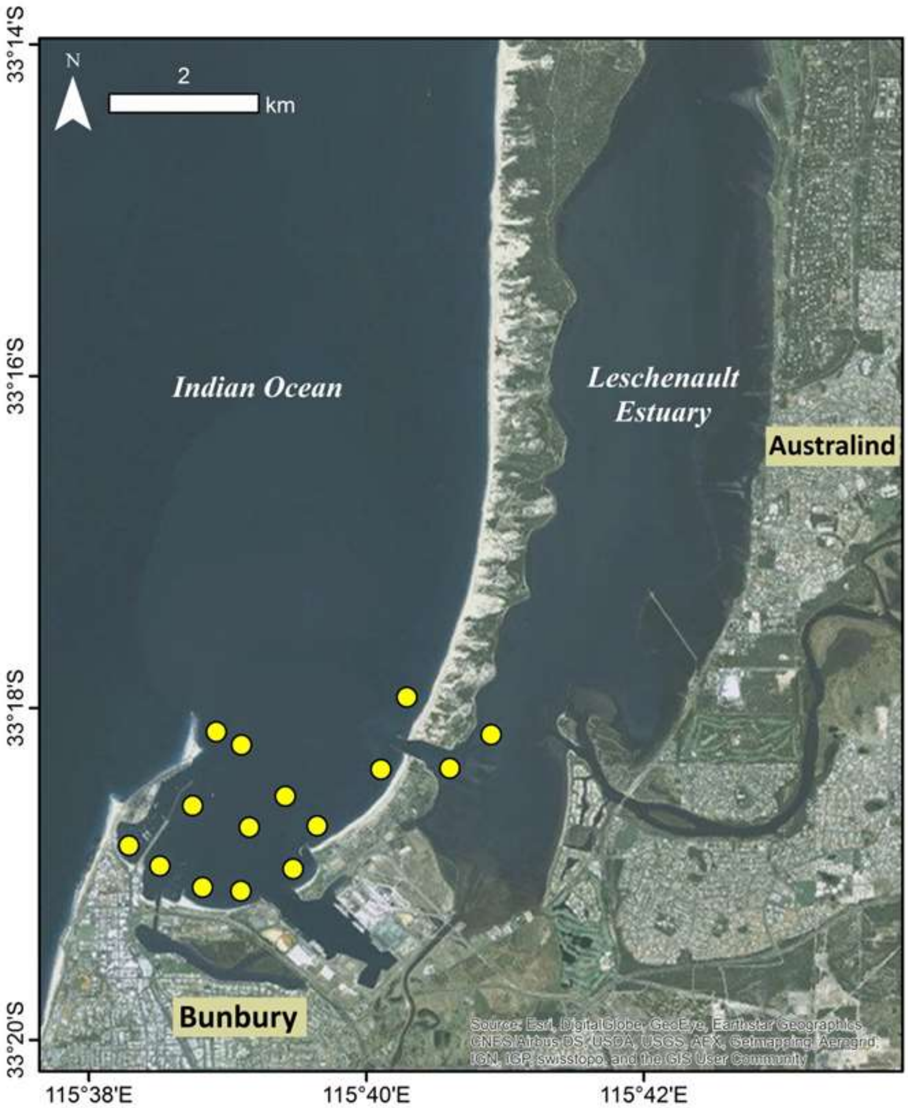


Fig 5.2. Tagging sites sampled in the Leschenault Estuary and Wider Bunbury area ( ) during the first field survey in October and November 2014.

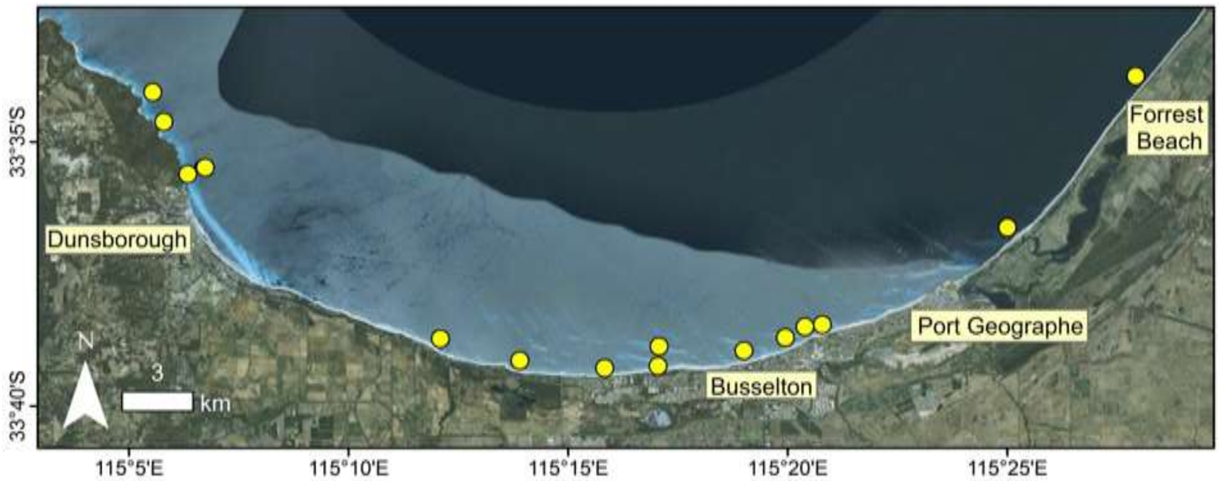


Fig 5.3. Tagging sites sampled in Geographe Bay) during the first field survey in October and November 2014.

Tagging

Upon retrieval of the traps, crabs were emptied into an ice slurry for 30 seconds. FloyTag polyvinyl glue-on tags (FloyTag Inc. Seattle, United States) were adhered to the dorsal carapace of each crab using Loctite 454 Prism Gel instant adhesive and left to cure for approximately 20 seconds (Fig. 5.4a). The rounded-rectangle tags were yellow in colour and measured 45 x 7 mm, with a 1 mm perforation hole on the left side to aid adhesion (Fig. 5.4b). Each tag was inscribed with a unique tag number, departmental identification and contact information and notification of a reward. The unique tag number from each tag was recorded along with CW, sex, state of maturity and shell condition before returning the animal to the water.

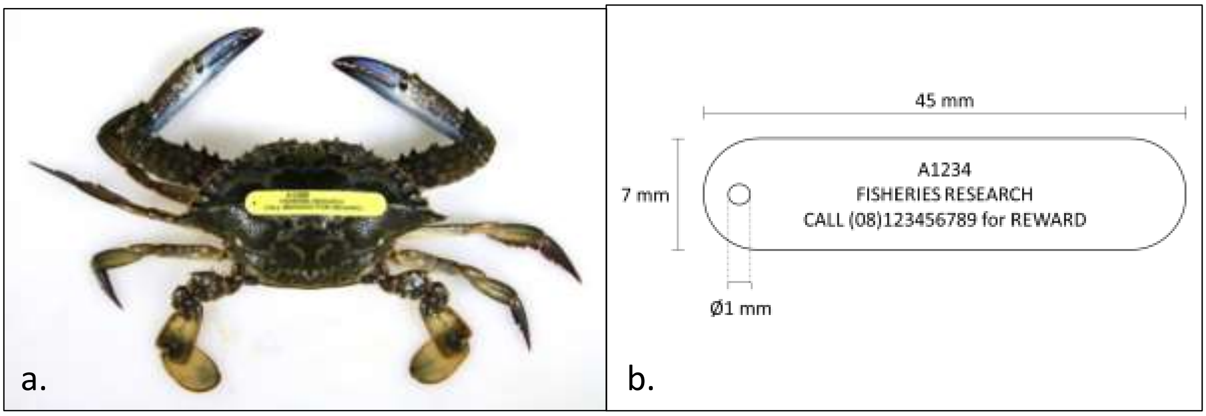


Fig 5.4. (a) A FloyTag polyvinyl glue-on tag attached to the dorsal carapace of a female *P. armatus*; (b) a diagrammatic representation of the FloyTag polyvinyl glue-on tag used during the glue-on tagging survey in October and November 2014.

Tag recaptures

Recapture information was collected from each recreational fisher and entered into a SWRCP tagging database upon making contact with DoF. All fishers were contacted to validate their data, and posted a letter (Appendix 9.2) detailing information on their recaptured crab, the aim and objective of the trial and how to join the SWRCP Recreational Angler Program. A $1.00 scratch-and-win ticket was included with their letter as a small reward for reporting their recapture.

5.2.2 First aquarium trial (ST)

Collection

P. armatus were collected from hourglass traps set in the SCE downstream from Point Walter (Fig. 5.9) in January 2014. Based on visual determination of pleopod setal development (Drach, 1939), 65 inter-moult crabs were selected and subdued by being placed in a 5°C ice slurry for 30 seconds. Upon removal they were placed into Styrofoam boxes and separated from one another using foam soaked in seawater. The boxes were collected at two intervals during the day (11:00 and 14:00) to minimise mortalities by limiting the amount of time crabs were out of marine conditions, and transported to the Western Australian Fisheries and Marine Research Laboratories (WAFMRL) where they were placed into individual tanks and allowed to acclimate for five days.

Of the 65 transported crabs, 48 crabs were randomly chosen and placed in individual tanks in the aquarium. The remaining 17 crabs were held in reserve under the same conditions in case of mortality in any of the control or treatment crabs, and in case any of the female crabs became ovigerous during the acclimation period.

The trial was conducted over seven weeks from Wed 22nd January to Tuesday 11th March 2014, spanning the peak moulting period for mature P. *armatus* in southwest Western Australia.

Power analyses to determine the appropriate sample size for each aquarium tagging trial

Prior to the commencement of the first aquarium trial, a power analysis was undertaken to explore the relationship between the precision of estimates of the proportion of tagged crabs surviving to the end of the trial (i.e. after moulting) and sample size. The analysis involved parametric resampling from the binomial distribution, i.e. $B(n,p)$, where n represents the number of trials and p is the probability of success (i.e. survival to end of the trial). The analysis compared specified sample sizes ranging upwards in increments of 5, from 5 to 50, i.e. 5, 10 …. 50. An estimate of the probability of survival of crabs, for a specified sample size, was generated by randomly resampling from a binomial distribution, applying an arbitrary value of 0.5 for the probability of a success. For each specified sample size, this process was repeated 1000 times, on each occasion, storing the estimates for probability of survival. The lower and upper 95% confidence limits associated with the 1000 estimates for each sample size was taken as the 2.5 and 97.5 percentiles, respectively. The confidence intervals (i.e. distances between the upper and lower 95% confidence limits) decreased substantially as sample size increased to about 20-30 individuals, beyond which there was little improvement in precision (Fig. 5.5). Given resource constraints, a sample of 20 individuals was considered likely to be adequate for providing estimates of survival of tagged crabs.

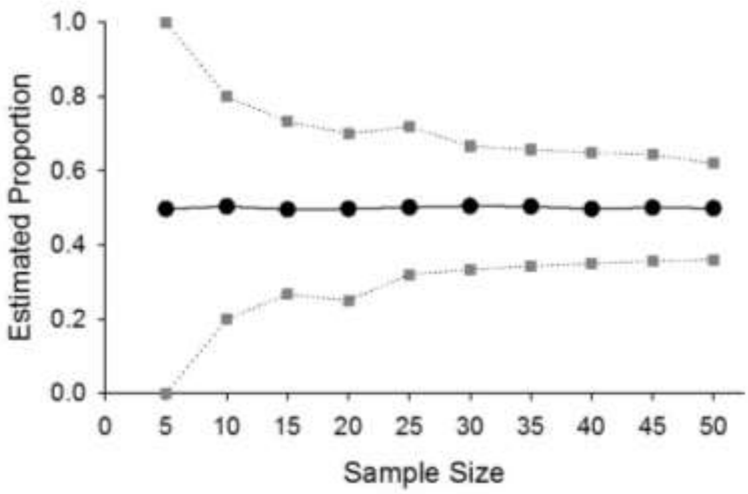


Fig. 5.5. The estimated proportions for the median (●), and upper and lower 95% confidence interval limits (■) of power analysis undertaken to determine appropriate number of treatments per T-bar tag location during the first T-bar tank trial between January and March 2014.

Tanks

Eight large coffin tanks were divided into six individual holding chambers (approximately 50 L each) (Fig 5.6). Each crab was placed into one of the chambers and acclimated for five days. The systems were supplied with a continuous stream of ambient seawater at a rate of 300 L/h through a spray bar at one end. The water flowed through holes in each of the dividing baffles towards a down-pipe at the opposing end of each tank. A layer of sanitised fine calcareous sand covered the base of each chamber to a depth of 25 mm. Circular PVC disks measuring 1 m diameter were placed across adjoining baffles to provide cover for each chamber and minimise the stress of each crab.

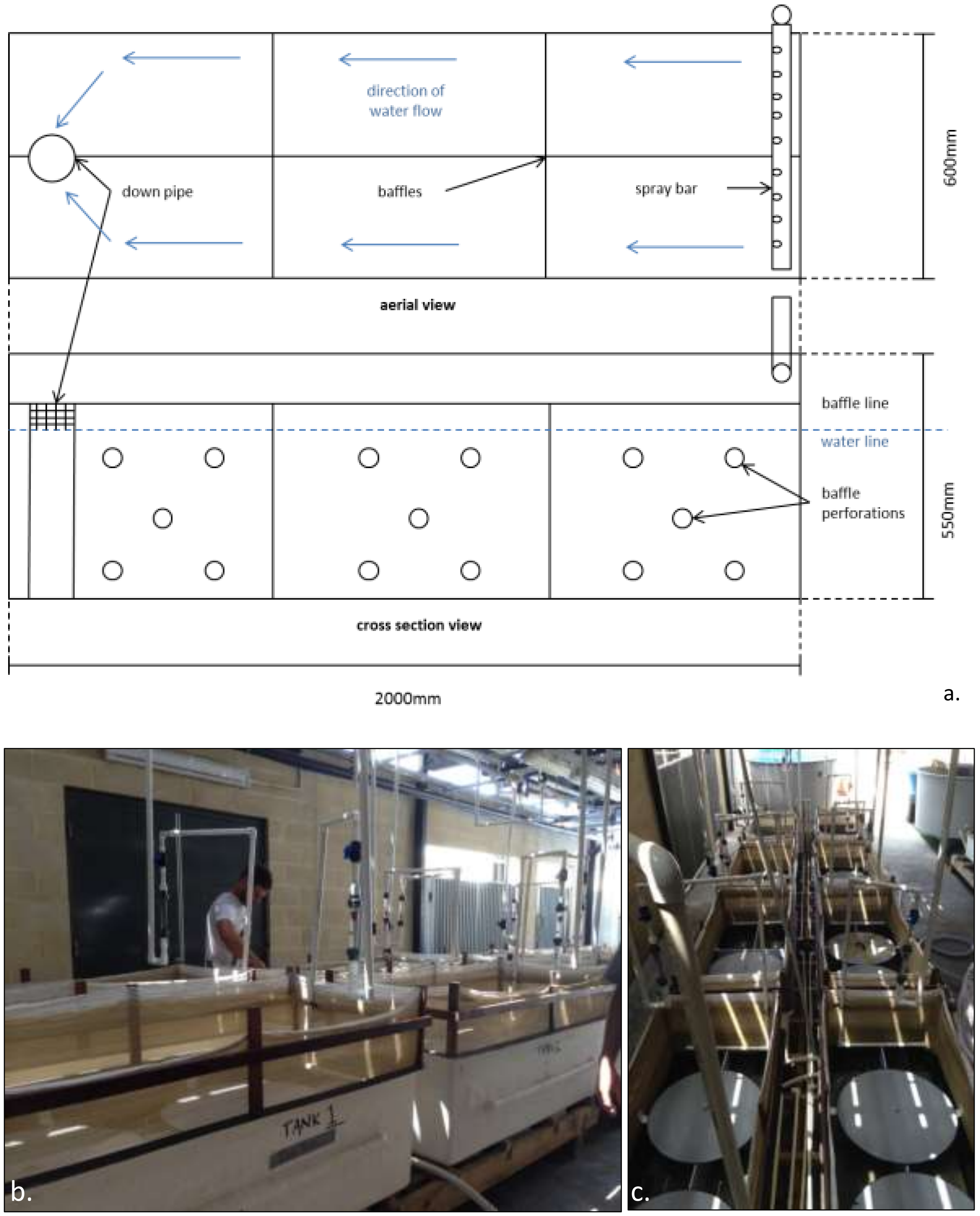


Fig 5.6. (a.) A schematic diagram of the coffin tanks used during the first and second aquarium trials. (b. and c.) The coffin tanks and circular PVC lids used to minimise disturbance during the first and second aquarium trials.

Tagging process

Following the acclimation period, individual crabs were removed from the holding tanks and placed in a 5°C ice slurry for thirty seconds to subdue the animal. After removal, the crab was tagged with an ST administered using an Avery-Dennison Mark III tagging gun fitted with a 'fine clothing' tagging needle. Each uniquely numbered tag measured 38 mm in total length, with a barrel length of 28 mm and width of 1.7 mm diameter, and a filament length of 10 mm (Fig 5.7). The T-anchor measured 7 mm in length. The ST was administered so that the plastic T-anchor and half of the filament was embedded in each animal (Figs 5.7, 5.8).

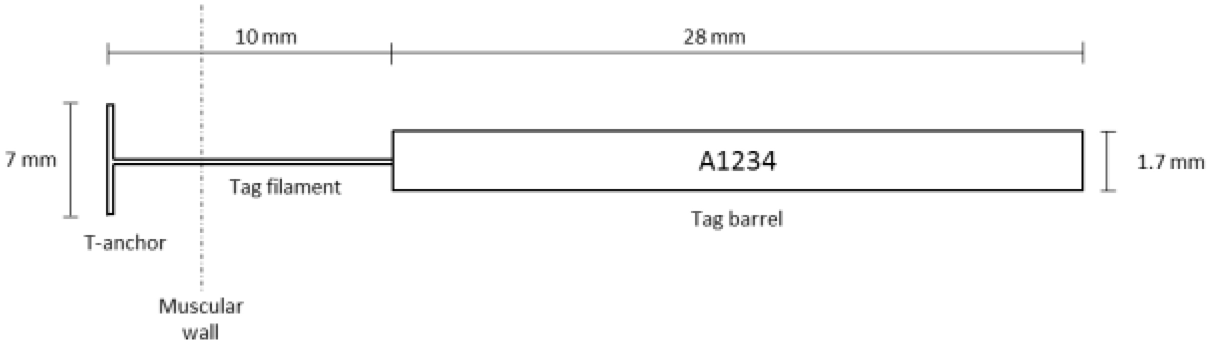


Fig 5.7. A schematic diagram of the ST tested during the first aquarium trial.

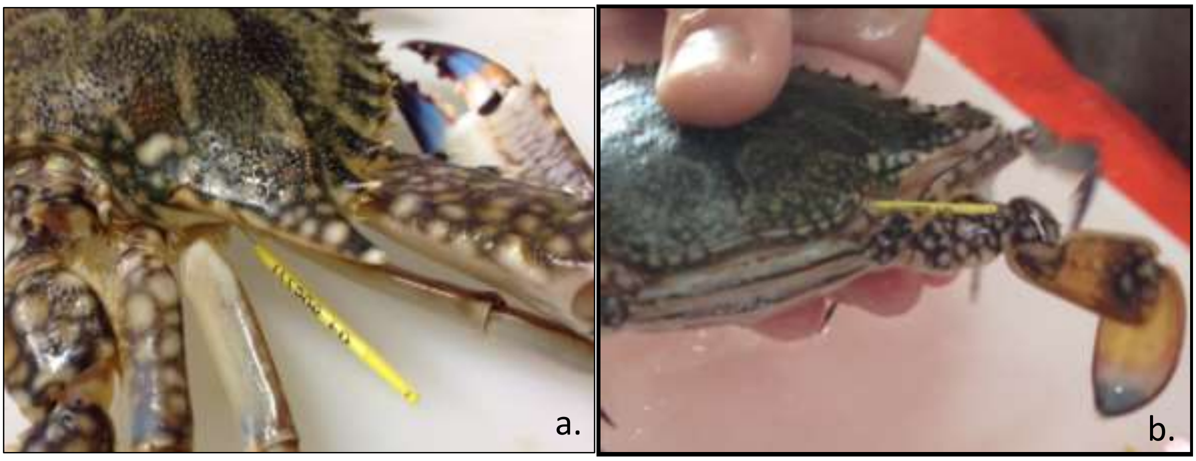


Fig 5.8. Application of the ST into (a.) the muscular tissue between the first and second walking leg on the right side, and (b.) the right swimmeret muscle of *P.armatus*. The filament of the T-bar tag can be seen protruding from the muscular tissue in each application.

Twenty randomly selected crabs were tagged in the muscular tissue that connects the right swimmeret to the dorsal carapace, while another 20 crabs were tagged in the muscular tissue between the first and second walking leg on the right side (Fig 5.8). The remaining eight crabs (controls) were subjected to the same protocol (including being run through the ice slurry and inserted with the tagging needle), but no tags were administered. To ensure consistency, all crabs were tagged within a thirty-second time-frame by the same operator and the tagging gun needle was sterilised in 100% ethanol between the tagging of each animal.

Husbandry

The crabs were checked daily to ensure the tags were retained, and fed every second day on an alternating diet of coral prawns (*Metapenaeopsis crassissima*) and mulies (*Clupeidae* spp.). Any uneaten food was removed prior to introducing new food. Mortalities were removed immediately and subject to a post-mortem examination to investigate the cause of death.

Partial water changes of 30% of tank volumes were conducted every three days using a gravel siphon to maintain water quality and minimise localised anoxia within the tank substrate. Physical and chemical parameters within the tanks were also monitored on a regular basis. Temperature and dissolved oxygen (DO) were recorded at the same time every day using a hand held Oxyguard meter. Ammonia (NH_3) and Nitrate (NO_3) was recorded prior to feeding the crabs using a Hach DR900 probe with respective test-reagents.

5.2.3 Second aquarium trial (MT)

Collection

P. armatus were collected from SCE and transported to the DoF aquarium in January 2015, using the methods described for the first trial. The trial was set to be conducted over seven weeks from Thursday 29th January to Wednesday 18th March 2014, spanning the peak moulting period for mature P. *armatus* in southwest Western Australia. However, the trial was terminated on Monday 23rd February due to high levels of mortality.

Tanks

The 65 crabs were housed in the same tanks used in the first trial, which had been emptied, sterilised and left dry for a period of months. Forty eight of the crabs were used in the trial, with the remaining 17 retained as reserves during the 5-day acclimation period. To reduce stress associated with the tank environment, a deeper lining (50 vs 25 mm) of fine sanitised calcareous sand was used to allow crabs to burrow more proficiently. In addition, individual hides made of 5 L PVC waste paper bins cut in half longitudinally were used in conjunction with the PVC disks to provide a greater level of shelter.

Tagging

Forty *P. armatus* were randomly selected and tagged with MTs in the muscular tissue that connects the right swimmeret to the dorsal carapace. Eight crabs served as controls and were subject to an identical tagging process but with no tag inserted.

The MT differed from the ST in that it had a shorter total length (33 vs 38 mm), the filament (from 10 mm to 3 mm) and diameter of the tag barrel (1.7 mm to 1.5 mm) were reduced, while t

he length of the barrel was increased (28 mm to 30 mm). With a shorter filament length, the ST was designed so that the barrel of the tag would inset into the muscular tissue of each tagged crab in an attempt to aid the successful discard of each moult during the moulting process (Fig. 5.9).

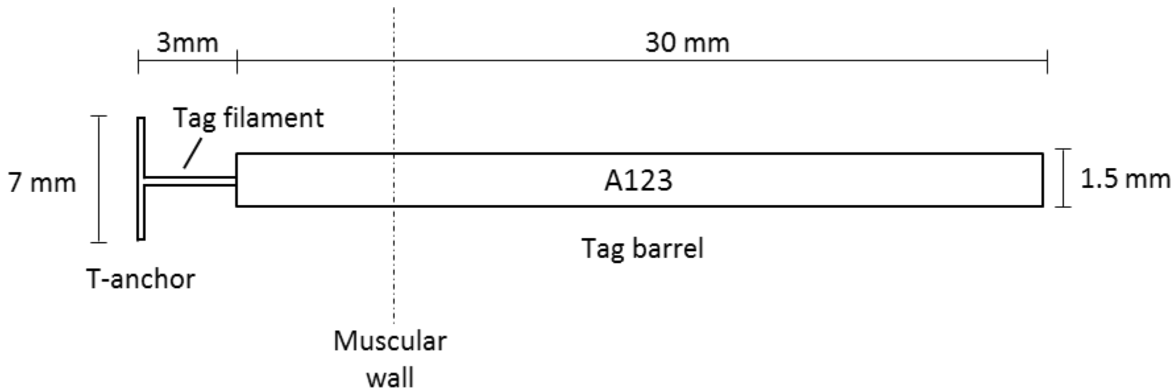


Fig 5.9. A schematic diagram of the MT tested during the second aquarium trial.

Husbandry

Crabs were attended on a daily basis with visual observations to ensure the retention of the modified T-bar tag. For consistency, the control animals were observed in the same manner to ensure the same level of disturbance to those tagged.

The crabs were fed on the same diet as the first trial. However, to maintain water quality, any uneaten food was removed within two hours of feeding and any moults or mortalities were also removed as soon as practicable.

Partial water changes and the monitoring of the physical and chemical parameters within the coffin tanks were carried out using the same maintenance schedule as the first trial. Continuous temperature loggers (eTemperature) were also used to record diurnal fluctuations in temperature across the range of tanks.

5.2.4 Second field survey: long-term marker (MT)

Survey regime

Monthly tagging surveys were conducted in the SCE over a twelve-month period between March 2015 and March 2016. Thirty sites were sampled each month, stretching from the Swan Entrance in East Fremantle, through to the Windan Bridge in East Perth and Salter Point in the Canning River. For analysis of recapture data, the 30 sites were divided equally into five sampling areas with six replicate sites within each area: Swan Entrance, Lower, Middle and Upper Swan, and the Canning River (Fig. 5.10).

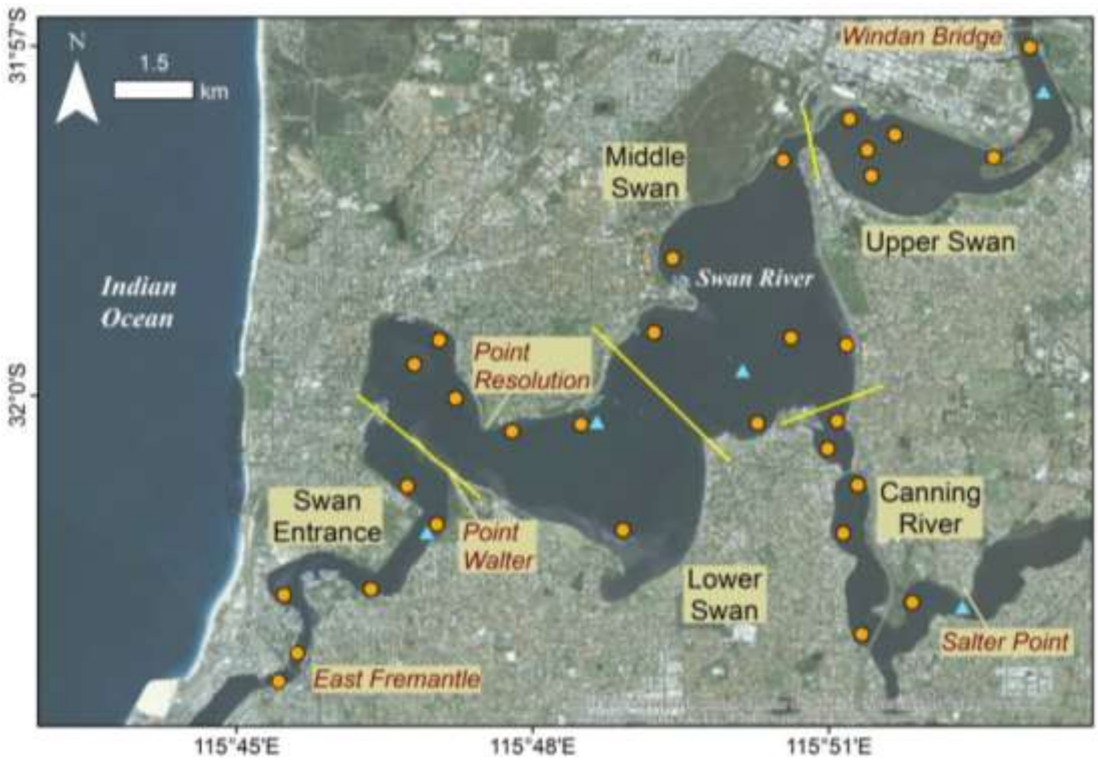


Fig 5.10. Tagging sites (●) sampled during the second field survey divided across five sampling areas (Swan Entrance, Lower Swan, Middle Swan, Upper Swan, and Canning River) with six replicate sites within each area. Water quality sites (▲) sampled as part of the Swan Canning Environmental Monitoring and Reporting Project conducted by the Department of Water.

Tagging process

Half of the *P. armatus* caught were tagged with the GT on their dorsal carapace only, while the remaining half was double-tagged with the GT on the carapace and an MT at the base of the right swimmeret (Fig. 5.11). Double tagging allowed for the determination of the impact of the T-bar tag on survival in the crab's natural environment,as well as estimating tag loss *in situ* for both GT and MT tag types.

To reduce the likelihood of bacterial infection via the entry site of the T-bar tag, a sterilization technique being developed by the DoF Fish Health unit was applied. A betadine solution (1:10 - betadine: distilled water) was sprayed onto the puncture wound immediately after insertion of a T-bar tag. A polymer, Poloxamer 407 (The Fish Vet, Western Australia), was then applied over the betadine solution to form an antiseptic gel-based membrane that temporarily sealed the wound.

The unique tag numbers were recorded in addition to the carapace width (mm), sex, state of maturity and shell condition.

Fig 5.11. An MT applied to the right swimmeret of *P. armatus* (a.), and in conjunction with a FloyTag polyvinyl glue-on tag (b.) during the second field survey. The first couple of millimetres of the T-bar tag barrel can be seen to be embedded in the muscular tissue adjoining the right swimmeret and carapace.

By October 2015, preliminary information from tag-recaptures indicated that the MT did not increase the mortality rate of marked crabs. It was therefore determined to focus the remaining four months of tagging surveys on examining whether the small size of the MT influenced detection of the tag. Between November 2015 and February 2016, half of *P. armatus* caught were double-tagged with the GT and MT, and the other half with the MT only.

While the betadine solution applied to the tag entry wound of crabs tagged with a T-bar tag to reduce the likelihood of bacterial infection was cheap, the antiseptic polymer used in conjunction with the Betadine solution was relatively expensive. So three additional hourglass traps were set at each of two additional sites in the SCE during the last three monthly tagging surveys (December 2015 to February 2016 inclusive) to test the impact of the polymer on crab survival. Half of the crabs from these traps were double-tagged with the GT and MT, and the other half with the MT only. However, only the betadine solution was applied to the tag wound.

Tag recaptures

As with the first field survey, recaptured crabs were reported using the contact details on each tag. Details of fishing location and date, method, tag number and type, size and sex of the crab, and whether the crab was kept or released were recorded into a SWRCP tagging database. An information sheet specific to this survey was sent out along with a $1.00 scratch and win card as a small reward for their efforts.

5.2.5 Statistical analysis

The movement patterns of all tag-recaptured crabs from the SCE were estimated using an individual-based process model containing five regions (Fig. 5.10). This included all crabs tagged with either a GT only, a MT only or double tagged with a GT and a MT from both field trials. The model assumed that there was no inter-annual variation in movement patterns and that tagged-recaptured crabs did not move either upstream of the most upstream region of the model or downstream of the most downstream region of the model (i.e. outside of the model bounds). Monthly movement was also assumed to be consistent between the five regions, i.e. if upstream movement occurred in the most downstream region then all regions would display upstream movement (except the uppermost region as crab could not move upstream of this boundary).

The model contained 24 parameters for each sex (12 monthly upstream and 12 monthly downstream movement parameters). Each tag-recaptured crab was released within the model in its release location, allowed to move within the model based on estimated movement parameters, and then its position within the model was compared to its actual recapture location after its observed liberty time had elapsed. The negative sum of the model estimated logged-probability of a crab being in its recapture region was used to produce a negative log-likelihood of the parameters being correct given the model structure and the observed data. This objective function was minimised using the "L-BFGS-B" (Byrd *et al*., 1995) method in the "optim" function on the statistical platform R (R Core Team, 2016), with upper and lower bounds for all parameters set to 1 and 0, respectively.

5.2.6 Environmental parameters

Information on salinity in the SCE was provided by the Department of Water, Western Australia through the Swan Canning Environmental Monitoring and Reporting Project, a long term monitoring program involving weekly sampling of water quality in the Swan and Canning Rivers and Swan Canning catchment.

A YSI 6600 V2 series sonde was used to measure the vertical profile of the water column at a range of sites in the Swan-Canning Estuary. Measurements were recorded at half metre intervals to a depth of 5m, then at 1m intervals to 0.5m above the benthos. Salinity was determined by an empirical relationship to conductivity and recorded as parts per thousand (ppt) (Department of Water, Western Australia, 2015).

Monthly salinity data presented in this report represents a mean of the weekly readings from 1.5m and 0.5m above the benthos, as these are the depths usually inhabited by blue swimmer crabs. Data is presented from five individual sites located in each of the five tagging areas: Swan Entrance, Lower Swan, Middle Swan, Upper Swan and Canning River (Fig. 5.10).

5.3 Results

5.3.1 First field survey: short-term marker (GT)

The first field survey investigated the suitability of the GT as a short term method for investigating movement of *P. armatus* within and between the SCE, LE and GB and their adjacent marine environments.

A total of 2,943 blue swimmer crabs were tagged with GTs in the SCE (1,148 crabs), OA (283 crabs), CS (640 crabs), LE (507 crabs) and GB (388 crabs) between September and December 2014 (Table 5.1). Just over 5% of these crabs were recaptured between October 2014 and March 2015. Recaptures of male crabs peaked in November, before declining rapidly over the summer months. In contrast, female recapture rates were fairly consistent from November through to January, before declining rapidly in February (Fig. 5.12).

Ten percent of the animals tagged in SCE were recaptured by recreational fishers, with the first recapture reported on 2nd October 2014 and the last on 13th March 2015. However, only 0.6% and 1% of crabs tagged in CS and OA, respectively, were recaptured (Table 5.1). Seven percent of the crabs tagged in GB were recaptured, compared with only 2% of the crabs tagged in the LE (Table 5.1).

Table 5.1. The number of blue swimmer crabs tagged with a GT each month between September and December 2014 and the percentage of reported recaptures.

Fishery	Sep	Oct	Nov	Dec	Total	Percentage recaptured (%)
SCE	266	349	272	261	1,148	**10**
GB	-	-	388	-	388	**7**
LE	-	-	507	-	507	**2**
CS	354	138	96	52	640	**0.6**
OA	48	77	62	96	283	**1**
Total	**668**	**564**	**1324**	**387**	**2,943**	**5.3**

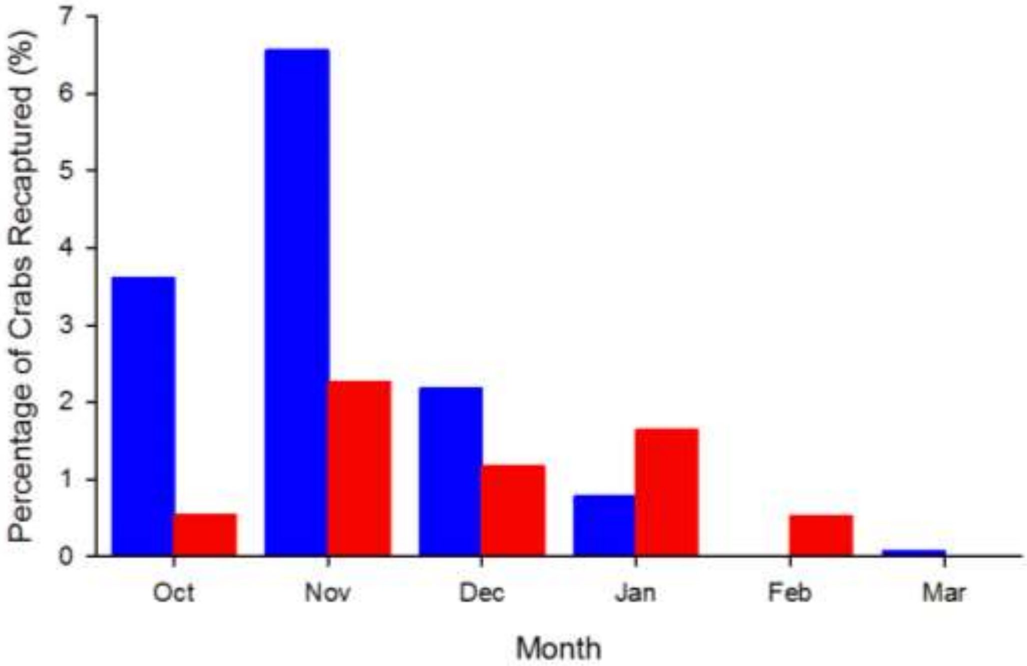


Figure 5.12. The percentage of male (■) and female (■) blue swimmer crabs tagged with a glue-on tag in the Swan-Canning Estuary that were recaptured by month between October 2014 and March 2015 during the first field survey.

Since there was little fishing in CS and OA, very few data was returned from these locations. As such the results will focus on data collected in the SCE, LE and GB.

Overall, the majority of recaptured blue swimmer crabs tagged with the GT were caught by boat-based fishers using drop nets (44%), followed by fishers diving or snorkelling for crabs (19%), using drop nets from shore (18%), or scooping for crabs in the shallows (14%) (Fig. 5.13). However, half the recaptures in GB were reported by fishers using scoop nets in the shallows. A small number of recaptures were reported by anglers using a fishing rod, the commercial fisher in the SCE using tangle nets, or caught in research hourglass traps either during closed season commercial monitoring in Cockburn Sound or breeding stock surveys in the SCE.

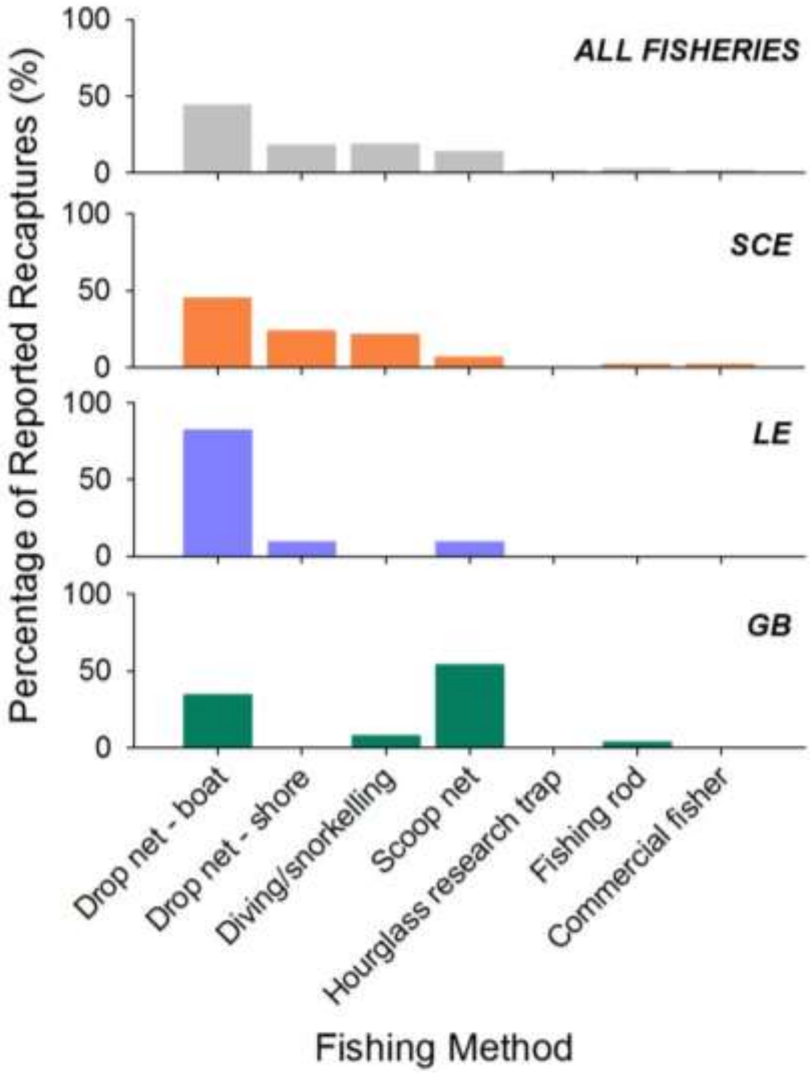


Figure 5.13. Method of recapture of blue swimmer crabs tagged with the GT by fishery during the first field survey.

Most recaptures of tagged crabs occurred a relatively short time after they were tagged, with 64%, 50% and 74% of recaptures taking place within 30 days of being released in the SCE, LE and GB, respectively (Fig. 5.14). The longest time at liberty in each of the fisheries was 114 days in the SCE, 83 days in the LE and 57 days in GB.

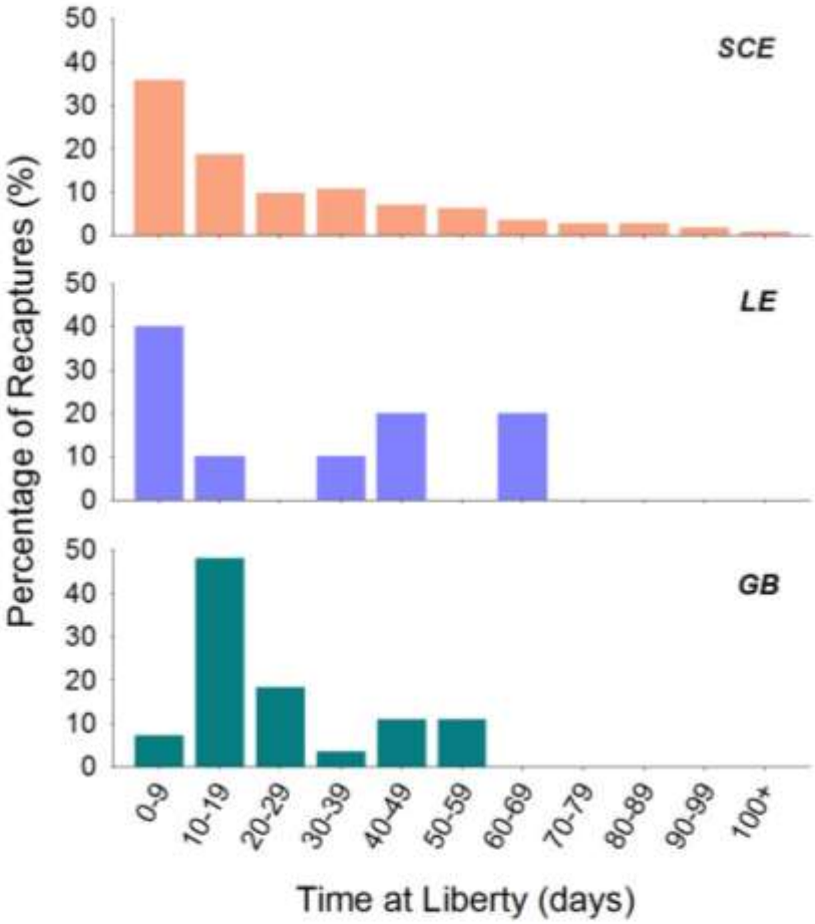


Figure 5.14. Time at liberty (days) of blue swimmer crabs tagged with the GT recaptured in the Swan-Canning Estuary (SCE), the Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) during the first field survey.

The majority of tagged crabs in the first field survey were recaptured in close proximity to their point of release, with 72%, 82% and 41% of crabs recaptured less than 2 km from where they were released in the SCE, LE and GB, respectively (Fig. 5.15). However, 4% of tagged crabs in the SCE, 9% of crabs in the LE and 37% of crabs in GB were recaptured over 6 km from where they were released. The furthest distance recorded between points of release and recapture in each fishery during the glue-on survey were:

- SCE: a 107 mm CW female crab tagged in Rocky Bay, North Fremantle on 30th October that was caught 42 days later and 6.7 km upstream off the Claremont Jetty.
- LE: a 130 mm CW female crab tagged immediately outside and to the north of the Cut entrance on 21st November which was recaptured 83 days later 6 km upstream into the Leschenault Estuary near the Australind boat ramp.
- GB: a 127 mm CW male crab tagged 100m of the shore from the Broadwater Resort on the 18th November that was recaptured 27 days later some 36.5 km east around the coast at Peppermint Grove Beach.

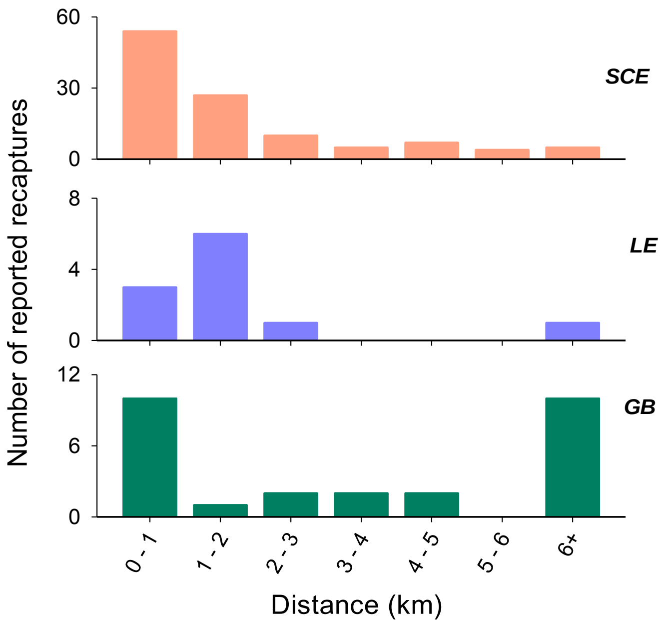


Figure 5.15. The distance (km) between tagging location and point of recapture for blue swimmer crabs tagged with a GT recaptured in the Swan-Canning Estuary (SCE), the Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) during the SWRCP glue-on tag survey.

5.3.2 First aquarium trial (ST)

The first aquarium trial was conducted to test whether an ST could be retained by *P. armatus* during a moult without adversely impacting the animal.

The collection of *P. armatus* from the SCE using hourglass traps and translocation to the aquarium in Styrofoam boxes was successful, with all animals surviving the process. During the five day acclimation period one crab moulted, three female crabs became berried and three crabs died. These crabs were replaced with reserve animals.

Of the 20 crabs tagged in the swimmeret location, only two animals moulted successfully during the trial such that the moult was discarded free from the animal and tag, with the tag retained in the crab (Fig. 5.16). Five crabs died before a moult occurred, and one crab died after a successful moult but before the trial finished. A further 4 crabs moulted with the moult becoming caught on the collar of the tag. These crabs were considered to have moulted unsuccessfully, as the crab's movement was severely restricted and mortality would be expected in the wild. Eight crabs tagged in the swimmeret location survived the trial period but did not moult (Fig. 5.16).

Three of the 20 animals tagged in the leg location moulted successfully (Fig 5.16). Three crabs died before they moulted, one crab after a successful moult, and one crab died during the moult process. A further three crabs moulted successfully, however the tag was removed from the animal with the moult. Seven crabs tagged in the leg location survived the trial period but did not moult (Fig. 5.16). In addition, a significant number of crabs tagged in the leg location developed deformities following ecdysis.

All of the eight control animals survived the trial period, with six of these moulting successfully (Fig. 5.16).

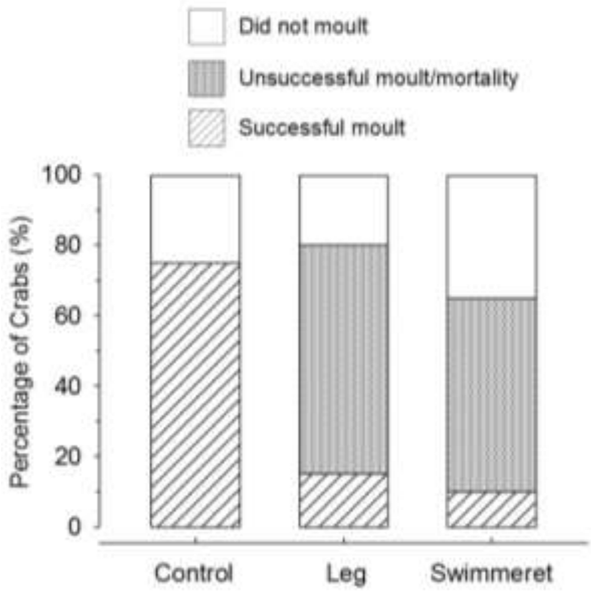


Figure 5.16. Frequency (percentage of crabs) of moult success and/or mortality amongst blue swimmer crabs with an ST inserted in either the muscular tissue between the right swimmeret and dorsal carapace (Swimmeret), or the muscular tissue between the right first and second walking leg (Leg) compared to control animals during the first aquarium trial.

5.3.3 Second aquarium trial (MT)

The second aquarium trial was conducted to test whether an MT could successfully be retained by *P. armatus* during a moult without adverse stress or mortality.

Of the 40 crabs tagged during the second trial, seven crabs moulted successfully and survived to the end of the trial (Fig. 5.17). One crab moulted successfully, but died over the following 24 hour period. There were substantial mortalities amongst the remaining crabs, with 21 crabs dying within 25 days of being tagged.

Three of the eight control animals moulted successfully and survived to the end of the trial (Fig. 5.17). One control crab moulted successfully but died two weeks later. Three control crabs survived to the end of the trial but did not moult, with the final control animal dying before it undertook a moult.

Given the unacceptably high level of mortality, the tank trial was terminated after four weeks of the anticipated seven week trial period. Three live crabs and one dead crab (that died on the day of submission) were submitted to the DoF Fish Health Unit for histological diagnostics to examine the cause of the unexpectedly high level of mortality encountered during the second trial. The three live crabs exhibited moderate numbers of haemocytes in the gills and hepatopancreas, with scant to heavy growth of *Vibrio harveyi*, *V. paraheamolyticus* and *Photobacterium damselae* from the gill and muscle tissue. The deceased crab displayed severe infiltration of haemocytes in the gill structures, hepatopancreas and around the tag entry site. A strip of severe necrosis was evident around the tag site, with large numbers of necrotic muscle fibres further away from the tag site. Large colonies of bacteria were associated with the necrotic tissue, with a similar colony in the gills. However, there was no evidence of septicaemia as no bacteria were isolated from the heamolymph of any of the sampled crabs.

Consequently, mortalities experienced during the tank trial were likely to have been caused by stress from the tank environment and bacterial entry through the tag wound. These two factors contributed to reduced immune defence mechanisms and chronic infection with bacteria around the wound and shed into the culture water.

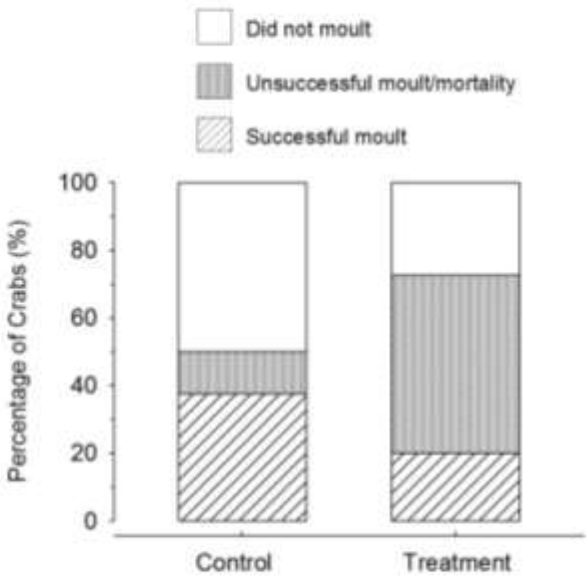


Figure 5.17. Frequency (percentage of crabs) of moult success and/or mortality for crabs tagged with an MT compared to control animals during the second aquarium trial.

5.3.4 Second field survey: long-term marker (MT)

The second field survey examined the suitability of the Hallprint TBF-1 Micro fine anchor T-bar tag for investigating the long term movement of *P. armatus* in the SCE.

A total of 3,267 blue swimmer crabs were tagged during the second field survey in the SCE between March 2015 and February 2016. Of these, 844 crabs were tagged with a GT only (GTO), 790 with an MT only (MTO), and 1,633 crabs double-tagged with both the GT and MT (GTMT) (Table 5.2).

Table 5.2. Numbers of blue swimmer crabs tagged with either a GT only (GTO), an MT only (MTO), or double-tagged with both the GT and MT (GTMT), and the proportions of reported recaptures (%) of each treatment during the second field survey in the Swan-Canning Estuary between March 2015 and February 2016.

TAG	MONTH													Prop'n
TYPE	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	TOTAL	Recap (%)
GTO	103	75	99	120	99	118	114	116	-	-	-	-	844	**10.5**
GTMT	103	76	103	122	90	95	139	133	132	181	253	206	1,633	**10.5**
MTO	-	-	-	-	-	-	-	-	132	183	248	227	790	**6.6**
TOTAL	**206**	**151**	**202**	**242**	**189**	**213**	**253**	**249**	**264**	**364**	**501**	**433**	**3,267**	**9.6**

Overall, 10.5% of GTO crabs tagged between March and October 2015 were recaptured, with the first recapture on 26th March 2015 and the last on 20th February 2016. The reported recapture rate of GTMT crabs tagged between March 2015 and February 2016 was also 10.5%, with the first recapture on 29th March 2015 and the last on 22nd June 2016. The reported recapture rate of MTO crabs tagged between November 2015 and February 2016 was 6.6%, with the first recapture on 22nd November 2015 and the last on 25th May 2016 (Table 5.2).

Ten of the 226 recaptured crabs (4.4%) that had been tagged with the MT during the second field survey had undergone a successful moult while retaining the tag and growing the expected amount.

MT viability – March to October 2015

To the end of October 2015, recreational fishers reported recapturing 10.5% of GTO blue swimmer crabs. By comparison, the reported recapture rate of GTMT crabs over the same period was 12.5% (Table 5.3). A randomisation test concluded that the difference in recapture rates of the two tag treatments was not significant (P=0.21).

Table 5.3. Numbers of blue swimmer crabs tagged between March and October 2015 with either a GT only (GTO) or double-tagged with both the GT and MT (GTMT), and the proportions of reported recaptures (%) of each treatment during the second field survey in the Swan-Canning Estuary.

TAG	MONTH									Proportion of
TYPE	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	TOTAL	Recaptures (%)
GTO	103	75	99	120	99	118	114	116	**844**	**10.5**
GTMT	103	76	103	122	90	95	139	133	**861**	**12.5**
TOTAL	**206**	**151**	**202**	**242**	**189**	**213**	**253**	**249**	**1,705**	**11.6**

MT visibility – November 2015 to February 2016

A total of 6.6% of MTO blue swimmer crabs were reported recaptured between November 2015 and June 2016, compared with the reported recapture rate of 8.3% for GTMT crabs over the same period (Table 5.4). A randomisation test concluded that the difference in recapture rates of the two tag treatments was not significant (P=0.21).

Table 5.4. Numbers of blue swimmer crabs tagged between November 2015 and February 2016 with either an MT only (MTO) or double-tagged with both the GT and MT (GTMT), and the percentage of reported recaptures (%) of each treatment during the second field survey in the Swan-Canning Estuary.

TAG	MONTH					Percentage of
TYPE	Nov	Dec	Jan	Feb	TOTAL	Recaptures (%)
MTO	132	183	248	227	**790**	**6.6**
GTMT	132	181	253	206	**772**	**8.3**
TOTAL	**264**	**364**	**501**	**433**	**1,562**	**7.4**

Impact of antiseptic polymer on crab survival – December 2015 to February 2016

A total of 8.2% of blue swimmer crabs tagged with an MT and treated with both antiseptic polymer and betadine solution were recaptured, compared to 6.4% of crabs that had been treated with betadine solution only (Table 5.5). A randomisation test concluded that the difference in recapture rates of the two antiseptic treatments was not significant (P=0.11).

Table 5.5. Numbers of blue swimmer crabs tagged between December 2015 and February 2016 with betadine solution and antiseptic polymer applied to the MT entry wound of tagged crabs (AP) or betadine solution only (No AP), and the percentage of reported recaptures (%) of each treatment during the second field survey in the Swan-Canning Estuary.

TAG TYPE	MONTH				Percentage of Recaptures (%)
	Dec	Jan	Feb	TOTAL	
AP	283	377	308	**986**	**8.2**
No AP	81	124	125	**330**	**6.4**
TOTAL	**364**	**501**	**433**	**1,298**	**7.9**

Tag loss

Three of the 172 double tagged blue swimmer crabs (1.7%) that were recaptured had lost the GT but retained the MT and had not grown, indicating that the GT was not shed through a moult. In comparison, 11 of the recaptured crabs (6.4%) lost their MT while retaining their GT (Table 5.6).

Table 5.6. Numbers of blue swimmer crabs double-tagged with the GT and MT between March 2015 and February 2016, and the percentage of tag loss for each tag type during the second field survey in the Swan-Canning Estuary.

TAG TYPE	Numbers of Crabs			Percentage of Tag Loss (%)
	Tagged	Recaptured	Lost tag	
GT	1,633	172	3	**1.7**
MT	1,633	172	11	**6.4**

General recapture information

A similar pattern was evident in monthly reported recapture rates of both GTO and GTMT crabs over the course of the second field survey.

The recapture of around 4% of GTO crabs were reported in April 2015 (Fig. 5.18). The proportion of recaptured animals then declined in May and June, before stabilising at around 1% of available crabs through the winter and spring months. There was a spike in reported recaptures to 3% in November before declining below 1% with no recaptures of GTO crabs reported after February 2016 (Fig. 5.18).

The recapture of around 4% of available GTMT crabs were reported in April 2015, followed by a decline in May and June. Recapture rates increased from this point to peak in November at just over 3%, before gradually declining to around 1% by February 2016. The recapture of only a few GTMT crabs were reported each month after with the last reported recaptures in June 2016 (Fig. 5.18).

The proportion of reported recaptures of MTO crabs increased from just over 1% in November 2015 to almost 4% by January 2016 (Fig. 5.18). Recapture rates then declined to just over 1% by March, with only a couple of recaptures reported in the months of April and May 2016.

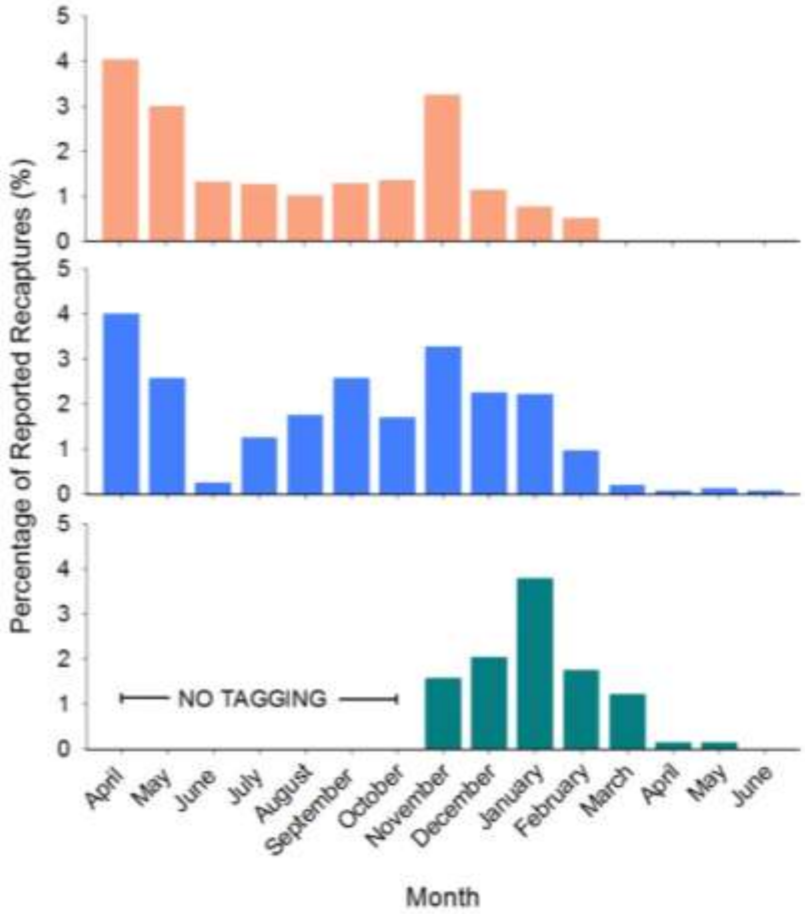


Figure 5.18. The percentage of blue swimmer crabs tagged with a GT only ( ), both the GT and MT ( ) or a MT only ( ) that were reported as recaptured by month between April 2015 and June 2016 in the Swan-Canning Estuary during the SWRCP second tag field survey.

As with the first tag field survey, the majority of recaptured blue swimmer crabs marked in the SCE during the second field survey were caught by boat-based fishers using drop nets (37%) (Fig. 5.19). Fishers diving or snorkelling for crabs reported the next highest proportion of recaptures (32%), followed by fishers using drop nets from shore (19%) or scooping for crabs in the shallows (7%). A small number of recaptures were reported by anglers using a fishing rod, or were caught in research hourglass traps during either breeding stock or tagging surveys.

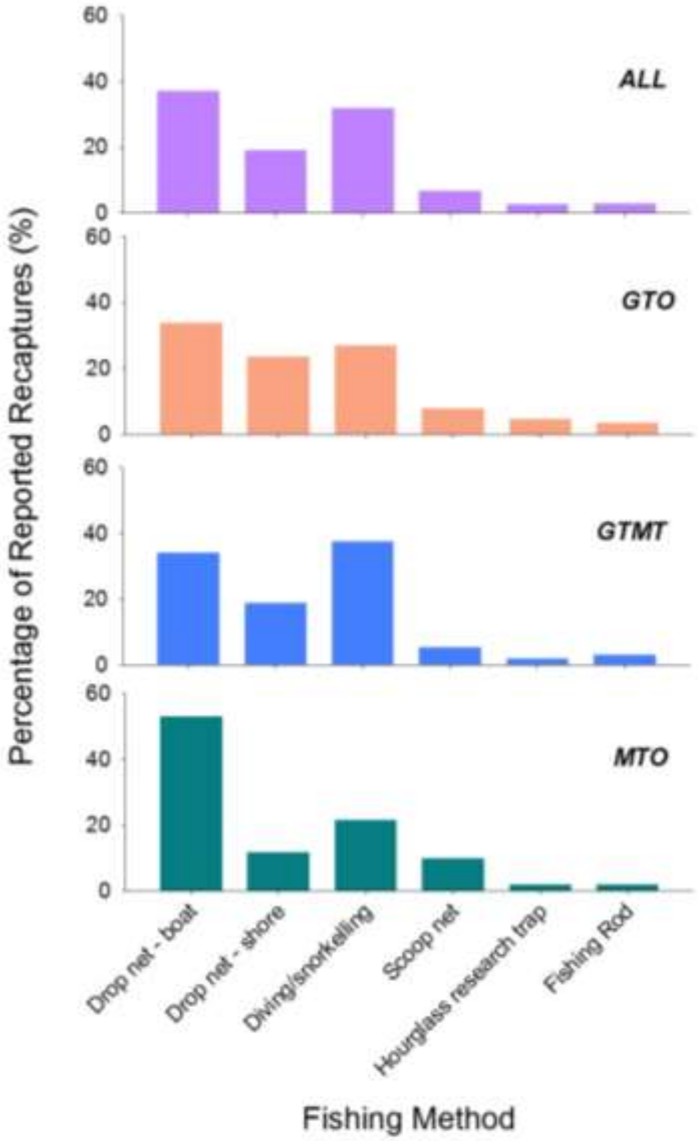


Figure 5.19. Percentage of reported recaptures by method of blue swimmer crabs in the Swan-Canning Estuary tagged with either the GT only (GTO), both the GT and MT (GTMT), or the MT only (TBO), and with all data pooled (ALL), during the second tag field survey.

More than half of all reported recaptures of crabs tagged during the second field survey occurred within 30 days of their release (Fig. 5.20). This was particularly evident for MTO (81%) and GTMT crabs (55%). The longest time at liberty was 269 days for both GTMT and GTO crabs, compared to 94 days for MTO crabs.

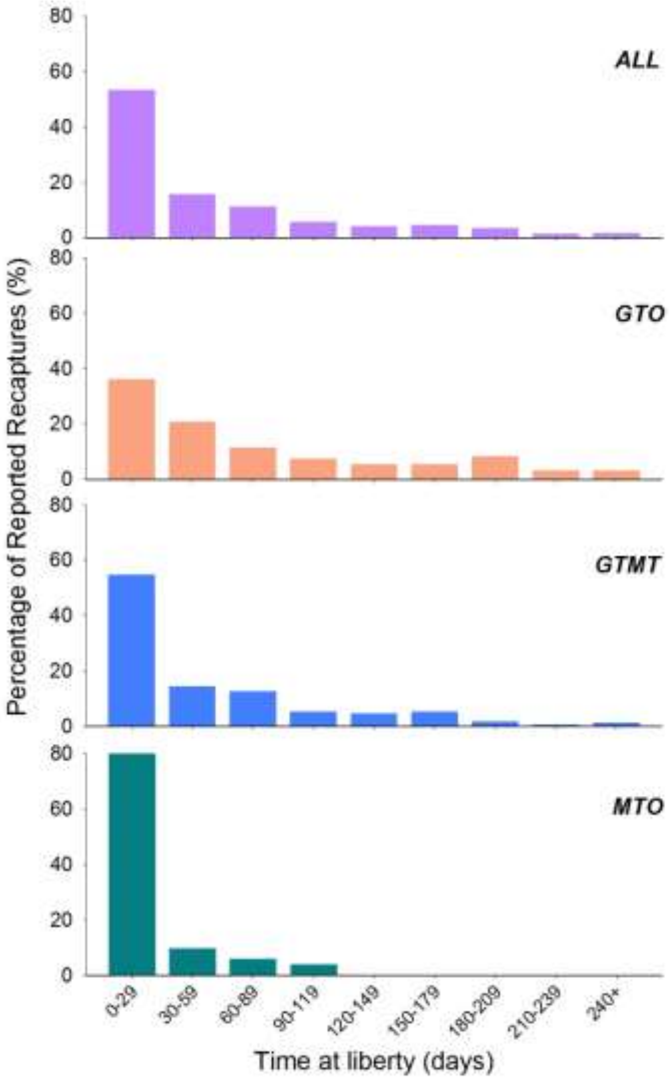


Figure 5.20. Time at liberty (days) between the release and recapture of blue swimmer crabs in the Swan-Canning Estuary tagged with either the GT only (GTO), both the GT and MT (GTMT), or the MT only (MTO), and with all data pooled (ALL), during the second tag field survey.

Most tagged crabs recaptured during the second field survey were caught in relatively close proximity to their point of release, with 58% of GTO crabs, 66% of GTMT crabs and 81% of MTO crabs recaptured less than 2 km from where they were released (Fig. 5.21). In contrast, however, 7% of GTO crabs, and 6% of both GTMT and MTO crabs were recaptured more than 7 km from where they were released. The furthest distance recorded between points of release and recapture for each tag treatment during the second field survey were:

- GTO: a 147 mm CW female crab tagged at Blackwall Reach in the Swan River on 13th April 2015 that was caught 88 days later and 26.5 km away near the southern end of Garden Island in the nearshore embayment of Cockburn Sound.
- GTMT: a 160 mm CW female crab tagged by Windan Bridge in the Swan River on 29th April 2015 that was recaptured 153 days later 25 km downstream in the Fremantle Port.
- MTO: a 154 mm CW female crab tagged at Deep Water Point in the Canning River on 23rd December 2015 that was recaptured 19 days later 8 km downstream at Point Walter.

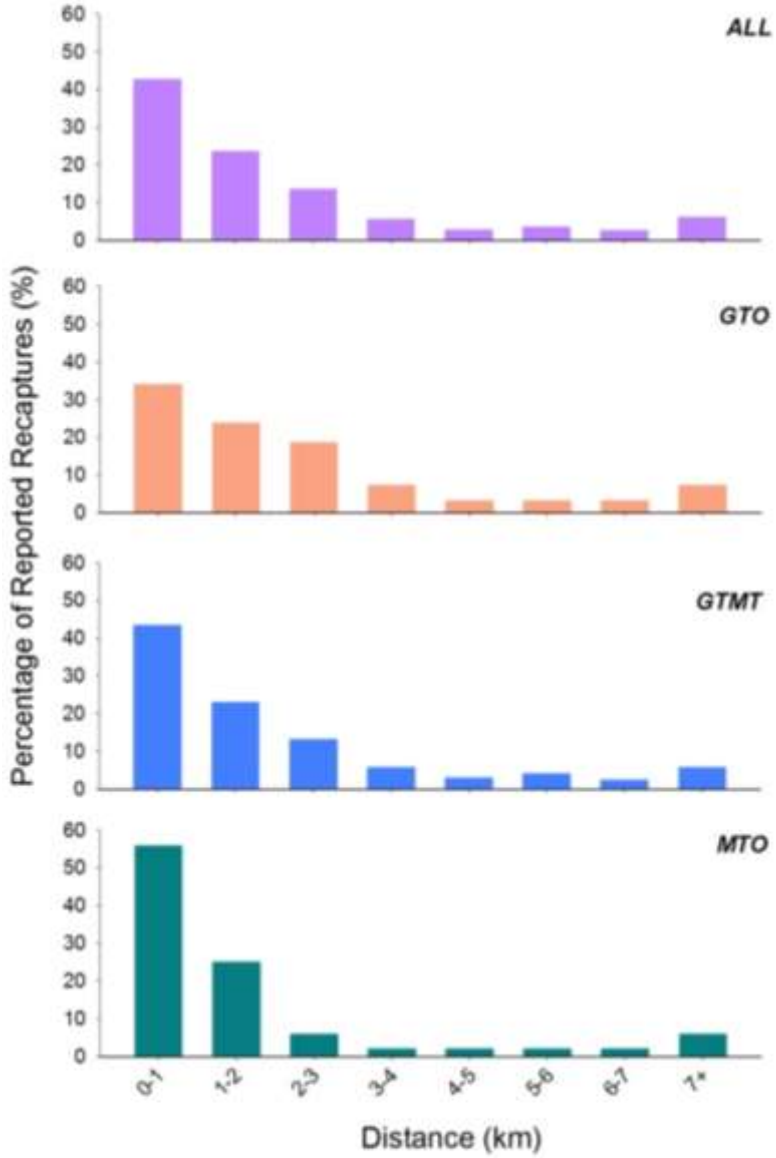


Figure 5.21. The distance (km) between tagging location and point of recapture for blue swimmer crabs tagged with either the GT only (GTO), the GT and MT (GTMT), or the MT only (MTO), and with all data pooled (ALL), the Swan-Canning Estuary during the second tag field survey between March 2015 and February 2016.

Crab movement

There was a general trend in upstream movement in spring and over the summer months by male crabs tagged during the first and second field surveys in the SCE, followed by a downstream trend in movement during the winter months (Fig. 5.22). This trend was more pronounced among tagged female crabs, with a general trend in upstream movement in October, December and April, but only downstream movement from May through to September (Fig. 5.23).

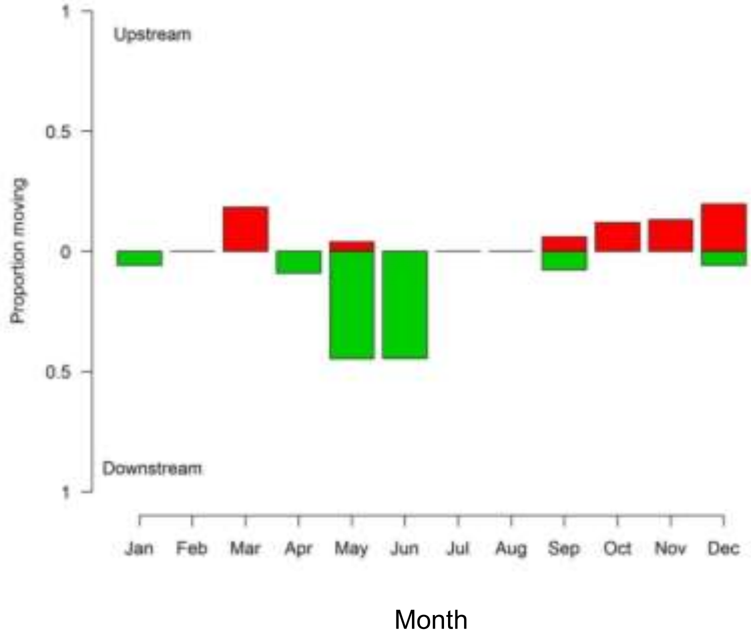


Figure 5.22. The proportion of male blue swimmer crabs tagged during the first and second tag field surveys in the Swan-Canning Estuary that were recaptured either upstream (red) or downstream (green) from their point of release by month.

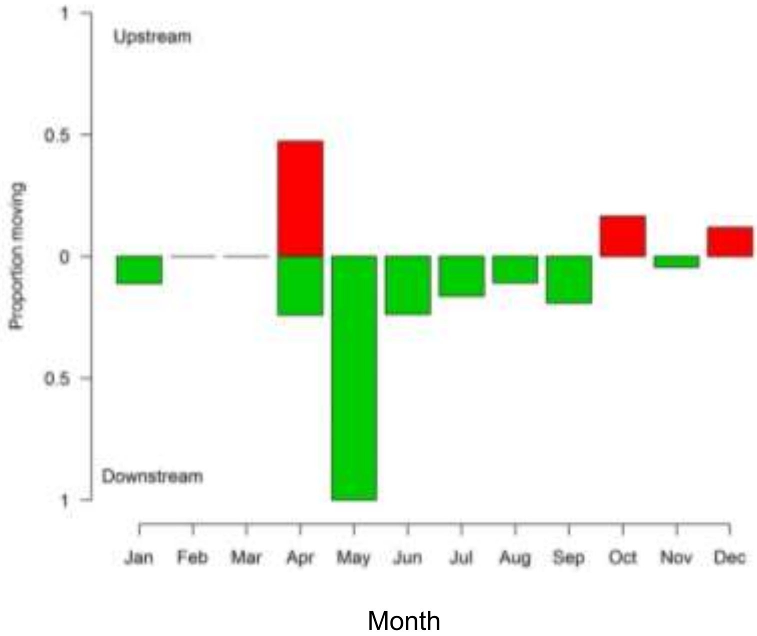


Figure 5.23. The proportion of female blue swimmer crabs tagged during the first and second tag field surveys in the Swan-Canning Estuary that were recaptured either upstream (red) or downstream (green) from their point of release by month.

Inter-annual temporal and spatial variations in catch rates of male and female blue swimmer crabs captured in hourglass traps during monthly tagging surveys in the SCE between March 2015 and February 2016 supported these hypotheses of crab movement within the estuary. While high catch rates of male crabs were recorded at sites in the lower reaches of the Swan River (Swan Entrance and Lower Swan) throughout the 12-month survey period, there was substantial variation in catch rates across seasons at sites further upstream (Fig. 5.24). Moderate numbers of male crabs were caught at sites in the Middle Swan, Upper Swan and Canning River areas in March. However, trap catch rates in these areas declined rapidly from this point with very few male crabs captured between April and September. Male crabs began to appear in traps again in these upper areas in October before peaking in January (Fig. 5.24).

A similar trend was evident amongst female crabs, with significant numbers captured in the lower reaches of the Swan River (Swan Entrance and Lower Swan) throughout the year. In contrast, small numbers of female crabs were evident in traps in the Middle Swan, Upper Swan and Canning River areas during the autumn months (March to May), with very few female crabs present in traps from June to September. Small numbers of female crabs re-appeared in the traps in the upper reaches of the Swan River and in the Canning River from October through to February (Fig. 5.24).

Mean salinity levels in the deepest 1.5 m of water (usually the depths inhabited by blue swimmer crabs) were found to be reasonably consistent at sample sites in the Swan Entrance and Lower Swan (~33-37 ppt), and to an extent the Middle Swan (~31-36 ppt) (Fig. 5.24). However, while benthic salinity levels at sites sampled in the Upper Swan and Canning River were within these ranges during summer and autumn, they dropped significantly to around 15 ppt during the winter and into spring (Fig. 5.24).

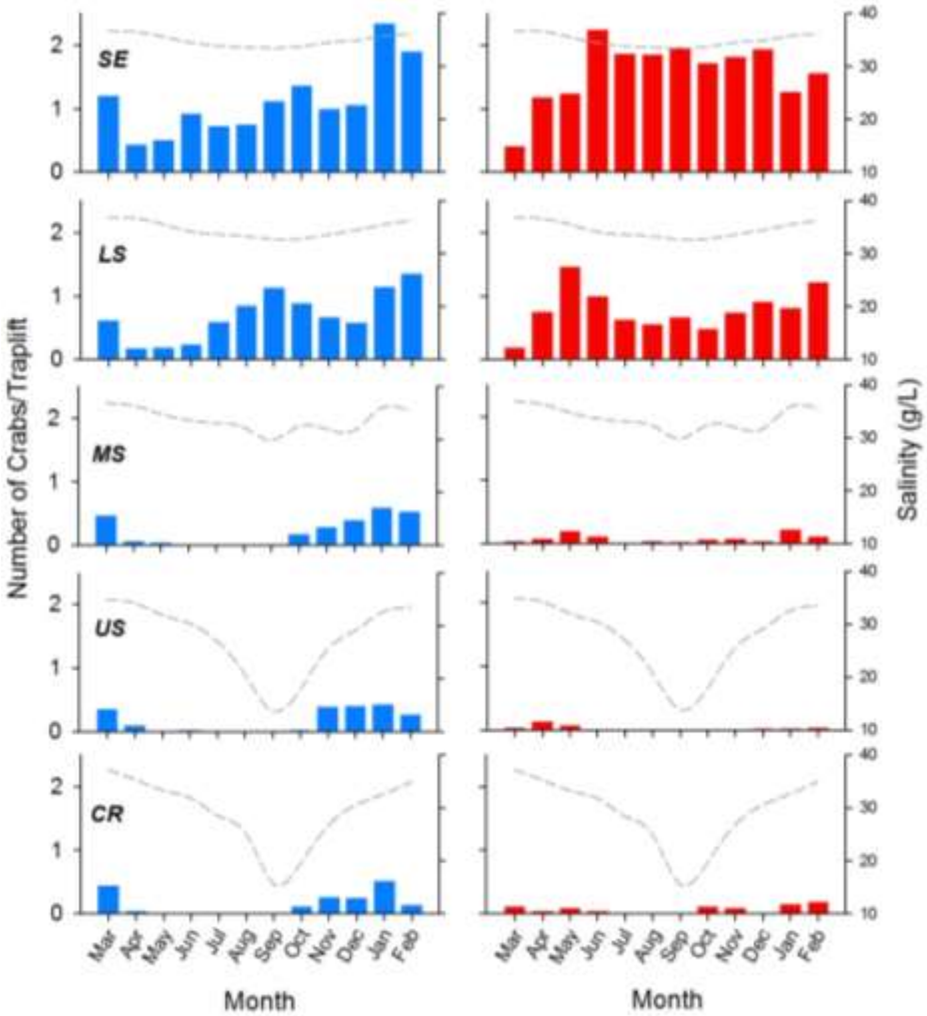


Figure 5.24. Mean monthly catch rates by area of male (■) and female (■) blue swimmer crabs captured in hourglass traps at 30 different sites sampled monthly between March 2015 and February 2016 throughout the Swan-Canning Estuary during the second tag field survey. ----- Mean monthly salinity levels (ppt) sampled as part of the Swan Canning Environmental Monitoring and Reporting Project conducted by the Department of Water.

5.3.5 SWRCP fisher participation in tagging field surveys

SWRCP Recreational fishers were keen to contribute to the tagging field survey work undertaken in the SCE, LE and GB, with a total of 38 fishers joining DoF researchers to tag blue swimmer crabs over the first and second field surveys (Fig. 5.25).

Figure 5.25. DoF research staff and SWRCP fishers undertaking blue swimmer crab tagging surveys during the South West Recreational Crabbing Project.

5.4 Discussion

While the FloyTag polyvinyl glue-on tag (GT) proved effective as a short-term marker for investigating the movement of blue swimmer crabs, its limitation was apparent as the tag was lost over the peak moult period. Consequently, the Hallprint TBF-1 Micro T-bar tag (MT) was trialled as a longer-term option for the mark and recapture of blue swimmer crabs. This tag was considered superior to the GT as a number of recaptured crabs had undergone a moult and grown the expected amount in size while retaining the tag, demonstrating that the MT can provide information on movement over a longer period of a crab's life.

Trialling a short-term marker (GT) for blue swimmer crabs

The GT proved successful as a short-term marker for blue swimmer crabs during the first field survey, as it was readily identifiable by fishers, resulted in minimal tag loss and had no apparent impact on marked animals. The survey provided valuable information on the movement of crabs in the SCE, LE and GB and the suitability of these fisheries for mark-recapture surveys.

The tag return rate for a mark-recapture survey that relies on fishers for tag recaptures is primarily impacted by three factors: the exploitation rate of the marked animals; tag loss through shedding or mortality; and reporting rates from fishers recapturing marked crabs. Assuming tag loss and reporting rates were consistent between fishing areas, the impact of variations in fishing pressure was clearly demonstrated during the first field survey. Just over 10% and 7% of tagged crabs were recaptured in the SCE and GB, respectively. These recapture rates compare favourably with previous studies using tags that were lost with the moult. Bellchambers *et al.* (2005) reported recapture rates of 4.7% and 3.2% for blue swimmer crabs tagged with Hallprint FPN glue-on tags in Shark Bay, Western Australia during 2001 and 2002, respectively. Lambert *et al.* (2006) reported a recapture rate of 12.3% for the blue crab, *Callinectes sapidus*, tagged with strap tags across the carapace in Chesapeake Bay, Virginia, while Bell *et al.* (2003) reported a recapture rate of 13.7% for the edible crab, *Cancer pagurus*, marked with paint on the east coast of England in 1998. However, the recapture rates from OA (1%) and CS (0.6%) during the first field survey were markedly lower than in SCE and GB. These low recapture rates could best be explained by a lack of fishing effort in these fisheries as CS was closed to both commercial and recreational crabbing over this period while OA has historically experienced low levels of fishing pressure.

After trialling several adhesives, Loctite 454 was found to be superior as it set rapidly with a very strong bond. Consequently, tag loss with the GT other than through a moult was minimal (1.7%). Furthermore, the adhesive is a gel so did not run and interfere with crab appendages and did not appear to negatively impact the animal in any way.

However, the limitations of the GT were readily apparent as reported tag recaptures during the first field survey declined rapidly over the peak moult period for mature (1+) crabs in southwest Western Australia. Mature male crabs in this region generally moult from December into January, followed by mature female crabs a month or so later. Consequently, despite peak fishing pressure occurring over summer, male recapture rates peaked in November before declining rapidly with only one recapture reported after January as the male crabs moulted and lost their tag. Similarly, reported recaptures of female crabs was reasonably consistent from October to January, before falling markedly in February with no recaptures reported after this month.

Trialling a long-term marker (ST/MT) for blue swimmer crabs

- **Laboratory trials**

Mortality during the first aquarium trial to test the ST was generally low, with a reasonable proportion of animals moulting and retaining the tag. However, the tag was considered unacceptable due to the physical deformities that occurred during the moult in animals tagged in the leg location, and the high incidence of the extruded moult catching on the barrel of the tag of crabs tagged in the swimmeret location.

Consequently, the MT tag was developed with a thinner barrel and substantially reduced filament so that the first couple of millimetres of the tag resided within the musculature of the tagged animal leaving nothing to restrict the cast-off moult. However, the second tank trial to test this tag was marred by high levels of mortality. Histological examination suggested these mortalities were likely to have been caused by stress from the tank environment and bacterial infection through the tag wound, rather than the tag itself.

Similar results have been experienced by researchers using t-bar anchor tags to mark blue swimmer crabs during laboratory trials. While Williams (1986) observed that blue swimmer crabs were capable of retaining a modified Floy FD67 anchor tag through a moult and reported negligible short-term mortality during the first week of two 28-day laboratory trials, a significant increase in mortality was experienced as the trials progressed. Potter *et al.* (1991) reported considerable variation in tagging mortalities between three laboratory trials using Floy FD-68 BA anchor tags, with mortality rates of 13%, 56% and 80% compared to a constant rate of 20-23% amongst control crabs that had not been tagged. McPherson (2002) reported significant mortality (43%) and a 100% failure rate of successful moults using standard T-bar tags to mark blue swimmer crabs when assessed under laboratory conditions. However, greater success was experienced with a modified tag similar to the MT in that the first few millimetres of the tag barrel resided within the animal's musculature with 64% of crabs tagged in the swimmeret location moulted and retained the tag for the length of the laboratory trial.

- **Second field survey**

The MT trialled as a long-term option for the mark and recapture of blue swimmer crabs during the second field survey proved superior to the GT. The tag did not increase mortality in situ or reduce the susceptibility of crabs to fishing, tag loss was relatively minimal, and recapture rates were not impacted by the MT's small size or location on the animal. A total of 8.6% of crabs tagged with the MT were recaptured during the second field survey in the SCE. This rate is consistent with recapture rates from previous crab tagging studies that have used tags designed to survive a moult: 4% of blue swimmer crabs tagged with a Floy FD67 anchor tag in Moreton Bay, Queensland (Williams, 1986); 8.5% recaptures for adult *Cancer pagurus* (L.) tagged with either T-bar tags or black cable ties with yellow numbered discs around the merus segment of the first periopod (claw) along the Swedish coast (Ungfors *et al.*, 2007); 14.7% of blue swimmer crabs tagged with a Floy FD-68BA anchor tag in Moreton Bay (Potter *et al.*, 1991). The fact that 4.4% of the recaptured crabs tagged with an MT had undergone a moult and grown the expected amount in size while retaining the tag demonstrated that the MT can provide information on movement over a longer period of a crab's life than the GT. Further research on the MT tag design will hopefully improve levels of post-moult tag retention and survival.

Crab movement

The field surveys provided valuable information on movement patterns amongst blue swimmer crabs in the SCE. There was a general upstream movement by both male and female crabs from late spring, through summer and into autumn. In contrast, movement was almost exclusively downstream from late autumn, through winter and into early spring. This trend was supported by catch rates of crabs caught in hourglass traps during the monthly tagging surveys between March 2015 and February 2016. Highest catch rates of male and female crabs were encountered in the very lower reaches of the Swan River throughout the year, with lesser numbers of male and female crabs appearing in traps at all sites sampled further upstream in the Swan and Canning Rivers during autumn. However, while significant numbers of crabs continued to be caught during winter in the lower reaches downstream from Point Resolution, very few crabs were captured in traps upstream from this location. Crabs started to reappear in upstream traps in late spring, with highest catch rates in these areas over summer.

This movement is most likely in response to changes in water conditions in different parts of the SCE at different times of the year, in particular water temperature, salinity and dissolved oxygen. Fluctuations in benthic salinity data appeared to correspond to changes in catch rates of crabs caught during the second field survey at five regions in the Swan and Canning Rivers. During summer and autumn, quantities of blue swimmer crabs were captured in hourglass traps at all sites in the Swan and Canning Rivers where salinity levels were consistently above 30 ppt. However, while salinity in the deepest 1.5 m of Swan Entrance and Lower Swan remained above 30 ppt through winter and spring, winter rains flowing into the estuary caused salinity upstream from these areas to fall as low as 13 ppt. de Lestang *et al.* (2003b) reported that blue swimmer crabs emigrated from both the Leschenault and Peel-Harvey Estuaries in southwest Western Australia into near-shore marine environments during the winter months as salinity levels dropped to 20.9 ppt and 11.5 ppt in each estuary, respectively. Romano and Zeng (2006) undertook aquaria tank trials to test the impact that varying salinity levels had on the growth and survival of early juvenile blue swimmer crabs. They reported that mortality was significantly higher for juveniles cultured at salinities of ≤15 ppt. Consequently, it would appear likely that the fluctuations in salinity levels caused by the influx of winter rains had a significant impact on crab distribution in the SCE, compelling crabs to move downstream from Point Resolution during winter and early spring.

The movement of tagged crabs between the SCE and its adjacent marine environment was not as well illustrated as the movement that occurs within the estuary. While several crabs tagged within the SCE were later recaptured outside the estuary, it was not possible to assess the relative proportion of the crab stock that moves from the SCE to either OA or CS due to the lack of fishing pressure in these latter water bodies. However, it was notable that none of the crabs tagged in either OA or CS during the first field survey were recaptured in the SCE given the high level of fishing pressure in this fishery. While this suggests that movement between the SCE and its nearshore marine environments could be unidirectional (from the SCE into OA or CS), this could not be determined due to the limited timeframe of the survey.

Tag recaptures from the field surveys suggested that although there was substantial movement by individual crabs in each of the three fishery systems, movement amongst the majority of recaptured animals was minimal. During both field surveys, most marked crabs were recaptured less than 2 km from where they were released which is consistent with previous studies. Potter *et al.* (2001) tagged 3000 blue swimmer crabs with Hallprint TBA-1 T-bar tags in Cockburn Sound, Western Australia, reporting that most recaptures occurred less than 2 km from the point of release. Potter *et al*. (1991) reported that 79% of blue swimmer crabs tagged with Floy anchor tags in a survey in Moreton Bay, Queensland, were likewise recaptured within 2 km of their release site. Bellchambers *et al.* (2005) tagged almost 5000 blue swimmer crabs with Hallprint FPN glue-on tags in Shark Bay, Western Australia and reported similar findings with the highest numbers of recaptured crabs travelling between 1.0 and 2.0 km from point of release to recapture.

However, it should be noted that it is not possible to determine the precise movement of tagged crabs between release and recapture. For example, a 154 mm CW male crab tagged and released in Nedlands in April 2015 was recaptured seven months later 2 km upstream in Matilda Bay. Given the winter migration of crabs in these areas of the SCE, it is unlikely that the crab had moved only in the upstream direction suggested by the points of release and recapture, but rather had moved downstream over winter before returning upstream in spring.

Moult increment

Tagging with the MT provided information on growth (moult increment) from both the laboratory trials and the second field survey. As this investigation was not in the scope of this project, the data will be analysed and published at a future date.

6 General Conclusion

The Southwest Recreational Crabbing Project (SWRCP) successfully developed cost-effective programs that delivered annual information on recreational fishing and stock dynamics in the iconic recreational blue swimmer crab fisheries of the Swan-Canning Estuary (SCE), the Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB).

Recreational fishers involved with the program were very supportive of the project: appreciating the opportunity to assist in developing a better understanding of their fishery and contributing towards maintaining its sustainability; developing an understanding of the survey work undertaken by the Department of Fisheries, Western Australia (DoF) when assisting with tagging surveys and fishery independent sampling; valuing having a platform to share their views on the management of their fishery; showing satisfaction at a DoF research presence in their fishery.

A successful Recreational Angler Program (RAP) for recreational crabbing was developed that provided useful temporal and spatial information on recreational catch and effort and catch composition, met the expectations of local communities, and was consistent with published literature on the respective crab stocks. The program has built on the success of the existing DoF RAP by refining efficiencies in data collection/validation and providing targeted information on recreational crabbing to support existing data which primarily covered finfish species. This data provides the primary catch and effort information available for these important recreational crab fisheries, and has proved useful for managers currently reviewing management arrangements for the southwest Western Australian crab resource.

Cost-effective breeding stock surveys using small mesh hourglass crab traps were developed in each of the three fisheries, with significant quantities of sexually mature and egg bearing female crabs sampled during all surveys. The mean annual catch rate in the SCE was consistent across the three years of sampling, while a slight decline was evident in the LE although this variation was not statistically significant. In contrast, a notable decline was experienced in GB with the reduction in catch rates between 2013 and 2015 of statistical significance. However, the three-year time series is not sufficient to determine the trends in this data. Sexually mature female crabs captured in the SCE were consistently larger than in the LE or GB, so while the mean annual catch rates were higher in the LE and GB than in the SCE, the breeding potential of the respective stocks was more comparable. This survey work identified the most suitable sampling locations in each fishery, confirmed October and November as suitable months to sample sexually mature and egg bearing female crabs and generated valuable catch rate information for annual egg production indices that will monitor the status of respective breeding stocks into the future. Otter trawling and beach seining were found to be suitable methods for collecting data to generate recruitment indices in SCE and LE, respectively.

The Hallprint Micro fine anchor T-bar tag (MT) proved superior to the FloyTag polyvinyl glue-on tag for the mark and recapture of blue swimmer crabs. While there were comparable recapture rates and movement data for crabs tagged with either marker, a number of recaptured crabs tagged with the MT moulted and retained the tag providing movement information over a longer period of the crab's life, along with moult increment data. The field surveys revealed there was a general upstream movement by both male and female crabs from late spring, through summer and into autumn in the SCE, with movement almost exclusively downstream from late autumn, through winter and into early spring. This movement is most likely due to changes in salinity caused by the influx of winter rains, which induce crabs to move downstream from Point Resolution during winter and early spring where spawning generally takes place. While some crab migration was identified from the SCE into the nearshore marine environments of Owen Anchorage (OA) and Cockburn Sound (CS), no crabs emigrated from these areas into the SCE during the survey period. Analysis of the methods employed by recreational fishers reporting tag recaptures during the two field surveys also provided a useful insight into the proportions of the different crabbing methods used in the overall crab fisheries of the SCE, LE and GB.

Future research

While the SWRCP has provided valuable data on crab stocks in the SCE, LE and GB, apparent trends need to be compared against longer time series of data to determine their biological significance. Therefore, DoF will maintain the RAP and fishery independent sampling components of the project to generate these longer-term datasets that could contribute to harvest strategies to monitor these fisheries into the future. The RAP will be maintained in its current form, and consideration will be given to incorporating CS and the Peel-Harvey Estuary (PHE) to supplement existing recreational fishing survey data in these fisheries. Future breeding stock surveys will be refined from 15 sites in each fishery to 10 sites in SCE and 8 sites in both LE and GB. This will save considerable resources as the SCE survey can be undertaken by two researchers rather than three, while the combined LE and GB surveys can be completed in two days rather than three. The recruitment trawl surveys in the SCE will also be maintained as the close proximity to Perth means costs are minimal.

Consideration will be given to exploring synergies with existing DoF crab survey work for tagging opportunities to refine the MT and hopefully improve levels of post-moult tag retention and survival, while further examining migratory patterns and the interrelatedness of crab stocks in the estuaries and embayments of southwest Western Australia, particularly between PHE and its nearshore marine environments. Information on growth (moult increment) of crabs tagged with the MT generated through the laboratory trials and second field survey of this study will be analysed and published at a future date.

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9 Appendices

9.1 Site location details

Table 9.1. Breeding Stock Survey site locations sampled using research hourglass traps in the Swan-Canning Estuary (SCE), the Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) sampled between October and November of each year of the SWRCP (2013-15). Refer to Fig 4.2-4.4 for individual site locations. These site locations were also sampled during the Glue-on Tagging Survey between September and December 2014.

Fishery	Site No.	Site Name	Latitude	Longitude	Depth (m)
SCE	S01	Sunny's Apartments	-32°02’464”	115°45’470”	5-7
	S02	Gilbert Fraser Reserve	-32°02’188”	115°45’628”	5-7
	S03	East Fremantle Boat Ramp	-32°01’980”	115°45’780”	4
	S04	North Fremantle Deep	-32°01’784”	115°45’513”	4
	S05	North Fremantle Shallow	-32°01’698”	115°45’520”	2
	S06	East Fremantle Yacht Club	-32°01’624”	115°46’240”	10
	S07	Bicton Baths	-32°01’511”	115°46’667”	15
	S08	Blackwall Reach	-32°00’991”	115°47’085”	17
	S09	Chidley Point	-32°00’829”	115°46’748”	17
	S10	Karrakatta Bank	-31°59’781”	115°46’732”	3
	S11	Dalkeith	-32°00’302”	115°47’563”	7
	S12	Ardross	-32°01’080”	115°49’020”	5
	S13	Heathcote	-32°00’132”	115°5’334”	7
	S14	Como	-31°59’485”	115°51’067”	4
	S15	Matilda Bay	-31°58’778”	115°49’386”	4
LE	L01	Canal Marker	-33°18’098”	115°39’009”	10-11
	L02	Breakwater	-33°18’071”	115°38’876”	10-11
	L03	Old Jetty	-33°18’460”	115°38’747”	5-7
	L04	Ski Area	-33°18’850”	115°38’572”	2-3
	L05	Dolphin Beach	-33°19’087”	115°38’736”	3-5
	L06	Power Station	-33°18’737”	115°39’667”	3-5
	L07	South of Cut	-33°18’414”	115°40’010”	3-4
	L08	North of Cut	-33°18’043”	115°40’258”	3-4
	L09	Turkey Point	-33°18’339”	115°40’522”	2-3
	L10	Belvedere Camp	-33°18’251”	115°40’745”	2-3
	L11	Leads	-33°18’510”	115°39’453”	6
	L12	North of Channel Marker	-33°18’963”	115°39’401”	7
	L13	Spit	-33°18’250”	115°39’671”	5-7
	L14	Cable Sands	-33°19’123”	115°39’182”	2-4
	L15	Casuarina Harbour	-33°18’771”	115°38’236”	2-4
GB	G01	Gannet Rock	-33°34’176”	115°05’382”	7
	G02	Little Meelup	-33°34’692”	115°05’764”	7

Fishery	Site No.	Site Name	Latitude	Longitude	Depth (m)
	G03	North Curtis	-33°35’379”	115°06’321”	7
	G04	Old Dunsborough	-33°35’401”	115°06’215”	7
	G08	Siesta Park	-33°39’035”	115°12’491”	4
	G10	Holy Mile	-33°39’351”	115°14’484”	4
	G12	Broadwater Outside	-33°39’091”	115°16’709”	5
	G13	Broadwater Inside	-33°39’292”	115°16’973”	4
	G14	Dolphin Road	-33°39’239”	115°18’209”	4
	G15	Bower Road Outside	-33°38’701”	115°18’595”	4
	G20	West of Busselton Jetty	-33°38’711”	115°19’875”	4
	G22	East of Busselton Jetty	-33°38’528”	115°20’883”	4
	G27	Wonnerup Inlet	-33°36’895”	115°24’657”	7
	G30	Forrest Beach	-33°34’912”	115°27’113”	3
	G33	Busselton Sea Rescue	-33°38’444”	115°21’298”	3

Table 9.2. Recruitment survey site locations for the Swan-Canning Estuary (SCE), the Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB) sampled between March and May of each year (2014 – 2016) of the SWRCP.

Fishery	Site No.	Site Name	Latitude	Longitude	Year Sampled	Methodology
SCE	S51	Gilbert Fraser Reserve	-32°02’183”	115°45’548”	2014 and 2015	Seine net
	S52	Zephyrs	-32°00’983”	115°45’510”	2014 and 2015	Seine net
	S53	Point Walter Spit	-32°00’618”	115°47’120”	2014 only	Seine net
	S54	Point Walter Dog Park	-32°00’560”	115°47’440”	2014 only	Seine net
	S55	Ardross	-32°00’926”	115°49’741”	2014 only	Seine net
	S56	Applecross Jetty	-32°00’329”	115°49’968”	2014 only	Seine net
	S57	Heathcote	-32°00’339”	115°50’360”	2014 only	Seine net
	S58	Canning River Boat Ramp	-32°00’983”	115°51’412”	2014 only	Seine net
	S59	Como Jetty	-31°59’700”	115°51’180”	2014 only	Seine net
	S60	Pelican Point	-31°59’280”	115°49’620”	2014 only	Seine net
	S61	Claremont Jetty	-31°59’700”	115°47’280”	2014 only	Seine net
	S62	Bicton	-31°01’380”	115°46’860”	2014 and 2015	Seine net
	S02	Gilbert Fraser Reserve	-32°02’183”	115°45’548”	2016	Otter trawl
	S03	East Fremantle Boat Ramp	-32°01’980”	115°45’780”	2016	Otter trawl
	S05	North Fremantle Shallow	-32°01’698”	115°45’520”	2016	Otter trawl
	S06	East Fremantle Yacht Club	-32°01’624”	115°46’240”	2016	Otter trawl
	S07	Bicton Baths	-32°01’511”	115°46’667”	2016	Otter trawl
	S08	Blackwall Reach	-32°00’991”	115°47’085”	2016	Otter trawl

Fishery	Site No.	Site Name	Latitude	Longitude	Year Sampled	Methodology
	S09	Chidley Point	-32°00'829"	115°46'748"	2016	Otter trawl
	S10	Karrakatta Bank	-31°59'781"	115°46'732"	2016	Otter trawl
	S11	Dalkeith	-32°00'302"	115°47'563"	2016	Otter trawl
LE	L51	Pelican Point	-33°18'480"	115°41'400"	2014 -2016	Seine net
	L52	Australind Boat Ramp	-33°16'560"	115°42'780"	2014 - 2016	Seine net
	L53	Balmoral	-33°15'240"	115°42'980"	2014 - 2016	Seine net
	L54	Casuarina Harbour	-31°18'900"	115°38'280"	2014 - 2016	Seine net
GB	G51	Toby's Inlet	-33°38'461"	115°10'670"	2014 only	Seine net
	G52	Milloy Drain	-33°39'020"	115°12'283"	2014 only	Seine net
	G53	Abbey Drain	-33°39'398"	115°14'877"	2014 only	Seine net
	G54	Queen Elizabeth Drain	-33°39'066"	115°19'441"	2014 only	Seine net
	G10	Holy Mile	-33°39'351"	115°14'484"	2015	Hourglass trap
	G13	Broadwater Inside	-33°39'292"	115°16'973"	2015	Hourglass trap
	G14	Dolphin Road	-33°39'239"	115°18'209"	2015	Hourglass trap
	G22	East of Busselton Jetty	-33°38'528"	115°20'883"	2015	Hourglass trap
	G27	Wonnerup Inlet	-33°36'895"	115°24'657"	2015	Hourglass trap
	G30	Forrest Beach	-33°34'912"	115°27'113"	2015	Hourglass trap
	G52	Buanyanyup Drain	-33°39'540"	115°14'640"	2015	Hourglass trap
	G37	Wonnerup Estuary	-33°36'720"	115°25'920"	2015	Hourglass trap
	G38	Port Geographe Marina	-33°37'800"	115°23'280"	2015	Hourglass trap
	G08	Siesta Park	-33°39'035"	115 ° 12'491"	2016	Otter trawl
	G11	-	-33°38'930"	115 ° 17'043"	2016	Otter trawl
	G12	Broadwater Outside	-33°39'091"	115°16'709"	2016	Otter trawl
	G13	Broadwater Inside	-33°39'292"	115°16'973"	2016	Otter trawl
	G14	Dolphin Road	-33°39'239"	115°18'209"	2016	Otter trawl
	G15	Bower Road Outside	-33°38'701"	115°18'595"	2016	Otter trawl
	G19	-	-33°38'643"	115 °.19'646"	2016	Otter trawl
	G20	West of Busselton Jetty	-33°38'711"	115°19'875"	2016	Otter trawl
	G22	East of Busselton Jetty	-33°38'528"	115°20'883"	2016	Otter trawl
	G27	Wonnerup Inlet	-33°36'895"	115°24'657"	2016	Otter trawl
	G33	Busselton Sea Rescue	-33°38'444"	115°21'298"	2016	Otter trawl
	G51	Toby's Inlet	-33 °38'461"	115°10'670"	2013	Seine net

Tagging surveys

Table 9.3. Site locations of the Glue-on Tagging Survey in the study areas of Owen Anchorage (OA) and Cockburn Sound (CS). Sampling within these areas took place between September and December 2014.

Fishery	Site No.	Latitude	Longitude	Depth (m)
OA	A1	-32°03’500”	115°44’491”	2.3
	A2	-32°04’084”	115°44’491”	3
	A3	-32°04’444”	115°43’551”	6
	A4	-32°04’371”	115°42’143”	15
	A5	-32°05’203”	115°41’347”	6
	A6	-32°05’276”	115°42’143”	12
	A7	-32°06’108”	115°42’467”	13
	A8	-32°06’324”	115°40’060”	14
	A9	-32°06’432”	115°41’276”	10
	A10	-32°07’551”	115°42’108”	6
	A11	-32°07’119”	115°43’191”	12
	A12	-32°07’588”	115°43’443”	3
	A13	-32°07’549”	115° 44’186”	3
	A14	-32°07’481”	115° 45’200”	3
	A15	-32°06’251”	115° 45’216”	10
CS	C1	-32°09’431”	115° 43’443”	18
	C2	-32°09’396”	115° 42’108”	21
	C3	-32°09’467”	115° 40’480”	14
	C4	-32°11’492”	115° 41’060”	12
	C5	-32°12’252”	115° 42’000”	21
	C6	-32°14’203”	115° 42’575”	17
	C7	-32°15’143”	115° 42’324”	3
	C8	-32°15’432”	115° 42’143”	4
	C9	-32°15’504”	115° 42’287”	16
	C10	-32°15’324”	115° 43’156”	18
	C11	-32°14’564”	115° 43’407”	19
	C12	-32°13’443”	115° 44’312”	17
	C13	-32°12’216”	115° 44’204”	17
	C14	-32°12’000”	115° 45’306”	8
	C15	-32°10’299”	115° 45’324”	9

Table 9.4. Tagging site locations for the second field survey in the SCE running from March 2015 – March 2016. Sites were divided into five areas within the SCE for spatial analysis.

Spatial Area	Site Number	Site Name	Latitude	Longitude	Depth (m)
Swan Entrance	S01	Sunny's Apartments	-32°02'464"	115°45'470"	5-7
	S02	Gilbert Fraser Reserve	-32°02'188"	115°45'628"	5-7
	S04	North Fremantle Deep	-32°01'784"	115°45'513"	4
	S06	East Fremantle Yacht Club	-32°01'624"	115°46'240"	10
	S08	Blackwall Reach	-32°00'991"	115°47'085"	17
	S09	Chidley Point	-32°00'829"	115°46'748"	17
Lower Swan	S10	Karakatta Bank	-31°59'781"	115°46'732"	5
	S33	Claremont Jetty	-31°59'461"	115°46'993"	10
	S32	Point Resolution	-32°00'059"	115°47'262"	8
	S11	Dalkieth	-32°00'302"	115°47'563"	7
	S12	Ardross	-32°01'080"	115°49'020"	5
	S29	Nedlands	-32°00'225"	115°48'300"	9
Middle Swan	S30	Jojos	-31°59'539"	115°49'139"	7
	S13	Heathcote	-32°00'132"	115°50'334"	7
	S31	Pagoda Spit	-31°59'539"	115°05'303"	3
	S14	Como	-31°59'485"	115°51'067"	4
	S15	Matilda Bay	-31°58'778"	115°49'386"	4
	S22	Swan Brewery	-31°57'960"	115°50'445"	4
Upper Swan	S16	Windan Bridge	-31°57'027"	115°53'073"	2
	S17	Herrison Island	-31°57'997"	115°52'594"	2
	S18	Barrack St. Jetty	-31°57'768"	115°51'853"	2
	S19	Ferry Channel West	-31°57'878"	115°51'332"	2
	S20	Ferry Channel East	-31°58'022"	115°51'343"	2
	S21	Elizabeth Quay	-31°57'650"	115°51'048"	3
Canning River	S23	South of Perth Yacht Club	-32°00'112"	115°51'135"	4
	S24	Raffles Hotel	-32°00'429"	115°51'029"	4
	S25	Canning Bridge	-32°00'715"	115°51'286"	5-9
	S26	Deepwater Point	-32°01'138"	115°51'078"	4
	S27	Mt Henry Bridge	-32°01'865"	115°51'215"	3
	S28	Salter Point	-32°01'780"	115°51'766"	2

9.2 Tag recapture information sheet

Government of **Western Australia**
Department of **Fisheries**

Southwest Recreational Crabbing Project

True Blue Swimmer Tagging Survey

Dear (insert name of fisher),

Thank you for contacting the Department of Fisheries about your tagged blue swimmer crab(s). We thought that you might like to know more about your tagged crab(s) and the True Blue Swimmer Tagging Survey.

What we're doing

The Crab Research section conducted a successful pilot tagging study on blue swimmer crabs over the 2014/15 summer. Temporary tags were glued to the carapace of 1125 crabs in the Swan-Canning Estuary between October – December 2014. More than 10% of these crabs were later recaptured by recreational crabbers which was a great result and provided some really useful information on crab movement in the Estuary. However, there were no more recaptures after February as the tags were lost when the crabs undertook their moult (between December and February).

So we are carrying out a second tagging survey during 2015/16 to further investigate crab movement in the Estuary, and to test a more permanent T-bar tag that we hope will remain attached to the crab through its moult and give us information over a much longer period.

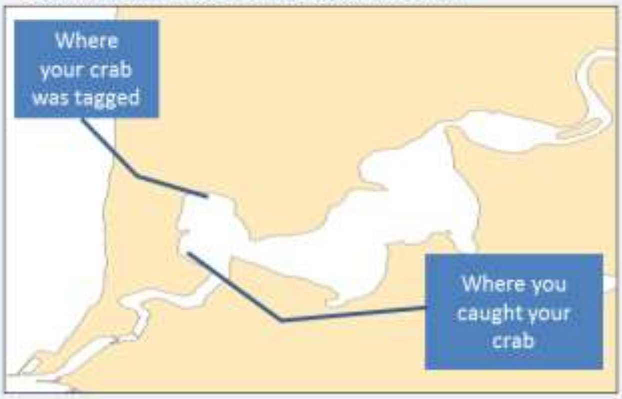
During this survey, half of the crabs we catch will be tagged with either the temporary tag glued onto the carapace or a T-bar tag attached to the muscle between the carapace and the right swimming leg of each crab, while the other half will be tagged with both the glue-on tag and the T-bar tag. We can then compare recapture rates to look at retention of the T-bar tag after the crabs moult.

Number of tags and reported recaptures

So far we have tagged 3,267 crabs in the Swan, 186 crabs around the Leschenault Estuary and 173 in Geographe Bay. We've already had 323 tagged crabs recaptured, of which 97 were tagged with a glue-on tag only, 52 with a T-bar tag only, and 174 tagged with both types of tags. Out of those, 180 have been consumed by crabbers, but we're pleased to say 139 were released back to the water to find out where they go next!

Information on your crabs:

Glue-on tag number: A5908 T-Bar tag number: C861
Sex & size tagged: F; 162mm
Date tagged: 26/02/2016
Date recaptured: 22/06/2016
Time at Liberty: 117 days
Distance between release and recaptures: 2.5 km



This project was made possible by the Recreational Fishing Initiatives Fund, which is financed with Recreational Fishing from Boat Licence (RFBL) fees and overseen by RecFishWest.

Contact information:

For information on the Southwest Recreational Crabbing Project or if you happen to come across a tagged crab please contact:
David Harris t: (08)92030252 m: 0427988220 e: David.Harris@fish.wa.gov.au
Josh Baker t: (08)92030176 e: Josh.Baker@fish.wa.gov.au
iPhone users can submit tagged crab sightings using our **FISHTAGWA** app on the appstore.
You can also submit the information using an **online form** at: https://lobsterapp.shinyapps.io/App_3/