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Improving confidence in the management of the blue swimmer crab (*Portunus armatus*) in Shark Bay

PART III: Proceedings of the Third National Workshop on Blue Swimmer Crab *Portunus armatus*

Western Australian Fisheries and Marine Research Laboratories, Hillarys, Perth, 3 – 4 June 2015

FRDC Project No. **2012/15**

Coordinated and edited by Arani Chandrapavan

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Supplementary Material

PowerPoint presentations and visual media presentations by individual authors are available by request. Please contact via email or telephone to arani.chandrapavan@dpird.wa.gov.au or (08) 9203 0158.

1 Executive summary

The 'Third National Workshop on Blue Swimmer Crab' was organised and held at Department of Fisheries (Western Australia) in Hillarys (3-4 June, 2015), almost 15 years after the second workshop in 1997. The workshop brought together fisheries scientists, managers, university researchers, consultants, industry stakeholders and fishers from across Queensland, New South Wales, South Australia, Tasmania and Western Australia and addressed six broad themed sessions;

- State overview of blue swimmer crab commercial fisheries
- Monitoring, stock assessment and harvest strategy
- Environmental drivers and climate change
- Blue swimmer crabs….from the sea to the plate
- Recreational fishing and surveys
- Management, policy and industry perspectives

Despite the large body of research knowledge acquired across all its crab stocks in Australia, there is a large variation in the performance of the fisheries which require intensive management. The average commercial catch in Australia during the 2000s was about 2500 t but this has declined to about 1500 t during 2012 and 2013 mainly due to reduced catches in WA and QLD. The estimated total recreational catch of blue swimmer crab nationally in 2011/12 was 6.6 million (by number), but there is an ongoing challenge to obtain accurate and precise estimates of recreational catch at spatial scales relevant to fisheries management.

Management strategies varied considerably across the different fisheries and between States. Crab stocks in South Australia and in Shark Bay (WA) are currently under quota management. Input controls such as minimum size limits, pot/trap regulations and protection of berried females were common across all fisheries while QLD crab stocks are managed under a single sex harvest strategy (although this is currently under review). Trapping is the most common commercial fishing method for blue swimmer crabs, and although there are no dedicated trawl based crab fisheries, crabs are harvested by the prawn (and to a lesser degree scallop) trawl fisheries in Shark Bay and prawn trawlers in QLD. Netting and fish traps were permitted in some States.

Monitoring programs varied between States with traps being the primary sampling tool in some jurisdictions whilst trawling was used by others. Monitoring programs also targeted different sized crabs (juvenile vs sublegal crabs) during these sampling programs. Stock assessments ranged from annual summaries of commercial catch and effort data in developing fisheries in WA and NSW, to more comprehensive assessments based on performance measures of biological (and economic in QLD) indicators that are linked to harvest strategies with defined control rules (e.g., SA and Cockburn Sound). The workshop also identified the need for both fishery dependent and independent monitoring of stocks with independent measures being very important for quota based fisheries. Fishery independent sampling is being applied extensively in both SA and WA blue swimmer crab commercial and recreational only fisheries. Third party Marine Stewardship Council assessment of blue swimmer crab fisheries are underway in WA and SA.

Understanding environmental drivers and adapting to climate change was recognised as the most recent challenge to face blue swimmer crab fisheries, particularly in light of recent extreme weather events (e.g., heat wave impact on Shark Bay fishery). Underlying climate change trends relating to annual rainfall and water temperatures was a common concern. A risk assessment of the vulnerability of blue swimmer crabs to climate change ranked them as one of 10 species with a high risk, therefore early detection of abundance changes is important to ensure sustainable management of the stocks. This can be achieved by (a) early detection of environmental changes and an understanding of their effect on stocks, (b) monitoring pre-recruits for early detection of abundance changes, and (c) having a harvest strategy that is responsive to abundance changes to protect spawning stock. A better understanding of seasonal variability in spawning success, spatial distribution and recruitment dynamics of blue swimmer crabs was identified as a key objective for improved management of blue swimmer crab fisheries.

Overall, the workshop highlighted the high number of managed blue swimmer crab fisheries across the country and the varying management strategies and monitoring programs within each jurisdiction. The underlying mechanism for state-wide differences largely arose from the difference in the stock biology, physical location of the stocks, availability of resources and funding, stakeholder involvement and the political drivers within each State.

1.1 Workshop introduction

Workshop coordinated by Arani Chandrapavan, Research Scientist, WA Department of Fisheries

The blue swimmer crab, *Portunus armatus* (formerly *Portunus pelagicus,* Lai et al. 2010), is both a commercially and recreationally important species across Australia. The first and second national workshops on blue swimmer crabs were held in 1997 (Kumar 1997) and 1999 (Melville-Smith 1999), when recreational and commercial fisheries for blue swimmer crabs across Australia were being recognised for their value, and research gaps were being addressed through a number of Fisheries Research and Development Corporation (FRDC) funded projects across the States. Since then, blue swimmer crab fisheries across Australia have dramatically expanded, adopted different management strategies, experienced environmentally driven stock declines, subject to evolving market dynamics, and continue to face resource allocation challenges.

The 'Third National Workshop on Blue Swimmer crab' was organised and held at the Hillarys Research Laboratories of WA Department of Fisheries in Perth (3-4 June, 2015) and funded by FRDC as an objective of the project "Improving confidence in the management of the blue swimmer crab (*Portunus armatus*) in Shark Bay' (Project 2012/015). The 2-day workshop brought together fisheries scientists, managers, university researchers, consultants, industry stakeholders and fishers from across Queensland, New South Wales, South

Australia, Tasmania and Western Australia. The workshop addressed six broad themed sessions:

- State overview of blue swimmer crab commercial fisheries
- Monitoring, stock assessment and harvest strategy
- Environmental drivers and climate change
- Blue swimmer crabs….from the sea to the plate
- Recreational fishing and surveys
- Management, policy and industry perspectives

The workshop was opened by a welcome address from Dr Lindsay Joll, Acting Deputy Director General of WA Department of Fisheries and this was followed by Dr Mervi Kangas who gave an introduction on the national status of blue swimmer crab stocks and the expected outcomes of this workshop that were to:

- Provide a forum for the exchange of current research undertaken and management challenges within each jurisdiction
- Provide networking opportunities for managers, researchers and industry (commercial and recreational) members
- Identification of synergies and challenges between research, management and industry needs for possible collaborative future projects
- Publication of the workshop proceedings

Overall, the workshop was deemed timely given the range of challenges and management review processes currently underway for blue swimmer crab fisheries across the country. The workshop highlighted a new era in blue swimmer crab fisheries management with the development of/or improvements in existing harvest strategies with defined performance indicators and control rule frameworks. Blue swimmer crabs have now achieved the status of the most popular invertebrate recreational species in Australia (with the largest numbers caught) putting greater pressure on management and compliance. Blue swimmer crabs are now commercially harvested using multiple gear types as well being either a target or by-product species. Therefore, accurately capturing catch and effort data to assess stock status was recognised as an ongoing challenge. The biology and life cycle of *P. armatus* vary across its geographic distribution and due to its recently observed vulnerability to climate change the species is now ranked as "high risk"**.** Recognising these issues and the overall downturn in the production of blue swimmer crabs in Australia (Figure 1), this workshop provided an opportunity to review current stock status and the reasons behind the variable performances of these fisheries.

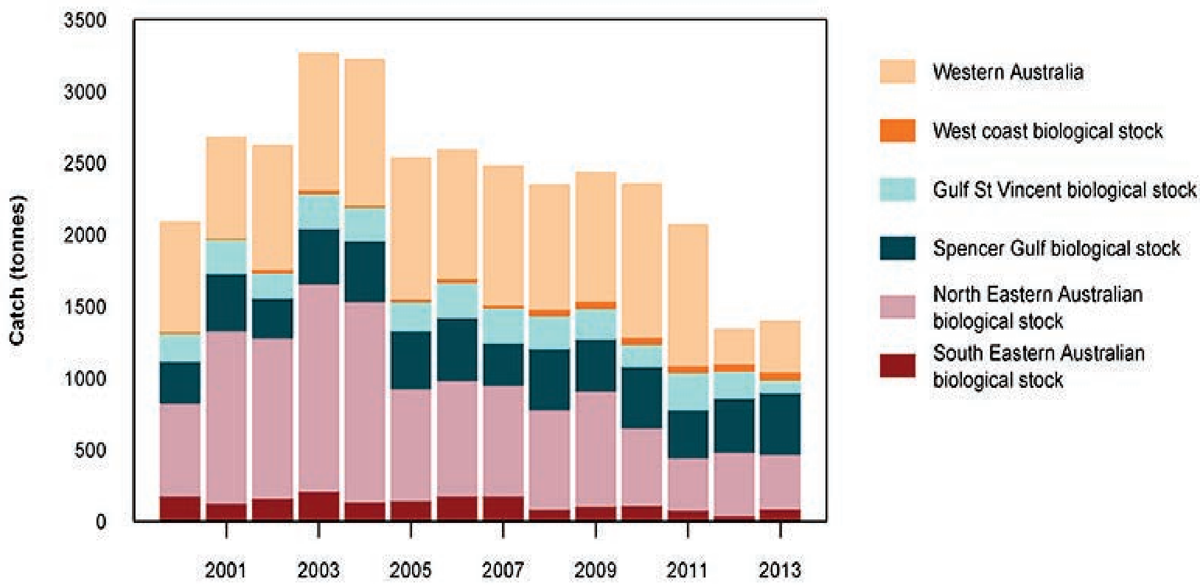

Figure 1. Commercial catch of blue swimmer crab (*Portunus armatus*) in Australian waters, 2000 to 2013 (calendar years). Source: Johnston et al. 2014. Status of key Australian fish stocks reports 2014, Fisheries Research and Development Corporation, Canberra.

2 Session 1: State Overview of Blue Swimmer Crab Commercial Fisheries

Chaired by Jim Penn, Emeritus Director Research, WA Department of Fisheries

Research scientists gave an overview presentation of their respective crab fisheries and stock status (Table 1). This session highlighted the high number of managed blue swimmer crab fisheries across the country and the varying management strategies and monitoring programs within each jurisdiction. The underlining mechanism for state-wide differences largely arose from the difference in the stock biology, physical location of the stocks, availability of resources and funding, stakeholder involvement and the political drivers within each State.

Western Australia had the most number of managed fisheries with stock status ranging from sustainable (e.g. Peel Harvey Estuary Fishery) to severe decline with fishery closure status (e.g. Cockburn Sound Fishery) and one in stock recovery (Shark Bay Crab Fishery). There is also a newly emerging fishery (e.g. WA South Coast Estuarine) due to geographic range extension of the species after the marine heat wave in 2010/11. South Australian and Queensland fisheries appeared to be the most stable with long-term sustainable crab stocks, however there is some debate in QLD about whether the offshore fishery is in a “transitional depleting” status. Blue swimmer crabs in New South Wales are not managed as a single species and due to the large degree of uncertainty and inaccuracies in the commercial and recreational catch and effort data, its stock status is currently undefined.

Management strategies varied considerably across the different fisheries and between States. Crab stocks in South Australia and Shark Bay in WA are currently under quota management, while QLD crab stocks are managed under a single sex harvest strategy (although this is currently under review). Input controls such as minimum size limits, pot/trap regulations and protection of berried females were common across all fisheries. Trapping is the most common commercial fishing method for blue swimmer crabs, and although there are no dedicated trawl based crab fisheries, crabs are harvested by the prawn (and to a lesser degree scallop) trawl fisheries in Shark Bay and prawn trawlers in QLD. Crabs although caught by SA prawn trawlers are prohibited to be retained. Netting and fish traps were permitted in some States.

Blue swimmer crabs are a major recreational species in all States which highlights its social importance. It was noted that in some fisheries such as in NSW and in the Peel Harvey Estuary Fishery, the recreational harvest is likely to be higher than the commercial landings. All States identified climate change as the most recent challenge impacting on the sustainable management of crab stocks. The marine heat wave event of 2010/11 in WA was one example of an extreme environmental event, but the underlying climate change trends relating to annual rainfall and water temperatures was a common concern. A better understanding of seasonal variability in spawning success, spatial distribution and recruitment dynamics of blue swimmer crabs was identified as a key objective for improved management of blue swimmer crab fisheries.

Table 1. Overview of blue swimmer crab fisheries around Australia, 2013/14

	South Australia	Queensland	New South Wales	Western Australia
Commercial fisheries	Gulf St Vincent (GSV) Spencer Gulf (SG) Marine Scalefish Fishery	Moreton Bay Hervey Bay Offshore Fishery	The Estuary General Fishery (70 estuaries- 5 account for 95% of landings)	Shark Bay Peel Harvey Estuary Cockburn Sound Swan River Warnbro Sound Mandurah to Bunbury Pilbara
GVP	$4.5 million	$ 3 million	$1 million	$ 2.9 million
Commercial catch	628 tonnes	346 tonnes (male only)	178 tonnes (13/14)	553 tonnes (13/14)
No. Licenses	4 SG 3 GSV	400+ potential 120 active	Not a single species managed fishery	Shark Bay (5 trap, 18 prawn trawl, 11 scallop trawl) Cockburn Sound (12 trap - 3 active before closure) Peel Harvey Estuary (10 trap) Swan River (1) and Warnbro Sound (1)
Stock status	Sustainable (13/14)	Sustainable	Undefined and uncertain	Shark Bay - Recovering Cockburn Sound is closed Warnbro Sound is under review All others -Sustainable
Size limits	110 mm (base of spines)	115 mm (base of spines)	60 mm (carapace length)	State-wide recreational size limit of 127 mm (tips of spine) Commercial size limits up to 135 mm (tips of spine)
Fishing gear	Trap, hoop/drop nets, rake	Trap, trawl	Traps, gill nets, trawls, seines (17 gear types)	Traps, trawl, gill nets
Protection measures	Berried females	All females	Berried females	Berried females
Recreational catch estimates	284 tonnes (07/08)	Estimates highly unreliable	150 – 310 tonnes	Shark Bay ~2.4 t West coast Bioregion ~ 72 t (13/14 boat based)
Recreational Limits	GSV 20/person or 60/boat All other waters 40/person or 120/boat	No recreational catch limit Effort limit of 4 traps/person	State-wide 10/person	State-wide - 10/person or 20/boat

Fishing season	1 July – 30 Jun (12 months)	12 months with most fishing Sep-Jun	12 months	Shark Bay – 1 Nov to 31 Oct (12 months) Peel Harvey Estuary – 1 Nov - 31 Aug Cockburn Sound – variable but now closed Warnbro Sound – closed but previously 1 Dec – 30 Sep Swan River – all year (but don't fish all months) Mandurah-Bunbury – all year
Harvest strategy	YES - performance indicators with reference levels	NO but under review	Not a single species managed fishery	Being developed for all fisheries
Monitoring programs	Annual or biennial fishery independent trap survey (June/July) small mesh pots sampling Logbook (compulsory)	Fishery independent monitoring (beam trawl survey-Nov/Dec) Daily logbook	Annually as part of state-wide assessment program	Commercial monitoring for all west coast fisheries Fishery independent trap and trawl surveys (different survey frequencies for different fisheries) Recreational trap and seine surveys Research logbooks
Management	TAC (70 % commercial, 29% recreational and 1% traditional)	Male only input controlled fishery – under review	Input control and share managed-under review	Shark Bay under TACC (66% trap, 33.8% prawn trawl, 0.2% scallop trawl) All others input controlled – minimum size, seasonal/temporal closures, trap numbers
Climate change impacts	Unknown	Unknown	Unknown	Marine heat wave of 2010/11 – stock decline in Shark Bay Decreasing rainfall – less flushing of estuaries Increasing water temperatures may shift spawning period Range extension to the south coast of WA Changes in primary productivity may be influencing crab production
External certification	MSC pre-assessment underway Coles wild seafood sustainability rating of GREEN	Coles wild seafood sustainability rating of GREEN	Nil	MSC pre-assessments of all fisheries MSC full assessment underway for Peel-Harvey Estuary MSC full assessment for Shark Bay in 2016 Coles wild seafood sustainability rating of GREEN for Shark Bay and RED for Cockburn Sound

2.1 Overview of Western Australia's Blue Swimmer Crab Fisheries

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The blue swimmer crab, *Portunus armatus*, forms an important component of both commercial and recreational fisheries in Western Australia, with the 2013/14 commercial landings estimated at 553 tonnes (the 7th highest species for WA) and valued at over $5 million. It is widely distributed along the WA coast, currently supporting 9 commercial fisheries spanning from the Pilbara on the north coast to Albany on the south coast (Figure 2). The purpose of this presentation is to provide an overview of each of these fisheries with a focus on the south-west, including a brief history, catch and current stock status.

The state catch increased steadily from 1999 to 2010, peaking in 2009/10 and 2010/11 at more than 1000 t (Figure 3). This trend was influenced by increases in Shark Bay, with the majority of the catch coming from this region. Following this peak there was a dramatic drop in state catch, due to the decline of the Shark Bay fishery after the 2010/11 summer marine heat wave event. This fishery is described in a separate presentation.

In the West Coast Bioregion, the south-west commercial blue swimmer crab fisheries include Cockburn Sound, Swan River, Warnbro Sound, Peel-Harvey Estuary and Mandurah-Bunbury (Figure 4). These stocks represent approximately 30% of the commercial catch for WA in 2013/14, however being in close proximity to the majority of the state population, the south-west represents around 90% of recreational catch. All fisheries operate as distinct management units under varying input controls of season length, minimum size and trap allocation, with all fishers (except for Swan River) using hourglass traps.

In 2013/14 the commercial catch for the West Coast Bioregion dropped from 215 t to 162 t as a result of the second stock decline in Cockburn Sound (first in 2006/07) (Figure 4). Catches in Cockburn Sound peaked at almost 350 t in the late 1990s, following the conversion from gill nets to traps. Due to *P. armatus* being a highly fecund and short-lived species, it was believed to be resilient to high fishing pressure, provided the minimum size limit was set well above size at maturity. The cause of first decline was a combination of unfavourable environmental conditions and heavy fishing pressure on mated pre-spawn females in winter following the conversion to traps. After a brief recovery, peaking around 60 t in 2012/13, the fishery underwent another decline and closed in April/May 2014. The causes of this second decline are being investigated but are likely to be environmental with the fishery classed as "environmentally limited".

The iconic Swan-Canning Estuary is unique in that the crabs in this area grow very large and it is the only WA commercial crab fishery using subsurface gill nets. There has been a single commercial operator since 2008 with catches around 10 t, but is a very important recreational fishery. Both commercial and recreational fishers are permitted to fish year-round however effort is concentrated over summer. Warnbro Sound crab fishery has one commercial operator and catches have recently declined following a peak of 35 t in 2011/12 and stocks are being monitored closely.

With the current closure of Cockburn Sound, the Peel-Harvey estuary is now the largest fishery in the West Coast Bioregion (104 t in 2013/14) and is experiencing some of its highest catches on record. Crabs recruit into the estuary over summer and are flushed out during winter rains with sexually mature females spawning near the entrance channels and offshore. The Mandurah to Bunbury Developing crab fishery is a small fishery with 2 operators, fluctuating between 2 and 26 t, but most recently below 10 t. Catches are mostly female and are thought to contribute to the breeding stock for the Peel-Harvey crab fishery.

Recent increases in crab catch within the South Coast Estuarine net fishery due to the warmer water temperatures in recent years (e.g. heat wave) have resulted in a crab pot trial commencing in 2015 in the Wilson and Irwin Inlets. Crab fisheries also operate in the Pilbara region of WA, mostly around Nickol Bay, with a single operator catching between 5 and 60 t annually depending on environmental conditions and level of effort.

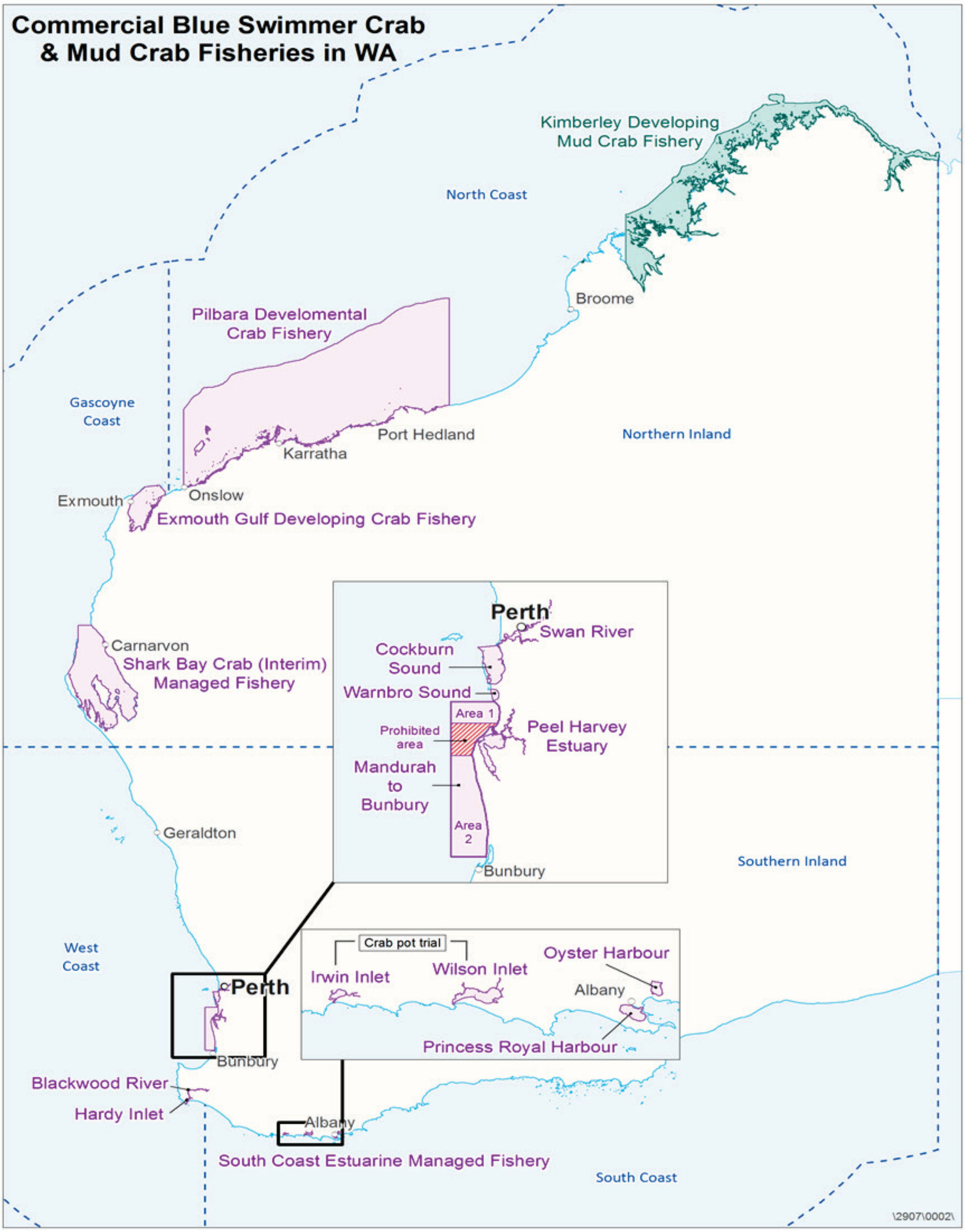

Figure 2. Distribution of commercial blue swimmer crab and mud crab fisheries in Western Australia.

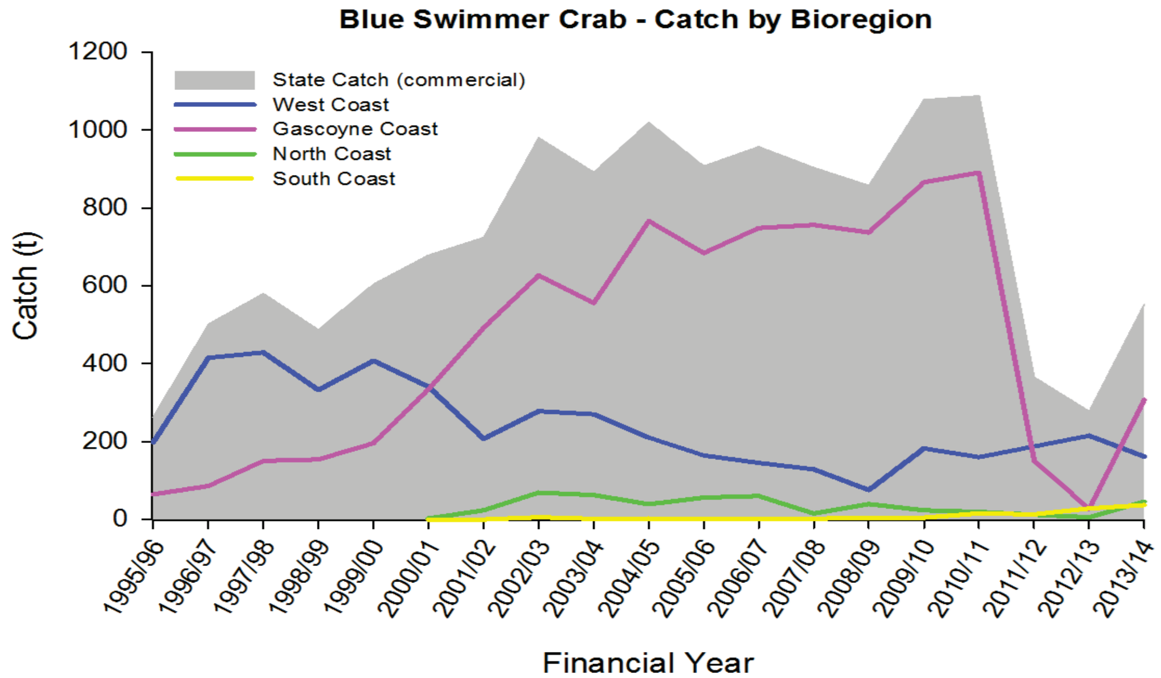

Figure 3. State and bioregion commercial catch history for the blue swimmer crab in Western Australia since 1995/96.

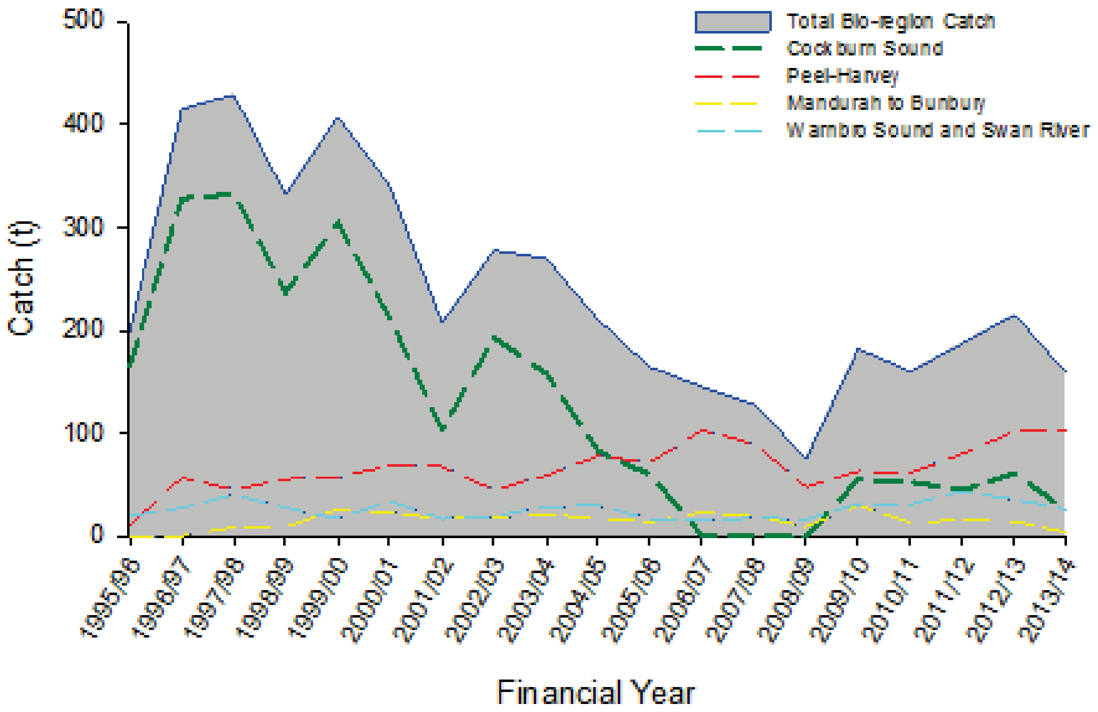

Figure 4. South-West bioregion commercial catch history for the blue swimmer crab in Western Australia since 1995/96.

2.2 The Rise, the Fall and Recovery of the Shark Bay Crab Fishery

Arani Chandrapavan, Mervi Kangas and Nick Caputi
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The blue swimmer crab (*Portunus armatus*) stock in Shark Bay, Western Australia once was Australia's highest producing blue swimmer crab fishery with landings peaking at 828 tonnes in 2010 (Figure 5). This resource is harvested commercially by the Shark Bay Crab trap fishery and the Shark Bay prawn and scallop trawl fisheries. However in late 2011, crab stocks were at historically low levels due to a recruitment failure and mortality of adult stock which led to the closure of the fishery. The stock collapse was attributed to an extreme marine heat wave event, which occurred over the austral summer of 2010/11 along the mid-west region of Western Australia where sea-surface temperatures were raised 2-4°C above average. This event altered the marine ecosystem with significant impacts on inshore habitats as well as fish kills, range extension of species and recruitment failures of several species that were the basis of major invertebrate fisheries. A correlation assessment of catch rates and monthly sea surface temperatures in the previous two years identified the cause of the recruitment failure in 2011/12 to be a combination of a very cool winter in 2010 followed by the heat wave in the summer of 2010/11. As of 2014 temperatures have returned to their historic average, which has allowed for the crab stock to recover, and commercial fishing to resume under a new ITQ management system.

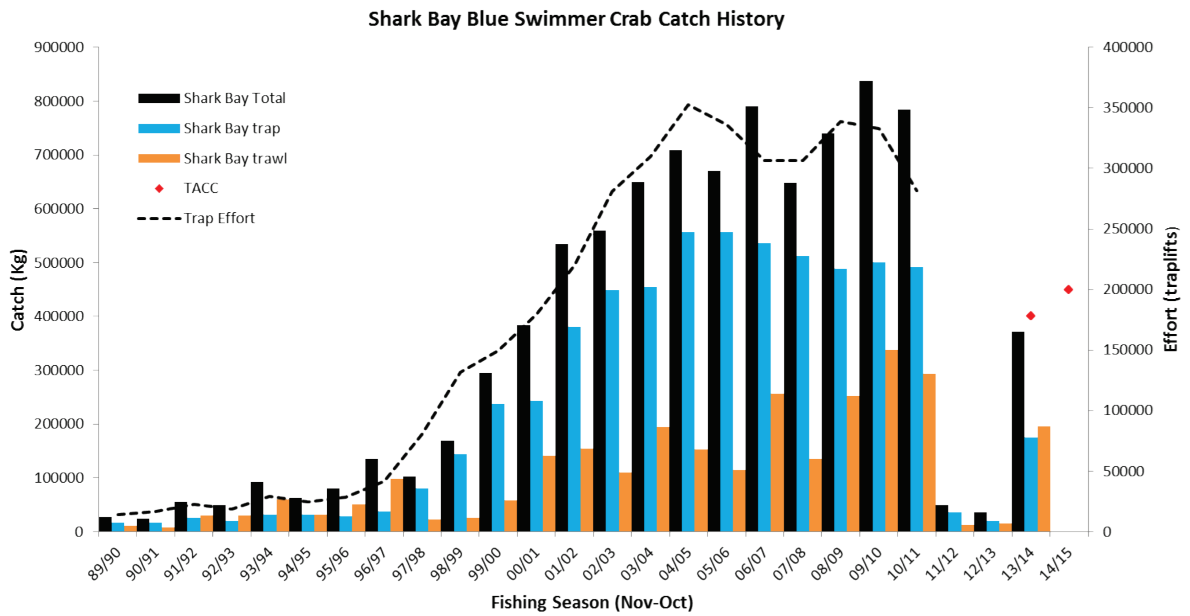

Figure 5. Commercial catch history of blue swimmer crabs in Shark Bay between trap and trawl sectors since 1989/90. The fishery was closed during 12/13 and catches generated for this period was from an experimental commercial fishing trial.

2.3 Overview of the South Australian Blue Crab Fishery

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In South Australia the majority of blue swimmer crab *Portunus armatus* stocks inhabit the warmer shallow waters of Gulf St Vincent (GSV) and Spencer Gulf in algal and seagrass bottoms, and on sandy and muddy substrata, from the intertidal zone to at least 50 m depth. Blue swimmer crabs are predominantly targeted in the shallow Gulf waters and seasonally on the West Coast of South Australia in waters adjacent to Streaky Bay and Ceduna. Two groups of licence holders operate within the Blue Crab fishery (BCF), Blue Crab Fishery licence holders (pot fishers) and Marine Scalefish Fishery licence holders. Commercial catches of blue swimmer crabs were first recorded in South Australia in 1983/84, with a majority harvested on the West Coast. Over the following 12 years, catches progressively increased across all commercial sectors, reaching 654.4 t in 1995–96 (Figure 6). In 1996, formalised management arrangements were put into place, these included pot restrictions, formation of two fishing zones (Spencer Gulf and Gulf St Vincent) and a single TACC with quota units allocated separately for each zone. The introduction of quota in the following season (1996/97) resulted in a 29% reduction in total catch to 462.4 t. In the succeeding years, total catch generally increased until 2007/08 when the entire TACC of 626.8 t was caught. Total catch has remained below the TACC since that time, mainly due to the GSV zone not reaching their TACC.

There are three performance indicators (PIs) for the fishery, all of which provide a measure of relative biomass or abundance of legal-size or pre-recruit crabs: 1) survey catch per unit effort (CPUE) of legal-size crabs; 2) survey CPUE of pre-recruit crabs; and 3) commercial CPUE of legal-size crabs. The first two indicators, which are derived from fishery-independent surveys, are the most reliable measures of biomass and stock status due to the consistent timing of the survey (i.e. during June or July), pot type used and sampling location and spatial coverage in each gulf. In contrast, the third PI, which is derived from commercial catch and effort data, provides a less reliable index of abundance of legal-size crabs due to historical changes in gear and vessel technology, fisher demographics, experience and behaviour, and temporal and regional changes in the distribution of catch and effort.

The 2014 Spencer Gulf fishery-independent survey yielded an average CPUE of 10.00 legal-size crabs/potlift and 9.45 pre-recruits/potlift. Both of these PIs were above the upper reference points, indicating high relative biomass levels. In 2013/14, almost the entire Spencer Gulf component of the TACC for the fishery was caught for the tenth consecutive year and commercial CPUE remained at a high level. Using the national framework for stock status reporting, the Spencer Gulf fishing zone of the BCF is classified as ‘sustainable’.

Based primarily on the low catch rates of legal-size and pre-recruit crabs in the 2013 fishery-independent surveys, the Gulf St Vincent stock was classified as 'transitional recovering' in 2012/13. In response, management arrangements were revised for the 2013/14 and 2014/15 seasons to promote stock recovery. These changes included the TACC being reduced by 20%

in 2013/14, recreational bag and boat limits being reduced by 50%, and the voluntary implementation of a six-month closure by commercial fishers in 2012/13. There are multiple lines of evidence that the relative biomass of blue swimmer crabs in Gulf St Vincent increased in 2013/14: 1) the survey CPUE of legal-size crabs increased from 1.45 legal-size crabs/potlift in 2013 to 2.54 legal-size crabs/potlift in 2014, the highest value since 2010 (3.11 legal-size/potlift) and above the limit reference point; 2) survey CPUE of pre-recruits increased from 1.23 pre-recruits/potlift in 2013 to 2.12 pre-recruits/potlift in 2014, the highest value since 2011 and above the limit reference point; and 3) commercial catch rates increased in the central and southern regions of the gulf. Thus, using the national framework for stock status reporting, the Gulf St Vincent fishing zone of the BCF is classified as 'sustainable'. While this reflects a substantial improvement in stock status from 2012/13, there is evidence that the stock is still in a rebuilding phase. This is because the abundance of pre-recruits in the 2014 survey remained among the lowest values on record and the recent increases in pre-recruit and legal-size abundance observed in the 2014 fishery-independent survey were spatially limited compared to their historical distribution.

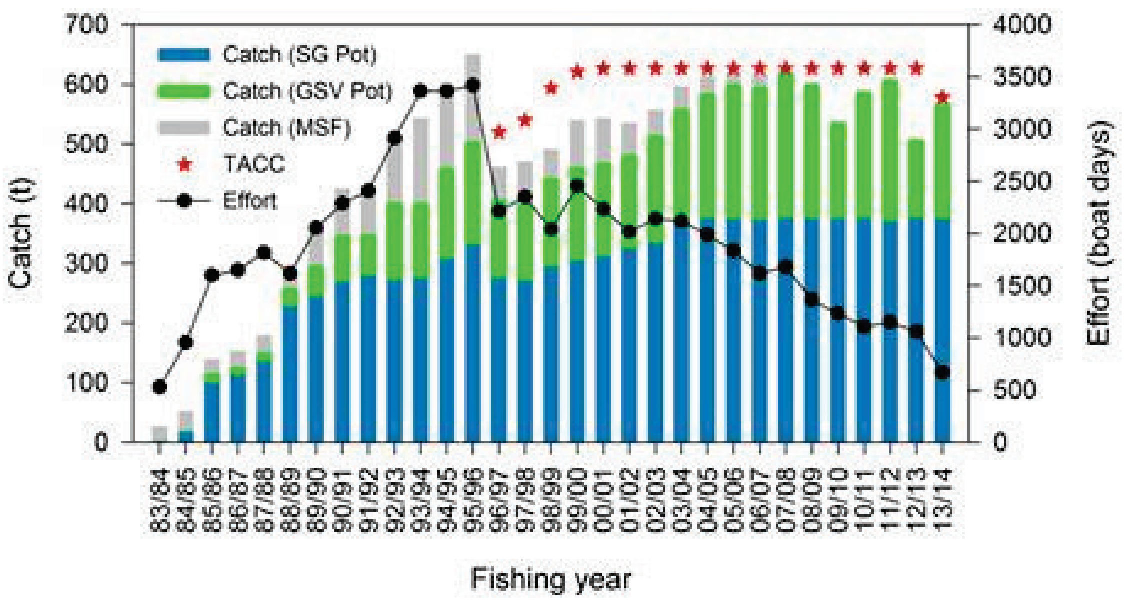

Figure 6. Commercial catch, effort and TACC for the South Australian Blue Crab Fishery from 1983/84 to 2013/14. SG Spencer Gulf, GSV Gulf St Vincent, MSF Marine Scale Fishery, TACC (total allowable commercial catch).

2.4 The Evolution of Blue Swimmer Crab Fishery in Queensland

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Blue swimmer crabs have been fished in Queensland for over 100 years and were traditionally taken in baited traps (pots) and mesh nets in the early days of the fishery. Mesh nets were subsequently banned during the 1950's and during this time prawn trawl fisheries developed in which increasing numbers of blue swimmer crabs were landed as incidental catch, although trawl catch has declined since the late 1990's (Figure 7). Blue swimmer crabs have always been an important recreational species but recent evidence from state-wide recreational surveys suggests that their importance has declined. Reasons for this decline are varied but have been linked to the banning of the favoured recreational fishing apparatus – suicide dillies in 2010.

The fishery was based predominantly in Moreton Bay but in recent decades has expanded into offshore areas of the Sunshine Coast and more remote areas of Hervey Bay where initial catch rates were very high before they declined in line with the development of previously unexploited or lightly exploited resources.

In Queensland the fishery is largely managed by input controls such as gear restrictions. Commercial fishers are allowed 50 traps per license while recreational fishers are limited to 4 per person. There is a size limit of 11.5cm (base of spine measure) which is the most conservative size limit of any Australian jurisdiction. All females are also totally protected in Queensland waters.

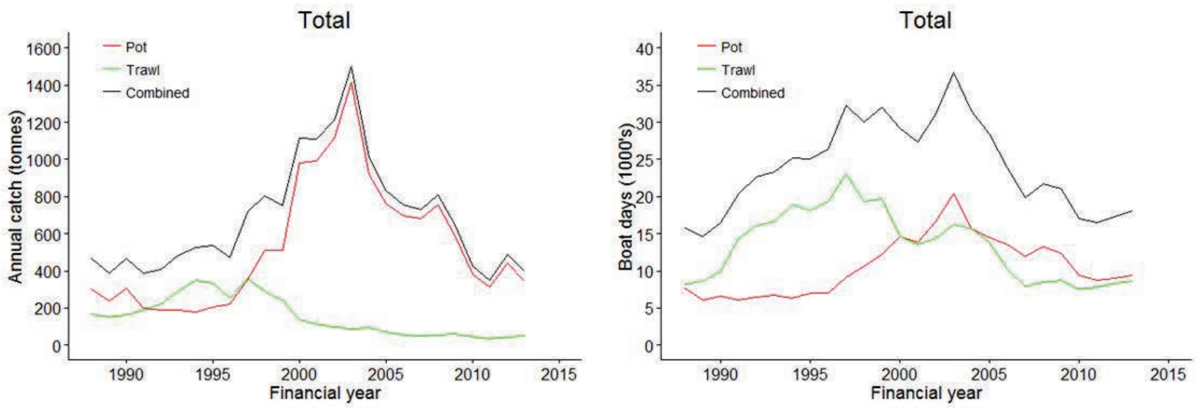

Figure 7. Annual change in the commercial catch of blue swimmer crabs in pot and trawl fisheries in Queensland since 1988 when compulsory daily logbook reporting commenced.

Historically trawl catches have been a significant component of the crab catch but management changes over the last 15 years which have placed in-possession limits on trawlers as well as generally reducing commercial trawl effort have seen the proportion of crabs taken by the trawl sector declining. Information from recreational surveys have likewise shown declining recreational catches of blue swimmer crabs in recent years which has been attributed by some as cause by the banning of entangling dillies which were popular among recreational fishers.

Management changes in other fisheries during the mid-1990's saw increased reporting of blue swimmer crabs by commercial pot fishers and there are currently over 400 licenses able to access the blue swimmer crab fishery despite the fact that around 100 pot fishers currently were operating in the fishery in 2014. The extent to which reported catches are accurate is widely debated across stakeholder groups. Over-potting is also an important issue as offsets and other techniques have to be used to make allowances for increases in effective effort which may not be immediately recognisable from analysis of the daily commercial logbook data.

Fishing power has also increased in the offshore areas of the fishery where more efficient and larger boats tend to operate.

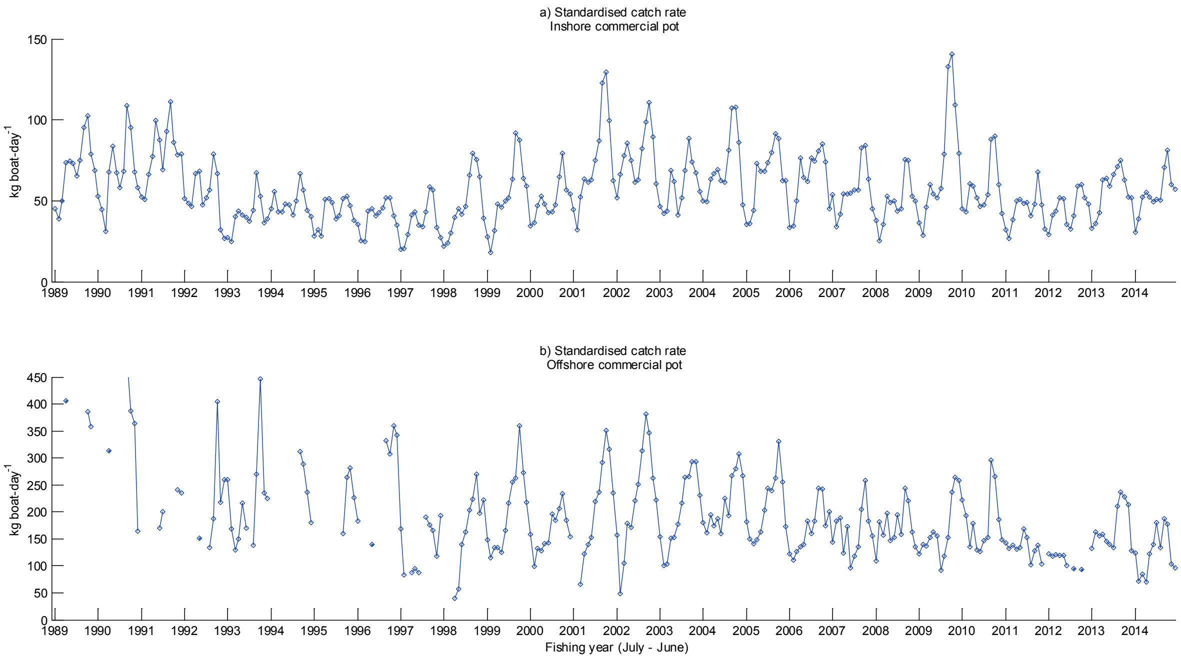

Figure 8. Standardised commercial catch rates (kg/boat/day) by trap fishers operating in two areas of the Queensland blue swimmer crab fishery.

Catch rates show a strong seasonal pattern with minima in catches occurring during winter (Figure 8). This pattern is particularly noticeable in inshore areas such as Moreton Bay but less obvious in the fisheries located in deeper waters further offshore. There is usually a smaller spring peak in catches followed by the highest catches, which normally occur during the following autumn.

Recent declines in catches in the offshore areas of the fishery (in particular) has highlighted economic concerns for this fishery as economically viable catch rates cannot be achieved in some areas of the fishery with the current restrictions on gear numbers, low catch rates and general market conditions.

Blue swimmer crabs are currently categorised as sustainable in all areas of the Queensland fishery although a recent stock assessment has highlighted significant economic problems in the fishery due to the high level of fishing effort caused largely by too many license holders who can enter the fishery at any time.

2.5 Stock Status and Fishery for Blue Swimmer Crabs in NSW

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Blue Swimmer crabs occur in coastal and estuarine waters along the length of the New South Wales (NSW) coastline. Recreational landings are not well documented but are thought to be significant, and occur throughout their range. Commercial landings of blue swimmer crabs from NSW waters in 2013/14 were 150 tonnes (Figure 9). This represented a 23 % increase on 10 year average landings (123 tonnes) and a 60 % increase on 2012/13 landings (93 tonnes). Fishers operating in the NSW Estuary General Fishery (EGF) harvested 95 % of total reported commercial landings in 2013/14. The NSW EGF is a multi-species multi-method fishery involving 592 fishing businesses state-wide, of which 169 are endorsed to trap for blue swimmer crabs. Of the 17 permitted gear types in the NSW EGF, catches of blue swimmer crabs were reported from 10 in 2013/14. Five estuaries account for 95 % of commercial landings, the most important being Wallis Lake.

One of the biggest challenges facing the sustainable management of fishery resources worldwide is determining the most cost-effective and reliable sources of data for monitoring and assessment. This is particularly the case in low value, multi-species, multi-method fisheries. Commercial CPUE is the main assessment method used to monitor blue swimmer crabs stocks in NSW. However, there are inconsistent or contradictory signals in the data that preclude determination of exploitation status, thus the status of the NSW stock is currently classified as uncertain.

The main sources of uncertainty include:

i) commercial landings and catch rates from crab trapping have declined in recent years and the majority of the catch is now reported from fish traps
ii) change in gear used in the fishery with rectangular traps replaced with more efficient circular traps
iii) a reduction in mean days fished per month with the adoption of more efficient traps and
iv) issues pertaining to the use of excess gear have been identified as potentially affecting catch rate analyses.

To address these, data on efficiency estimates of different gear configurations and soak-times and proportion of fishers adopting different technologies are needed. This will allow the transformation of observed effort into effective effort data which accounts for the increased efficiency due to the adoption of new and more efficient gear in the fishery.

Moreover, future research programs are required to:

(i) define key biological parameters of blue swimmer crab populations throughout NSW,
(ii) derive links between recruitment bottlenecks, catch rates and physicochemical factors and
(iii) resolve temporal and spatial patterns in habitat association and settlement of juveniles, to determine if nursery habitat availability creates localised recruitment bottlenecks.

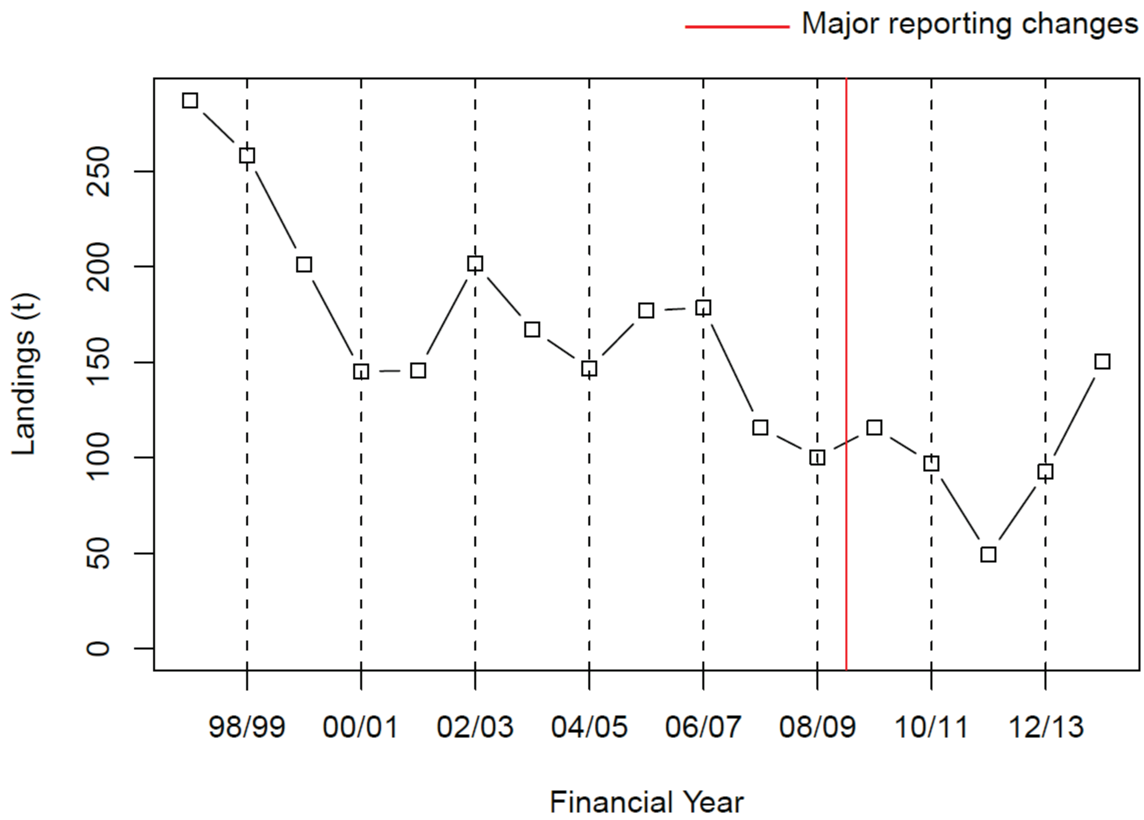

Figure 9. Historical landings of Blue Swimmer Crab (*Portunus armatus*) from the NSW Catch Records 1997/98 to 2013/14

3 Session 2: Monitoring, Stock Assessment and Harvest Strategy

Chaired by Mervi Kangas, Principal Research Scientist, WA Department of Fisheries

Each state provided an overview of the blue swimmer crab stock monitoring and assessment methods being utilised and the research/management gaps or challenges. Monitoring programs varied between states with traps being the primary sampling tool in some jurisdictions whilst trawling was used by others. Monitoring programs also targeted different sized crabs (juvenile vs sublegal crabs) during these sampling programs. Stock assessments ranged from annual summaries of commercial catch and effort data in developing fisheries in WA and NSW, to more comprehensive assessments based on performance measures of biological (and economic in QLD) indicators that are linked to harvest strategies with defined control rules (eg. SA and Cockburn Sound). This session also identified the need for both fishery dependent and independent monitoring of stocks with independent measures being very important for quota based fisheries. Fishery independent sampling is being applied extensively in both SA and WA commercial and recreational only fisheries.

Discussion during the session centred on the difference between the observed local commercial catch rates (from more efficient traps targeting areas of higher abundance) and fishery independent surveys using standard historical traps in an attempt to monitor the stock as a whole. Similarly trap fishers believed trawl based sampling could not fully cover the full spatial distribution of crabs. There was a common lack of confidence in the fishery independent survey designs by industry members from WA and SA who felt these surveys provided a single snap-shot in time which may not fully reflect the overall stock status. It was noted that both trap and trawl sampling methods have problems and these need to be considered in stock assessments. These included changes in catchability related to size of crabs, aggressive behaviour, water temperatures, moon phase and the moult/ reproductive cycles.

The need for standardisation of commercial catch rates was a key discussion point with the inherent difficulty in comparing commercial catch rates over time to monitor changes in annual stock abundance. Particularly in SA fisheries where continuous innovation in trap designs had significantly increased economic viability, but its use in stock assessment and management purposes were more difficult. Of particular interest was the changes in fishing efficiency and effort distribution reported in TAC/ITQ managed fisheries, which highlighted the need for long term fishery independent monitoring systems under this higher risk (for short lifecycle species) management strategy. This need for historically consistent abundance data in ITQ fisheries where catches close to MSY rather than safer MEY levels are envisaged. This issue was also noted to be of significance where commercial catches are controlled through a TACC, but recreational catches are relatively uncontrolled such that overall catch is closer to MSY.

The value of using of fishery independent trawl surveys of crab recruitment in WA in managing the impacts of the heat wave induced stock collapses in Shark Bay and stock recruitment issue in Cockburn sound was noted. These surveys provided for a timely response to a significant stock decline and was also noted as critical to the process of managing stocks in the SW of the WA through the environmentally driven recruitment changes which are expected to become more frequent over time.

Modelling highlighted the importance of improved estimates of growth, natural mortality and spawning stock recruitment (and environment) relationships. The recent stock decline in Cockburn Sound emphasized the critical need to understand stock-recruitment-environment relationships particularly as the south-west coast of WA is identified as a climate change hotspot. Fishers were very keen to incorporate economics into any modelling.

In terms of formal harvest strategies for managing crab stocks, SA had the most established model that is linked to their TACC setting process and was based on performance indicators with defined reference levels and control rules. However, the harvest strategy does not provide definition of when stock is considered ‘recruitment-overfished” so performance indicators not linked to stock status, and therefore they are used as “weight of evidence” to determine stock status. SA industry members stated that the current harvest strategy does not allow for an increase in the TAC and only allows for maintenance and reductions. In WA, harvest strategies were being developed for all crab fisheries in accordance with MSC (Marine Stewardship Council) standards and requirements. However the uncertainty of stock connectivity among the south-west coast fisheries poses several challenges to developing appropriate harvest strategies that are highly stock defined. Changes in sex ratio in traps to female dominance in winter and fishing of pre-spawned females over those winter months was not providing adequate protection from the current spawning closures in place.

Challenges and knowledge gaps:

Queensland;

- Uncertainty in assessment models (both MSY and MEY) relates to growth of crabs which varies seasonally and also due to the impact on growth from fishing males only
- Determining cohorts (0^+, 1^+, 2^+) is highly unreliable
- Connectivity of stocks between embayment and offshore fisheries
- Reliable index of abundance (fishery independent data important in future assessments)
- Using less aggregated economic data in MEY models
- Need for a restructure of fishing fleet with reduced effort and “50” pot limit is widely abused
- Sperm limitation does not appear to be an issue in relation to declining exploitable biomass however there is a decline in the mean size of females
- Sex ratio in traps does change from male dominance to female dominance due to fishing down of males but also due to behavioral changes due to change in seasonal temperatures
- Selectivity of larger crabs in trawl gear – large crabs may be able to avoid gear
- Current stock assessment models does not inform any harvest strategy

South Australia;

- There is a need to evaluate the reliability of the current indices of stock abundance (standardisation of data, optimising the cost/benefit of the survey design, alternate datasets)
- The current harvest strategy for the fishery is being reviewed (evaluation of performance indicators, develop reference levels, defined control rules, economic indicators)
- Resolve the time lag between data collection and their use in quota setting through an additional survey
- FRDC project looking at the trophodynamic model in Gulf St Vincent to resolve snapper interactions with blue swimmer crabs
- Continued monitoring of the disease status – *Hematodinium* infections has been identified but its prevalence and impact is unknown

Western Australia;

- Need to standardise survey data for factors affecting catchability (eg. time of night, large crabs can avoid trawl gear depending of trawl speed, moon phase)
- In Shark Bay, although spawning and recruitment occurs all year round, successful recruitment is likely to come from peak spawning months, determining batch frequency should be investigated
- Fishery independent sampling using research traps on non-trawl grounds in Shark Bay
- Inability to develop a crab catch rate for the trawl sector – difficult as it is not a primary target species and incentives to retain crabs can depend on a number of factors and variable during the fishing season
- Inability of monitoring programs to capture the whole crab spatial distribution which is critical to understand the fishing "foot print " in a particular region
- Industry felt surveys provide only a "snap-shot" of a proportion of the stock abundance and within a limited distribution in a space and time and therefore it should be complemented with commercial logbook data for stock assessments
- Sex ratio – female dominance over winter months have led to heavy fishing pressure on mated pre-spawn females which contributes to overall stock declines
- Management changes required to protect female breeding stock in south-west WA fisheries
- Movement, genetics and elemental studies to confirm relationship between stocks in south-west WA fisheries – further clarification of stock connectivity needed
- Require fishery independent trawl survey or seining to determine juvenile index for all crab fisheries (similar to Cockburn Sound)
- Environmental impacts on recruitment and spawning require ongoing monitoring
- Stock-recruitment-environment relationships are critical for management

3.1 Long-term Monitoring and Results of the 2014 Stock Assessment of Blue Swimmer Crabs in Queensland

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The blue swimmer crab (BSC) fishery in Queensland has undergone considerable change since its development in the middle of the 20th century. In the last 30 years the fishery has progressed to being fully fished with the expansion of crab-pot fisheries to areas outside of Moreton Bay. After the implementation of the Fisheries (East Coast Trawl) Management Plan 1999, the reported harvest from the trawl sector decreased significantly, with the commercial and recreational crab-pot sectors now accounting for the majority of the reported blue swimmer crab harvest. The commercial pot fisheries outside Moreton Bay also developed rapidly in the late 1990s. Concerns have been raised by a number of crab-pot fishers about poor economic viability under current management rules and reduced catch rates from a number of Moreton and Hervey Bay areas.

Queensland is in a good position to assess the blue swimmer crab fishery as there are daily commercial catch and effort logbook specified at a resolution of 6 nautical mile square grids since 1988. There is good long term fishery independent monitoring of 0^+ yr cohort in Moreton Bay using 5m beam trawl surveys since 2005 (earlier surveys discontinued) and there is a sound base of biological data on growth, reproduction and movement. In addition there is observer information from specific research conducted at irregular intervals in 1984/86, 1998 to 2000 and 2013/14.

The most recent blue swimmer crab stock assessment that used all the available data was completed in December 2014 and indicated that the population was not overfished to the point where the spawning biomass was significantly reduced. However, the current levels of population size of male legal crab and fishing effort were not suitable to produce acceptable levels of catch rates for economic profit or angling quality. Estimates of MSY under different parameter scenarios were highly variable ranging between 300 and 700 tonnes for the Moreton Region fishery (Figure 10).

Declining catch rates identified in the assessment appear to be related to overly competitive fishing, resulting in a smaller population size of male legal crab. Increases in the number of pots used by fishers in all regions is likely a result of escalating costs of fishing, particularly fuel, impacting on profits due to declining beach price relative to inflation. To cure this state, the data and analyses indicate that effort reduction is required to significantly improve catch rates and generate economic profits.

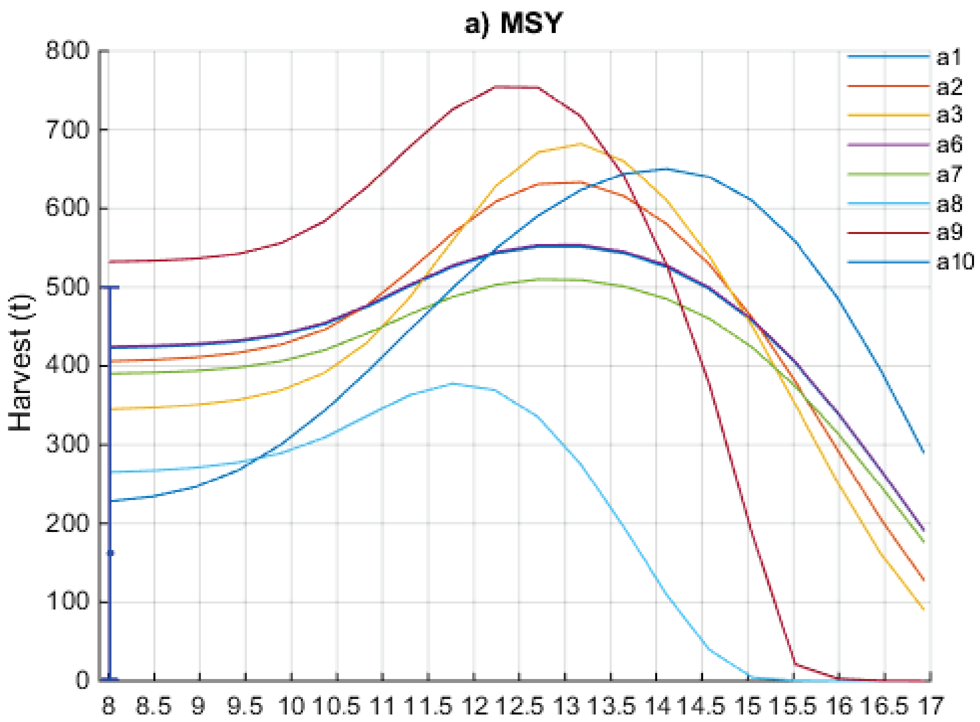

Figure 10. Sensitivity of maximum sustainable (MSY) of blue swimmer crabs from Moreton Bay and Sunshine Coast waters to different parameter scenarios. The 90% confidence error bar shown adjacent to the y axis was calculated from scenario a3, and is used to illustrate approximate uncertainty on all estimates.

An evaluation of raising the minimum legal size (MLS) in order to reduce fishing pressure indicates that this would have a negative impact on fishery economics. Analysis of historic catch rates during the 1980's when the MLS was 15 cm (spine tip-to-tip measure), suggested that profitable catch rates would only be achieved during the peak of the season in March and April.

Some important areas of further development and research were identified by the stock assessment including

(1) The need to better model crab growth (which was a highly influential parameter on model output

(2) A greater understanding of the connectivity between embayment and offshore

(3) Validating commercial catch and effort logbook data to provide a more accurate and precise index of relative abundance and

(4) Collect better economic data and use disaggregated economic data to gain a greater understanding of the economic effects of management changes on the different sized and structured fishing businesses that are involved in the blue swimmer crab fishery.

Other means of monitoring the blue swimmer crab fishery have been using data obtained from fisheries independent trawl surveys of eastern king prawns, blue swimmer crabs and snapper have which been conducted since 2006. Although the objectives and logistics of the sampling have changed over time, there has been a relatively consistent sampling in November and December each year, using beam trawl apparatus.

Given possible problems with the commercial logbook data, it is important that fishery independent beam-trawl surveys are continued as they are used in the current stock assessment model, and their worth will continue to increase over time as more data are added to the time series. It is vital that some form of fisher independent index of relative abundance is available for this fishery, and this has been recognized in both South Australia and Western Australia, where the management of blue swimmer crabs relies on the use of similar independent surveys. The pulse of recruits seen in the 2008/09 survey (Figure 11) was reflected in higher catches the following year, so the predictive value of the survey is already established. Careful consideration should be given to the timing of surveys if the program needs to be altered in the future. Surveys before November or after March would miss the pulse of juveniles resulting from the spring spawning event and compromise results for reasons discussed. All available evidence suggests that the optimal period for sampling recruits in Moreton Bay would be December to February, capturing the peak in recruitment while minimizing the effects of dispersal, reduced catchability and effects of harvest by fishers.

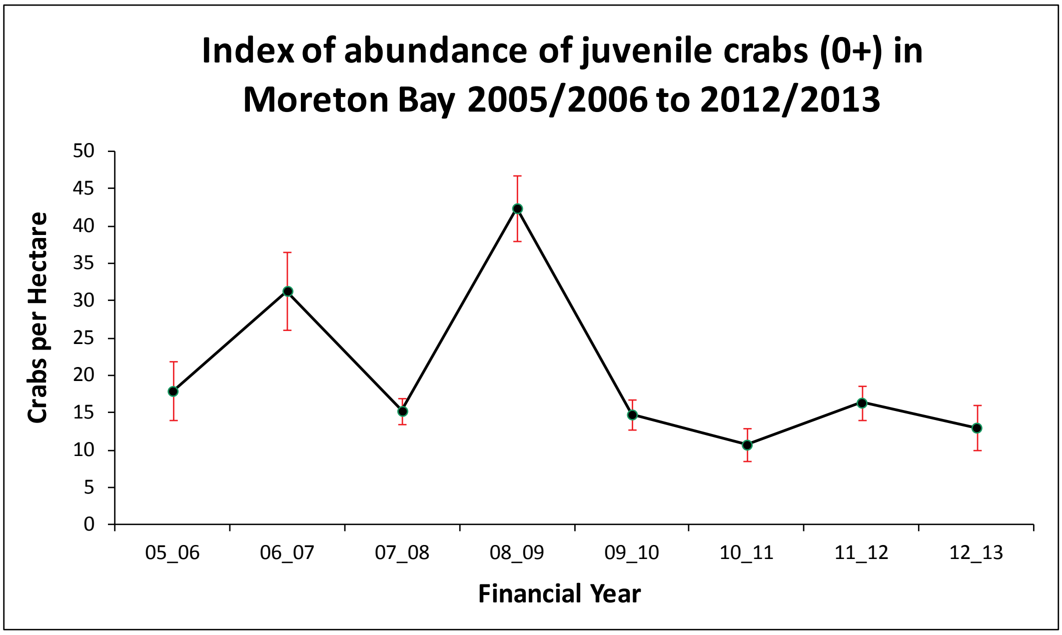

Figure 11. Index of abundance of juvenile crabs (0+) in Moreton Bay between 2005/2006 and 2012/2013 as predicted from the two-part conditional generalized linear modelling.

The blue swimmer crab fishery currently has a harvest strategy based on input controls and monitoring standardized catch rates with target reference levels of upper and lower deciles of the last 10 years running average. There is also a performance management that follows repeated declining trends in both catch and standardized catch rate over consecutive years. At present the harvest strategy in Queensland does not a have a formal set of harvest control rules with management action triggered when threshold reference points are reached. However, a review process is in place when performance measures fall outside agreed target levels.

3.2 The South Australian Blue Crab Fishery Research Program

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The current research program for the Blue Crab Fishery conducted by SARDI Aquatic Sciences comprises four components.

These are to:

1) conduct fishery-independent stock assessment surveys during winter to inform fishing strategy decisions and assess the fishery against the PIs defined in the Management Plan;

2) manage fishery-dependent commercial logbook data;

3) collate and analyse fishery-dependent pot-sampling data; and

4) produce an annual stock assessment report for the fishery.

The first stock assessment report for the Blue Crab Fishery was published in 1998 and annual reports have been published since. The report: 1) synthesises information for the BCF for each of the Spencer Gulf and Gulf St Vincent pot fishing zones; 2) assesses the current status of the blue swimmer crab resource in each gulf and considers the uncertainty associated with each assessment; 3) comments on the current biological performance indicators (PIs) and reference points for the fishery; and 4) identifies future research needs. The report formally provides the information required to make decisions in accordance with the TACC decision rules provided in the Harvest Strategy of the Management Plan.

There are three PIs for the fishery, all of which provide a measure of relative biomass or abundance of legal-size or pre-recruit crabs:

1) survey catch per unit effort (CPUE) of legal-size crabs;

2) survey CPUE of pre-recruit crabs; and

3) commercial CPUE of legal-size crabs.

The first two indicators, which are derived from fishery-independent surveys, are the most reliable measures of biomass and stock status due to the consistent timing of the survey (i.e. during June or July), pot type used and sampling location and spatial coverage in each gulf. In contrast, the third PI, which is derived from commercial catch and effort data, provides a less reliable index of abundance of legal-size crabs due to historical changes in gear and vessel technology, fisher demographics, experience and behaviour, and temporal and regional changes in the distribution of catch and effort. The harvest decision rules for the Blue Crab Fishery stipulate that if the limit reference point for any PI is not achieved, PIRSA Fisheries and Aquaculture and the South Australian Blue Crab Pot Fishers' Association (SABCPFA) will review the TACC and consider the possibility of a decrease from the baseline TACC of 626.8 t. This is deemed to be a precautionary response in the Management Plan that reflects the current level of understanding about the species, fishery production and dynamics, and the limitations of existing fishery data. One of the aims of this report is to assess the performance of the fishery in terms of the PIs and reference points specified in the Management Plan.

The current harvest strategy for the fishery is being reviewed, due for completion in June 2015. This review will 1) evaluate the reliability of the existing PIs for determining stock status; 2) develop the reliability of the existing PIs for identifying when a stock will be defined as recruitment overfished; 3) review the potlift locations to be used for setting reference points; 4) identify other potential indicators; and 5) consider how the biological PIs should be weighted when assessing stock status and setting TACC. In addition, further research for the Blue Crab Fishery is required to evaluate the reliability of the current indices of stock abundance. The options for standardisation of fishery-dependent data (e.g. commercial CPUE and pot-sampling CPUE) should continue to be evaluated, alternative datasets that could be used as PIs to assess stock status should be explored and fishery-independent survey design should be optimised to maximise information for assessment of stock status. The latter is particularly relevant because of the patchy distribution of crabs in Gulf St Vincent where consistently low crab abundances are recorded in some areas, skewing the data and adding uncertainty to the assessment of stock status. In addition, a *Hematodinium*-like parasite was recently identified in blue swimmer crabs from Gulf St Vincent. Although the prevalence and impact of *Hematodinium* infection has not been quantified in South Australia, similar infections have negatively affected a number of commercial crustacean fisheries worldwide. Continued monitoring of the disease status of blue swimmer crabs in both Gulfs will be useful to determine the extent and potential impact on stock status.

3.3 Stock Recovery and Development of a New Harvest Strategy for Shark Bay Crab Fishery

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The Shark Bay crab fishery entered into a stock rebuilding phase after the closure of the commercial fishery in April 2012. This led to the development of trawl-based fishery independent survey program (4 surveys per year) and the existing commercial trap monitoring program became a fishery independent survey program during the closure. Research surveys were designed to monitor stock abundance and composition in key deeper water fishing grounds (trap and trawl) and inshore, shallow water fishing grounds (trap) that have historically been used to commercially target crabs. The trawl based survey data provides indices of spawning biomass (catch rates), recruitment (immature crabs), sublegal and legal sized crabs (see Chandrapavan et al. 2017 for full study).

Stock recovery during the 2012 and 2013 was largely observed within the inshore regions of the Bay (depths < 15 m) and increased levels of recruitment during 2013 resulted in higher stock levels in 2014 and 2015. *Portunus armatus* in Shark Bay has an 18 month life-cycle from spawning to attaining legal (commercial) size. Spawning is observed all year, but the peak spawning period appears to be the cooler winter months from which the recruits first appear in the following summer months. Recruitment levels have peaked during the February survey in 2014 and 2015 and this cohort will grow and enter the fishery from November onwards (which coincides with the fishing season).

Improved stock levels and recruitment (survey catch rates) provided some confidence to resume commercial fishing under an interim harvest strategy with a limited Total Allowable Commercial Catch (TACC) for 2013/14. A notional TACC of 400 tonnes was set with a mid-season review to assess the impact of resumed fishing on the recovering stock. At the end of the season, 371 tonnes was achieved without any adverse decline in the stock indices. In fact recruitment levels increased during 2014 and this provided confidence for an increase in the TACC for the following 2014/15 season to 450 tonnes.

The main challenge for assessing the current Shark Bay crab stock status through the fishery independent indices is the limited long-term datasets for comparison and the lack of recent reliable commercial catch rates. The biological performance indicators through trawl sampling have primarily been developed after the stock decline and therefore a target reference level that reflect pre-stock decline period is not available. The commercial trap catch rates were used to assess for fishery (stock) performance, however under the current TACC system the trap fisher behaviour and fishing intensity has changed considerably, with the majority of the catch now being taken by the trawl sector (due to quota leasing). Hence an accurate assessment of stock status and harvest levels is currently a weight of evidence approach, utilising available data from survey indices (pre-recruits), monitoring environmental conditions and keeping the harvest strategies flexible rather than prescriptive until a more robust framework is developed.

3.4 Monitoring, Stock Assessment and Harvest Strategy of the WA Crab Fisheries – Focus on the South-West

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In addition to the statutory catch and effort statistics (CAES), data used in the stock assessment of blue swimmer crab (*Portunus armatus*) fisheries in Western Australia is obtained from three types of monitoring programs; fishery-dependent commercial monitoring, fishery-independent trawl and trap surveys and research logbooks. A preliminary harvest strategy has been developed for each of the crab fisheries where the primary performance indicator is nominal commercial catch rate (Swan River, Warnbro Sound, Mandurah-Bunbury Developing Crab Fishery, Pilbara Developing Crab Fishery), standardised commercial catch rate (Peel-Harvey), or fishery-independent juvenile and egg production indices (Cockburn Sound). Reference levels (limit, threshold and target) and a set of control rules have been developed for each harvest strategy and these will be the basis in which the sustainability of these fisheries will be assessed in the future.

Commercial monitoring is carried out on a monthly basis across all south-west blue swimmer crab fisheries during periods of operation, and also during closure months for Cockburn Sound (Table 2). Departmental research staff accompanies commercial fishers and obtain information on catch composition; recording sex, carapace width measured from spine to spine, discards, bycatch and spatial distribution. Reproductive data such as size at maturity is also recorded along with the presence of any ovigerous (berried) females in the catch. Length-weight relationships and fecundity estimates have also been determined in recent years.

Fishery-independent monitoring is carried out in two major fisheries in the south-west. In Cockburn Sound fishery-independent trawling, using small (*RV Cassels*) and large (*RV Naturaliste*) research vessels, commenced in 2001 to estimate juvenile and breeding stock abundance. Similar data to commercial monitoring surveys are reported. From April to July, juvenile trawl surveys are carried out to calculate a juvenile (0^+) and residual (1^+) index. Data collected during the spawning period on board the *R.V. Naturaliste*, as well as commercial monitoring, are used to calculate an egg production index. A fishery-independent trap survey commenced in the Peel-Harvey Estuary in 2007 using small mesh hourglass traps to estimate juvenile and breeding stock abundance. Data is currently being used to develop pre-recruit to fishery and breeding stock indices.

Length frequency data is generated from all commercial monitoring and fishery-independent surveys. Trap selectivity is an issue for all south-west crab fisheries and that sex ratio changes between months and between fisheries. For example, in Cockburn Sound, the abundance of males in traps strongly influences the proportion of females, so when there is a high abundance of males, the females will not enter traps. This is most likely due to aggression of males and reproductive behaviour of the females not moving into traps until they have moulted/mated by April. There appears to be a pattern where estuarine fisheries like the Swan River and Peel-Harvey Estuary have females dominating the catch in a few months of the year (May-August), whereas embayment fisheries like Cockburn Sound and Warnbro Sound, females dominate the catch for a longer period (April-November) and for oceanic fisheries like Comet Bay and Mandurah-Bunbury (Area 1 and 2 of the Mandurah to Bunbury Developing crab fishery) females dominate the catch all year. These changes in sex ratio have implications for the management of these fisheries highlighting that greater protection of the female breeding stock, particularly mated pre-spawn females over winter, may be required given that these fisheries have none or only 2 month season closures.

A preliminary harvest strategy has been determined for the Cockburn Sound Crab Fishery where the primary performance indicators are the juvenile index and egg production index. A weight of evidence approach is used for the stock assessment where the indices, in addition to commercial catch rates and the proportion of females in the commercial catch, are taken into account to assess stock status. The juvenile index for Cockburn Sound fell below the limit in 2013 and 2014 and the egg production index fell below the threshold in 2012/13 and below the limit in 2013/14. This, combined with commercial catch rates falling to 0.5 kg/traplift and a high proportion of females in the catch, resulted in an early closure of the Cockburn Sound crab fishery in April/May 2014. The stock is currently considered to be environmentally limited. Reasons for the stock decline are currently being investigated, including potential changes in growth rates and the proportion of berried females.

A preliminary harvest strategy has been determined for the Peel-Harvey Crab Fishery where the primary performance indicator is standardised annual catch rate (taking into account factors of year, month and vessel). The standardised catch rate of 1.2 kg/traplift for the 2013/14 fishing season was well above the threshold of 0.7 kg/traplift, so currently the risk to sustainability is low. Fishery-independent indices for pre-recruit to fishery and breeding stock are currently being developed for this fishery, given its assessment for Marine Stewardship Certification.

Size at maturity and batch fecundity estimates are currently being determined in many blue swimmer crab fisheries in Western Australia to investigate whether changes have occurred over time and whether there are latitudinal trends within WA and compared to eastern states. Preliminary data suggests there has been a slight temporal change in size at maturity for Cockburn Sound and Peel-Harvey Estuary with a larger change (increase) for Shark Bay. There are also apparent latitudinal trends within WA, with southern populations (Cockburn Sound and Peel-Harvey) having a higher batch fecundity at a given size than Shark Bay. This may be related to Shark Bay crabs spawning all year round, with fewer eggs produced in each batch. Similarly females at southern latitudes (South Australia, Peel-Harvey and Cockburn Sound) had a higher batch fecundity than females at northern (tropical) latitudes (Shark Bay and Queensland), although these latitudinal trends were less obvious than within WA, possibly due to methodological differences between studies.

Table 2. Monitoring programs currently undertaken by the Department of Fisheries for blue swimmer crab fisheries in Western Australia (excluding Shark Bay).

	COMMERCIAL							RECREATIONAL		
FISHERY	Cockburn Sound	Swan R	Peel-Harvey	Warnbro	Comet Bay	Man-Bun	Pilbara	Swan R	Lechenault	Geographe
Fishery Dependent Commercial Monitoring	✓	✓	✓	✓	✓	✓	×			
Frequency	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	1 -2 x year			
Months	All months in season									
Years	1999+ open 2007+ open/closed	1998 - 2000 2007+	1998 - 2000 2007+	2007+	2007+	2006+	2002 - 2008			
Data collected	Commercial catch composition (sex, berried, size) discard, bycatch & spatial distributions									
Data Analyses	Egg Production Index (CS only)									
Fishery Independent Monitoring	✓ Trawl		✓ Trap					✓ Trap/Seine	✓ Trap/Seine	✓ Trap
Frequency	Monthly		Monthly					Monthly		
Months	Apr - Jul (JUV) Oct - Dec (BS)		Jan - Dec (07 - 12) Jun - Nov 2013+					Mar - May Sept - Nov		
Years	2001+		2007+					2013+		
Data collected	Stock composition		Stock composition					Stock composition		
Data Analyses	JUV index BS index		Pre-recruit index BS index					JUV index BS index		
Daily Research Logbook					✓	✓	✓			
Data collected					Catch, sex, berried, discards, bycatch & fine scale spatial distribution					

3.5 What Factors Influence the Vulnerability of the Cockburn Sound Crab Stock to Fishing Mortality

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During the last decade, the stock of blue swimmer crabs in Cockburn Sound declined twice to very low levels requiring, on both occasions, strong management (i.e. fishery closures) to facilitate stock recovery. In the years just prior to the initial stock decline in the mid-2000s, fishing pressure was very high relative to historical levels, implying that fishing pressure may have been an important factor contributing to that decline. Such a view, however, is at odds with the results of a previous study based on per recruit modelling, which indicated that the Cockburn Sound crab stock is likely to be resilient to high levels of fishing pressure, even if individuals had started to be fished at young age (0.4-0.5 years) and small size (70-81 mm CW) (Melville-Smith et al. 2001).

Using, as a starting point, the same general type of model developed by Melville-Smith et al. (2001), we explored the extent to which alternative modelling assumptions impact on model estimates of the relationship between stock abundance (i.e. spawning biomass) and fishing mortality. Firstly, we confirmed that a per-recruit model of the same form as constructed in the earlier study yielded the same results.

The model was then extended to include a 2-month temporal closure (which was in place during recent years when the fishery was open), post-release mortality of undersize crabs and berried females of 10%, and sex-specific selectivity to trap gear. The latter assumption was based on empirical data demonstrating that the abundance of females in traps is negatively-related to that of males (presumably due to agonistic male behaviours towards females when in traps). Although, by including these additional assumptions, the model better captured the seasonal dynamics associated with commercial catch of female and male crabs, it still indicated that the stock is resilient to high levels of fishing pressure.

Next, variation in growth among individual crabs (based on a common standard deviation for the mean lengths of crabs at age, derived by fitting a seasonal growth curve to length frequency data) was incorporated into the model. This accounted for faster-growing crabs becoming vulnerable to fishing at relatively younger ages compared to slower-growing crabs, and also allowing for the possibility that some crabs may never even grow to attain the minimum legal size and become vulnerable to fishing throughout life. Although incorporating variation in growth improved the realism of the model, it still indicated that crab stock is resilient to high fishing pressure.

Finally, the model was extended further to include a (Beverton and Holt) stock-recruitment relationship, which thereby accounted for impacts of fishing on recruitment, i.e. through its impact on spawning biomass. The sensitivity of the model to two alternative values for the steepness parameter of the stock-recruitment relationship, which affects its shape, was explored, i.e. 0.75 and 0.4 (Figure 12a, b). Assuming a value of 0.75, i.e. which implies that recruitment is only weakly dependent on stock size, except when stock size is reduced to a low level, the model behaves in a manner similar to that described above for the models without a stock recruitment relationship (Figure 12c). However, lowering the value to 0.4, which results in a "shallower" curve, implying that recruitment is strongly-linked to stock size at all stock sizes, leads to a very different result. That is, high values of fishing mortality are now expected to cause a marked reduction in stock size (using spawning potential ratio as an indicator of spawning stock size). It is thus relevant that existing empirical data on the stock-recruitment relationship for crabs in Cockburn Sound suggests that this stock does, in fact, have a relatively shallow stock recruitment curve (de Lestang et al. 2010).

The key implications resulting from this modelling exploration was that 1) it is important to consider the relationship between recruitment and stock size when constructing fisheries models for crab stocks and 2) that the crab stock in Cockburn Sound may be far less resilient to fishing pressure than once thought and therefore 3) that effective management to prevent overfishing is vital for ensuring the sustainability of this stock. An important aspect that was not considered in this model exploration is impacts of factors other than fishing on stock size. Thus, for future work, it is recommended that the impact of environment factors on stock size be explored, ideally in a modelling-based framework that also accounts for impacts of fishing mortality.

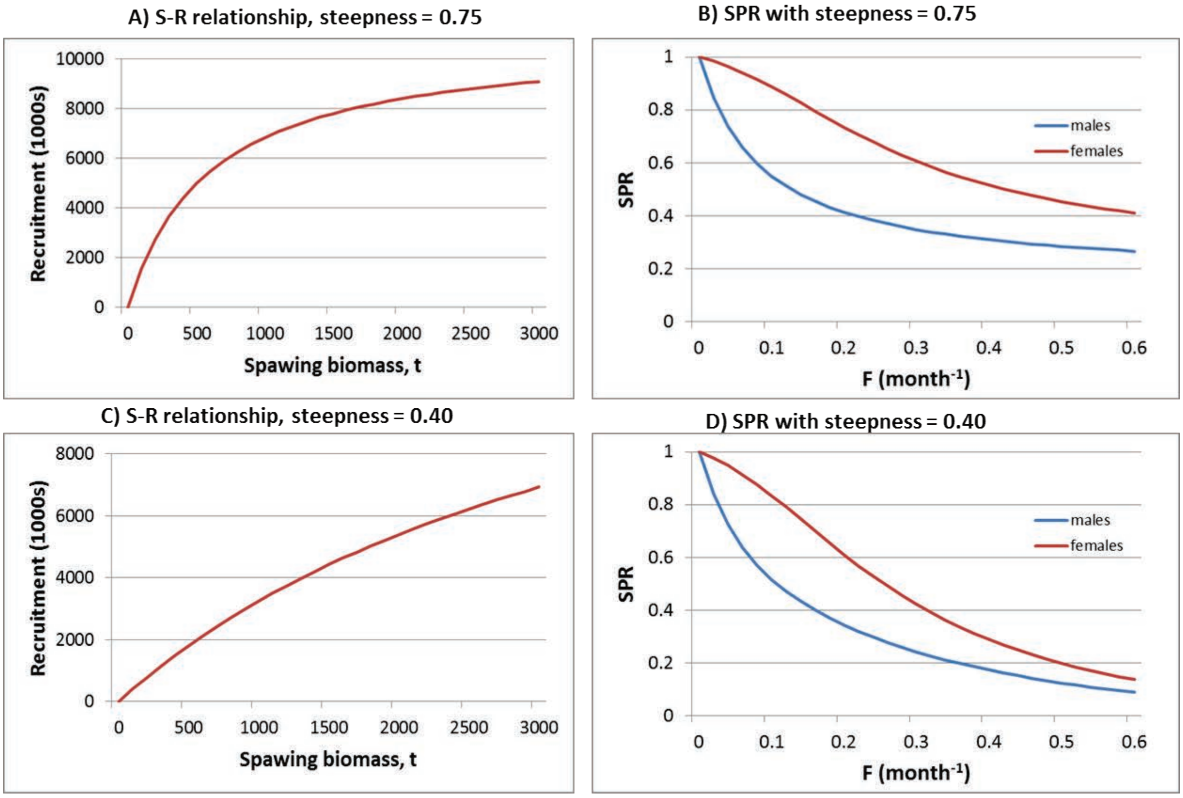

Figure 12. Beverton and Holt stock-recruitment relationships for blue swimmer crabs assuming steepness values of a) 0.75 and c) 0.4. Estimates of spawning potential ratio (SPR, the level of spawning biomass for a given level of fishing mortality relative to that for an unfished stock) derived assuming a steepness values of b) 0.75 and d) 0.4. Note that a value of SPR is often considered as a limit reference point, below which the stock is at high risk of recruitment failure.

4 Session 3: Environmental Drivers and Climate Change

Chaired by Nick Caputi, Supervising Scientist, WA Department of Fisheries

Environmental drivers of stock abundance, recruitment, commercial catch rates and catchability in general are key aspects of stock assessment, and one that is gaining momentum with recent climate change challenges. Although the life cycle of blue swimmer crabs are well understood in most of the major fisheries, correlations of life history traits with environmental variables, which requires long time-series data sets, was an ongoing challenge identified by all States. Key environmental drivers were water temperature, wind-driven currents, rainfall, tides and extreme weather events. These drivers are capable of having short-term, long-term and "time-lagged" impacts on crab stocks.

There was a general consensus that there is presently a lack a clear understanding of how temperature, winds, rainfall, tides etc. affect stock distribution, larval dynamics under "normal" environmental conditions. Therefore the impact of climate change on crab stocks was even more difficult to assess. Interspersed within decadal shifts in climatic conditions are short bursts of extreme events (e.g. marine heat waves, flooding, cyclones) which can be equally devastating on populations. The marine heat wave event in WA lasted for only 4 months, but its timing with the peak recruitment phase of the Shark Bay crab stock resulted in a significant recruitment failure and subsequent stock decline. The same event is thought to be the cause of a range extension for this species on the south coast of WA. The term "environmentally limited" is now coined to describe stock status of fisheries that are closed or recovering from environmentally driven stock declines.

Water temperature is one of the easiest parameters to measure and monitor and therefore it is viewed as a proxy for other environmental changes. Alan Pearce stressed the point of *in situ* temperature loggers providing invaluable data on the changing water temperatures and chemistry, and also critical in capturing extreme events. The merits of satellite derived SST vs temperatures from data loggers were discussed;

- Satellite SST data are only a proxy based on the surface water layer (up to 20 m) and inaccuracies due to cloud cover does occur
- Data loggers provide "real temperatures" particularly on the sea bottom (when it differs from the surface temperatures due to water column stratification)
- The retrieval of data loggers can be logistically difficult and costly in remote locations such as Shark Bay
- In SA's prawn surveys, temperature sensors are attached to the trawl boards that record water temperatures while the gear is in use

In WA, major climate-driven events have significantly altered the status of key fisheries. There is also a strong focus on incorporating environmental factors into stock-recruitment relationships of crab stocks due to the longer term warming trends forecast for the lower west coast and the high sensitivity of blue swimmer crabs to water temperature changes. Early detection of any impacts on the stocks through monitoring the pre-recruits will allow for quick management responses for both the protection of the stock and to inform industry.

The resilience of crab stocks to recover from significant declines was shown with examples of Cockburn Sound and Shark Bay both adversely impacted by environmental conditions. A single generation (~18 months) was affected in Shark Bay stock, while Cockburn Sound has suffered two stock declines within a 10 year period.

Stock connectivity was raised as a relevant issue in regards to management of crab stocks particularly along the south-west coast of WA. An Australia-wide genetic study of blue swimmer crab stocks indicated QLD and NSW stocks to share a high degree of genetic exchange due to the close proximity of estuaries that would allow for crab larvae to be dispersed and exchanged along the coastline. In contrast, SA and WA and the east coast stocks were genetically distinct populations based on extensive sections of open coastlines between the major fisheries. The discrete nature of these stocks appear to have made them more sensitive to the environmental perturbations and fishing pressure and the very low level of larval exchange appears to have contributed to the relatively slow rate of stock recovery following closures.

Environmental observations for WA include;

- The lower coast of WA hot spot for water temp increase and one of 30 spots around the globe
- Strong warming trends in autumn/winter and weak warming trend in summer, long term projection of Leeuwin Current to weaken in winter
- The heat wave was one of the major heat wave global events and invertebrate species the most vulnerable to mass mortalities
- Australia wide climate change risk assessments showed that blue swimmer crabs are classified as High Risk
- Changes in spatial distribution and range extension

Environmental observations for SA include;

- Crabs are being caught further south of the fishery's range in both gulfs which suggests range extension underway with warming temperatures
- Observed trend of increased abundance of pre-recruits during the annual survey in recent years may imply changes to the timing of recruitment
- Larval duration is influenced by water temperatures and in SA where the coolest temperatures occur, the long larval duration is longer than other States. With warming temperatures, the effect of such a climatic shift on larval settlement would also largely be influenced by how adults adapt to climatic shifts and affect their distribution during the spawning period. Such adult behavioural responses remain unquantified.

Environmental observations for QLD include;

- Rainfall and flooding does not appear to have significantly impact on overall crab catch rates and only a slight negative effect on recruitment is observed
- In Moreton Bay (1990s and 2000s) there is good correlations between winter water temperatures and declining catch rates
- Wind can have short term effects on catch rates – fishermen have observed strong south-easterly winds in northern Moreton Bay can tend to stir up sediments and catch

rates increase, and in southern MB northerly winds can stir sediments and catches increase
- Wind direction and strength can influence on larval movement, distribution and settlement therefore seasonal effects on recruitment processors is highly likely

4.1 Overview of Oceanographic Processes Associated with Summer 2011 Marine Heat Wave

Alan Pearce[†] and Ming Feng
Principal Research Oceanographer, WA Department of Fisheries
([†] Deceased 30 March 2016)

The south-flowing Leeuwin Current is the dominant ocean current off Western Australia, transporting warm, low-salinity tropical water southwards from Ningaloo to Cape Leeuwin and then eastwards into the Great Australian Bight. It normally flows most strongly during the autumn and winter months, but in some years the peak flow may be in summer and/or spring. In its passage southwards, it tends to hug the edge of the continental shelf, but periodically large (~200 km) meanders divert the flow westwards and many of these meanders then break away to form anti-clockwise eddies. Because of the strong and persistent southerly winds that blow during the summer months, the Leeuwin Current tends to weaken and may move a little further offshore; at the same time, the wind drives a northward inshore counter-current (the Capes Current) from the Capes region as far north as Shark Bay. A similar wind-driven summer current is often found along the Ningaloo Reef (the Ningaloo Current).

The strength of the Leeuwin Current is directly influenced by *El Niño*/Southern Oscillation (ENSO) events emanating from the equatorial Pacific Ocean. During ENSO events, when the Southern Oscillation Index (SOI) is relatively low, the flow of tropical Pacific Ocean water into the eastern Indian Ocean through the Indonesian island groups is reduced and the Leeuwin Current weakens. Less warm water is transported southwards so sea surface temperatures (SSTs) off the southwest tend to be lower than average. By contrast, during *La Niña* events when the SOI is very high, an increased Indonesian Throughflow results in a much stronger Leeuwin Current and correspondingly warmer water along our coast. Occasionally, the stronger throughflow is further intensified by stronger-than-average northerly winds in the Exmouth region (recently named as “Ningaloo Niño” conditions) combined with unusually high atmospheric heat input to the ocean, leading to the “marine heat wave” which was experienced off Western Australia in early 2011 (Figure 13). Similar environmental conditions, albeit less severe, occurred the following summer, and even in 2013 the Leeuwin Current was still stronger than average with above-average water temperatures. By 2014, the environment was returning to normal, although a stronger Leeuwin Current and warmer water appeared to be persisting into 2015 despite the onset of an ENSO situation (low SOI).

During the 2011 heat wave, monthly-averaged SSTs over a large area were almost 3°C above the long-term mean. Hourly temperature logger measurements near the coast and out at the Abrolhos Islands, however, indicated that local water temperatures exceeded 5°C above average for brief periods around the peak of the heat wave (Table 3). The availability of the *in situ* temperature logger data showing the record temperature rises during the heat wave events emphasises the importance of maintaining a high quality water temperature monitoring network along the coast.

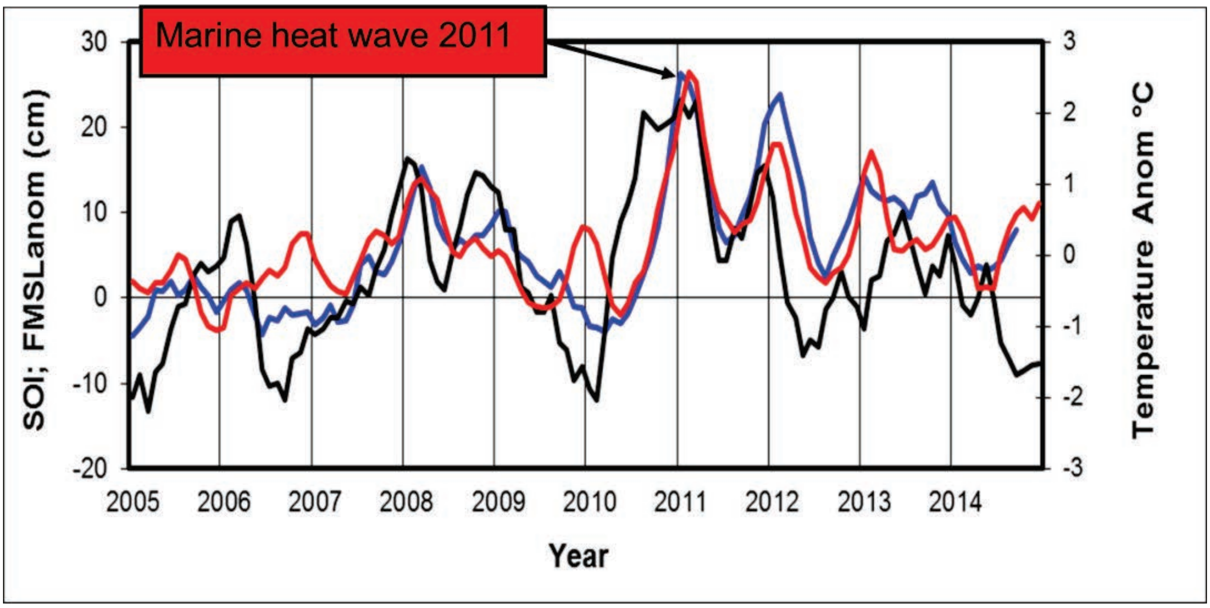

Figure 13. Monthly values of the Southern Oscillation Index (SOI, in black), the Fremantle sea level anomaly (FMSLanom -- the difference between a monthly sea level value and the long-term average for that month, in blue) and the sea surface temperature anomaly at the Abrolhos Islands (right axis, in red) between 2005 and 2014. High values of the SOI indicate *La Niña* conditions and low values reflect *El Niño* conditions, while high sea levels indicate a strong Leeuwin Current. The record strength Leeuwin Current and record high temperatures in February/March 2011 constituted the unprecedented marine heat wave which devastated coral reefs and some commercial fisheries along the mid-west coast over the following months.

Table 3. Peak water temperatures (and anomalies in brackets) at selected temperature logger locations at the peak of the marine heat wave in late February/early March 2011. The highest anomalies are flagged in red font.

Location	Temp.°C (anomaly)	Data Source
Rat Is. (Abrolhos)	**28.7° (5.0°)**	**M. Rossbach**
Dongara	**29.4° (4.9°)**	**M. Rossbach**
Jurien Bay	**28.3° (5.5°)**	**M. Rossbach**
Rottnest Is.	**26.2°**	**A. Hoschke**
Warnbro Sound	**26.6° (3.3°)**	**M. Rossbach**
Busselton Jetty	**25.6° (3.8°)**	**S. Teede**

4.2 Environmental Drivers of Recruitment of Crabs in Western Australia

Nick Caputi, Arani Chandrapavan, Danielle Johnston, Ainslie Denham, Ming Feng, Alan Pearce and Yasha Hetzel
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The lower west coast of Australia has been identified as one of the hotspots of water temperature increases in the Indian Ocean with a 1°C increase over the past 40 years, particularly during the austral autumn/winter period. An extreme marine heat wave event in the mid-west region of Western Australia (WA) occurred in the 2010/11 austral summer, with sea-surface temperature (SST) anomalies of 2-5°C above normal climatology. The heat wave occurred as a result of a strong Leeuwin Current (associated with an extreme *La Niña* event) in combination with an anomalously high heat flux from the atmosphere into the ocean, at a global warming hot spot in the Indian Ocean. The effect of the heat wave has been exacerbated by above-average SST in the following two summers, 2011/12 and 2012/13. The lower west coast of WA has also been affected by declining rainfall since the 1970s with 3 of the lowest rainfalls in over 50 years occurring in the last 10 years. Climate change models project that increases in water temperatures and decreases in rainfall are projected to continue over the next 30-50 years.

In late 2011, blue swimmer crab stocks in Shark Bay were found to be at historically low levels due to a recruitment failure and increased mortality of adult stock. The low stock abundance was confirmed by a fishery-independent trawl survey in November 2011 and by the very low commercial catch rates. A correlation assessment of commercial trap catch rates and monthly SST in the previous two years identified two key periods where SST was significantly correlated with the commercial catch rate. The first was during the summer, which covered the heat wave period, and showed a negative relationship between SST with the catch rates ($r = -0.76$, $p < 0.01$). The second was near the time of peak spawning in late autumn/winter of the previous year ($r = 0.70$, $p = 0.01$). The multiple regression relationship based on SST during both periods was highly significant (multiple $r = 0.93$, $p < 0.001$). Therefore the cause of the low recruitment in 2011/12 was a combination of a very cool winter in 2010 followed by the heat wave in the summer of 2010/11.

A stock-recruitment-environment relationship indicated that the decline in Cockburn Sound crab stocks in the mid-2000s was due to a series of low water temperature prior to spawning resulting in poor recruitment. Fishing pressure on these poor recruitment year classes resulted in the spawning stock falling to very low levels. The poor recruitments in 2013 and 2014 may have been due to environmental conditions affecting the growth of crabs during the 2011/12 and their spawning in 2012/13. Despite the early closure of the fishery in 2014 the spawning stock has fallen to very low levels which may affect the recovery of the stock.

An assessment of the annual decline in catch rates in the Peel-Harvey Estuary from summer to winter is influenced on the level of winter rainfall that contributes to the movement of crabs out the estuary.

The two peaks in crab catches on the South Coast of WA over the last 20 years, in 2001 and 2013-14, appear to occur about 1-2 years after periods of strong Leeuwin Current that are associated with above-average water temperatures.

The above studies show that blue swimmer crabs are sensitive to environmental conditions and a risk assessment of the vulnerability of species to climate change ranked blue swimmer crabs as one of 10 species with a high risk. Therefore early detection of abundance changes is important to ensure sustainable management of the stocks. This can be achieved by (a) early detection environmental changes and an understanding of their effect on stocks, (b) monitoring pre-recruits for early detection of abundance changes, and (c) having a harvest strategy that is responsive to abundance changes to protect spawning stock.

4.3 Genetic Determination of the Stock Structure of Blue Swimmer Crabs in Australia

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This research describes a genetic investigation into the stock structure of *Portunus armatus* in Australian waters. Most of the work was completed between 1998 and 2001, as a part of FRDC project 98/118. The main aim of the research was to use genetic data to investigate the number and location of biological stocks of *P. armatus* in Australian waters. A secondary aim was to investigate the environmental features associated with stock demarcation in this species. The results are based on the analyses of variation at 4 to 6 microsatellite loci in samples of *P. armatus* from the east, west and south coasts of Australia. The assemblages on each of these coasts formed genetically distinctive regional groupings. Since there were large gaps between sampling locations on the different coasts, the nature of the genetic transition from one regional grouping to another is not clear. The results indicate that the assemblages of *P. armatus* at the sampling locations on the south coast (Gulf Saint Vincent, Spencer Gulf and west coast region around Streaky Bay) are genetically different from each other and therefore correspond to separate biological stocks (Figure 14). Similarly, the results indicate that the assemblages in Exmouth Gulf, Shark Bay, Port Denison and Cockburn Sound on the west coast are each genetically different and therefore correspond to separate biological stocks. Assemblages in the Peel-Harvey Estuary and Geographe Bay on the lower west coast were, on the other hand, genetically similar to each other and probably represent overlapping stocks. The sampled assemblages on the east coast (Mackay, Hervey Bay, Moreton Bay, Wallis Lake and Port Stephens) were all genetically similar and probably comprise a series of overlapping stocks. The results of a distance-based redundancy analysis suggest that the main environmental factors associated stock demarcation in *P.armatus* are: (i) geographic distance; (ii) gaps in the distribution of sheltered coastal habitat; and (iii) restricted water exchange between certain embayments and the adjacent ocean. In conclusion, *P. armatus* comprises multiple biological stocks over large and medium spatial scales in Australian waters. Questions remain about the stock structure of this species over fine spatial scales, *e.g.* between adjacent water bodies, such as Cockburn Sound and the Swan River Estuary.

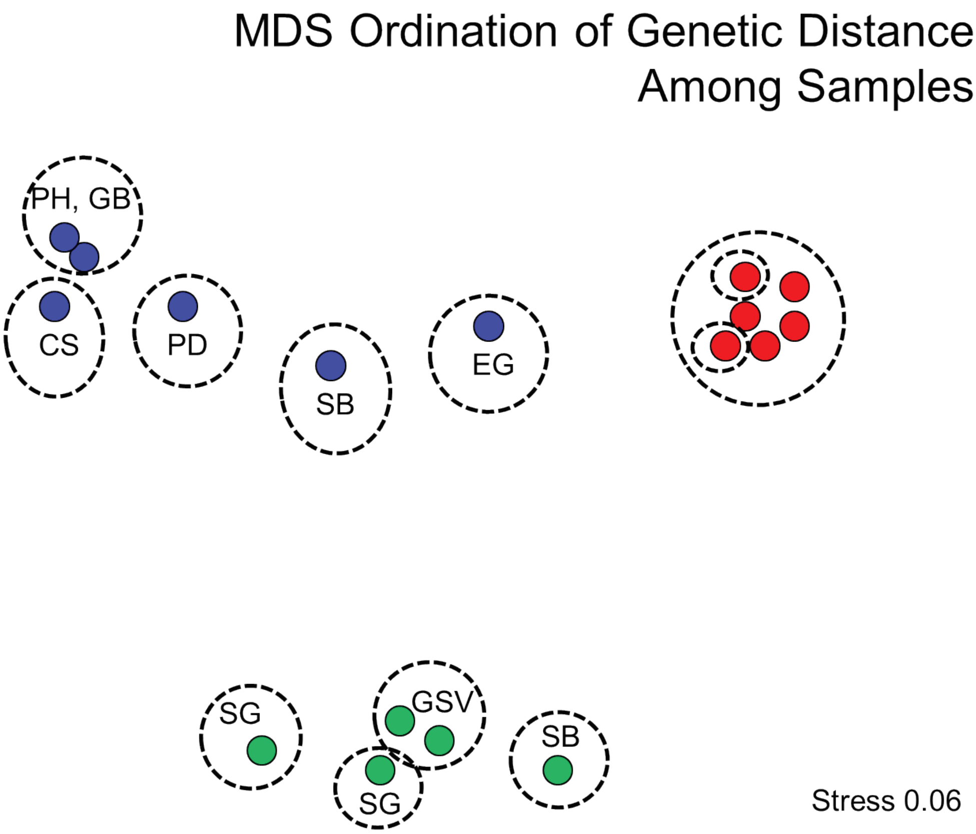

Figure 14. Multidimensional scaling ordination plot of the genetic distance among blue swimmer crab samples collected from Western Australia (blue dots – PH, Peel Harvey; GB, Geographe Bay; CS, Cockburn Sound; PD, Port Denison; SB, Shark Bay; EG, Exmouth Gulf), East coast (red dots – samples from Mackay, Hervey Bay, Moreton Bay, Wallis Lake, Port Stephens), and South Australia (green dots – SB, Streaky Bay; SG, Spencer Gulf; GSV, Gulf St Vincent). Additional work has shown that crabs in Cockburn Sound, Warnbro Sound and Swan River Estuary are not genetically differentiated from each other (Chaplin and Sezmis 2008).

4.4 Biophysical Management Tool for the South Australian Blue Crab Fishery

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Information presented on behalf of research undertaken by L. McLeay, M. Doubell, S. Roberts, S. Dixon, C. Anderacchio, L. James, C. Luick and J. Middleton (FRDC project no. 2008/011)

The oceanographic factors affecting the dispersal and settlement of blue swimmer crab larvae within South Australia's Gulfs are not well understood. South Australia's Gulfs are semi-enclosed marine systems that are uniquely classified as hypersaline inverse estuaries. In Spencer Gulf, water temperatures fluctuate seasonally between 12^{o}C and 24^{o}C, with higher summer temperatures and colder winter temperatures in the north compared to the south. Evaporation exceeds precipitation year round, leading to the formation of dense salty water in shallower waters of the upper gulf and clockwise water circulation around the gulf that is modulated by strong tidal currents and vertical mixing.

A voluntary fishery-dependent pot-sampling program has been undertaken in by members of the Blue Crab Fishery (BCF) since 2006.The primary purpose of the pot sampling program is to collect fishery-dependent data relating to the abundance of pre-recruits and legal sized catch. Many areas of the fishery have not been sampled during normal pre-Christmas fishing operations, and as a consequence, the sampling undertaken has not provided data suitable for robust calculations of egg production. Estimates of egg production also require data relating to the size-specific maturity and spawning frequency of female crabs. These data were also not available. However, the data collected in the program do provide some broad insight into the spatial patterns of reproduction for blue swimmer crabs in Spencer Gulf during the peak time of their spawning season.

Larger, more fecund, female blue swimmer crabs were generally sampled from areas located in southern Spencer Gulf. However, the areas with the largest percentage of spawning females (>25%) were generally located in the eastern gulf to the north of Wallaroo. Depending on the density of crabs found in these areas, it is possible that areas in the eastern gulf to the north of Wallaroo make the largest contributions to egg production and larval settlement. A more stratified approach to sampling blue swimmer crabs across their distribution in the future, coupled with reproductive information relating to spawning frequency and size at maturity for crabs in different parts of Spencer Gulf would help to reliably estimate egg production across their distribution. It would also enable relative estimates of crab biomass to be calculated thereby allowing estimation of fishing exploitation. This information would be useful to assist management of the fishery.

These results have important implications from a climate change perspective. Larval durations are likely longer in southern Spencer Gulf compared to northern Spencer Gulf due to the lower average temperatures in the southern gulf. Results from the biophysical model developed in this project indicate that the longer larval durations of larvae occurring under typical average temperatures of southern Spencer Gulf likely enhance their probability of reaching northern settlement grounds. Any increase in water temperature in Spencer Gulf caused by global warming would result in decreases in larval duration periods thereby reducing the probability of larvae that originate in this area from reaching the northern settlement grounds. The effect of such a climatic shift on larval settlement would also largely be influenced by how the behavioural responses of adults adapt to climatic shifts and affect their distribution during the spawning period. Such adult behavioural responses remain unquantified.

4.5 Environmental and Other "Non-Fishing" Factors Affecting Blue Swimmer Crabs in Moreton Bay Queensland

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The Queensland blue swimmer crab fishery exhibits strong seasonal variations in catch that are broadly consistent from year to year. Typically in Moreton Bay, catch rates increase during the spring from a winter low, declining again in summer before reaching the usual autumn peak (March/April). Trends offshore do not follow the same strong pattern, although there does tend to be a seasonal component to catch. This relatively consistent annual cycle is certainly related to patterns of recruitment and growth, but may also be affected by environmental factors such as temperature and rainfall, since catch rates within the fishery are generally lowest during winter. The relatively rapid growth rate and relatively short life cycle of blue swimmer crabs means that a single year class (or at most two year classes), the strength of which could be influenced by environmental factors during the spawning season and early juvenile development stages, is responsible for the bulk of the catch. The success of the annual recruitment, as well as subsequent growth of the 0^+ year cohort (in particular), may thus be influenced by environmental conditions at critical times of the life cycle. The fact that there is a trend for juveniles to have a higher relative abundance in the western side of Moreton Bay (Sumpton et al. 1994) also makes them vulnerable to the effects of river flow and flooding events that can dramatically reduce salinities, particularly in the southern and western parts of Moreton Bay and parts of western and southern Hervey Bay.

Environmental factors have been shown to influence blue swimmer crab fisheries in both Cockburn Sound and Shark Bay in Western Australia, but we found no conclusive evidence to support similar effects in Queensland. The fact that high rainfall in Queensland normally occurs during the summer means that juveniles are particularly vulnerable due to their preference for shallower flood-prone inshore areas. Despite this, there was only a weak negative correlation between river flow (a measure of rainfall and flooding) and historic catch rates of blue swimmer crabs. There have been only two extraordinary flood events in Moreton Bay since the collection of logbook catch information in 1988, and too few years of data are available to conclusively determine any environmental links to abundance or recruitment (Figure 15). However localized effects on catches were noted in some areas, particularly on the western side of Moreton Bay where the impact of the flood was greatest.

The fact that wind has been found to be important in a range of crustacean fisheries that rely on inshore recruitment of larvae and juvenile life history stages, suggests that it is also an important factor affecting the blue swimmer crab fishery. The impact of northerly winds during the time of larval dispersal and juvenile settlement in Moreton Bay (September to November) is an important area of further research.

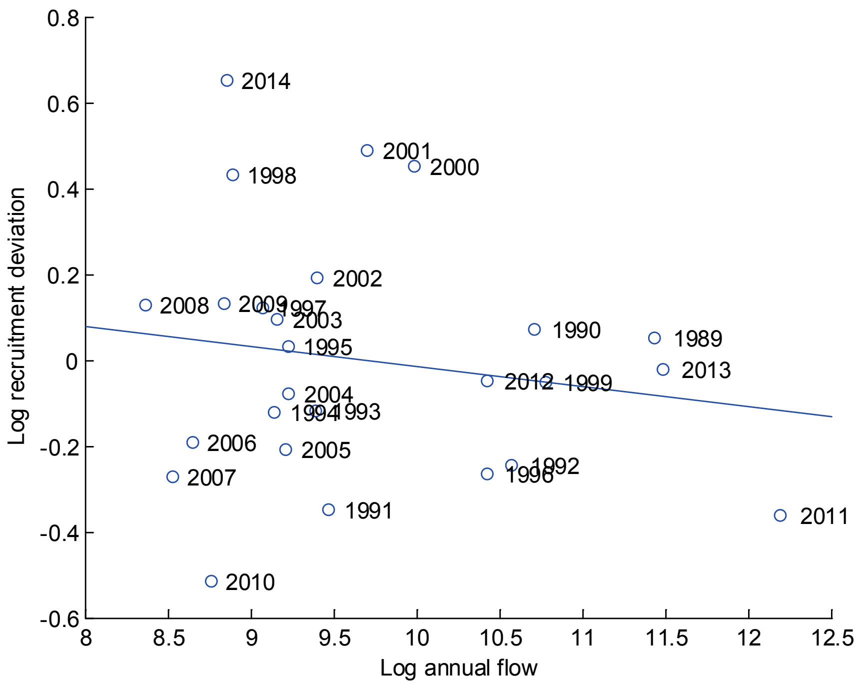

Figure 15. Correlation between river flow and recruitment deviation for blue swimmer crab Moreton region population.

The levels of parasitism and disease in Blue swimmer crabs in the Moreton Region were found to be low and have not changed significantly in the last 30 years. Levels of parasitism by *Sacculina granifera* have actually declined. There was limited baseline data on which to compare parasitism by the dinoflagellate *Hematodinium* and the microsporidian *Ameson* sp., but available evidence suggests that levels of these parasites have not increased over time. No fishers have recently commented on increasing levels of disease or parasitism of crabs in pots. However, the fact that samples were only taken from the commercial pot fishery which predominantly catches adult crabs may mask any potential effect of *Hematodinium* infection which has been shown in other areas of the world to cause mortalities in juvenile crabs. It is recommended that further research be undertaken across Australia to assess the potential for *Hematodinium* to impact on fisheries productivity. Such research would involve an assessment of the prevalence of the dinoflagellate in juvenile crabs and its potential impact on crab mortality.

5 Session 4: Blue Swimmer Crabs….from the Sea to the Plate

Chaired by Danielle Johnston, Senior Research Scientist, WA Department of Fisheries

This session covered a mixture of topics related to blue swimmer crabs and provided a broad perspective on some of the interactions during their journey from the sea to the plate.

Some key issues raised in this session were;

- Current research at the University of Western Australia highlighted the negative impacts of blue swimmer crab predation (and major bioturbators) on seagrass seedling recruitment, thus hindering the restoration success of degraded seagrass beds.

- Dennis and Karen Holder from South Australia provided a personal story of their crab fishing journey and their industry perspective on the current management of the blue swimmer crab fishery. They provided an interesting insight on the evolution of fishing gear, boat modifications to achieve their current commercial operations. They raised the issue of the negative interactions between snapper and blue swimmer crabs in GSV (currently being investigated by SARDI) and how the management strategies of the snapper fishery had negatively impacted on the crab fishery. The quota setting process was also criticised for not allowing an increase in the TACC, and fishery independent surveys poorly representing the "true" stock abundance. They felt frustration at fisher knowledge being ignored and devalued in regards to the management of the resource.

- Bycatch from crab trap fishing in the SA crab fishery provided valuable information that is so often poorly recorded and/or underestimated. Although the bycatch from crab traps are relatively low compared to other fishing gear, the configurations of a particular trap, the location of the fishery and the time of sampling can all influence the abundance and composition of bycatch.

- Crustaceans are prone to many diseases and one that is of growing concern to blue swimmer crab fisheries is *Hematodinium spp.,* a parasitic dinoflagellate capable of causing significant stock declines through direct morality of the host crab. Its prevalence in blue swimmer crabs stocks around Australia is currently poorly understood but reports of its existence is widespread. There is a critical need to undertake a nation-wide baseline study, and so the next step would be to secure external funding and support from stakeholders.

- A quick insight into the post-harvest and marketing of blue swimmer crabs for consumption by end users was provided in an interesting presentation that brought together the fisher/processor (the supplier), the crab (seafood product) and a chef (the end user).

5.1 Blue Swimmer Crabs are a Key Biotic Filter to Recruitment Success of *Posidonia australis* Seedlings in a Degraded Seagrass Ecosystem

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Processes that influence the establishment of seedlings are often diverse and complex, with seeds and seedlings navigating a landscape of biotic and abiotic bottlenecks. A clear understanding of those environmental factors limiting recruitment is a critical step in understanding which intervention approaches would deliver more effective restoration outcomes. Here we identify recruitment bottlenecks limiting seedling establishment in degraded seagrass ecosystems. We determined the degree to which early life-stage transition rates vary spatially and temporally along ecological gradients by planting germinated seeds of *Posidonia australis* at locations with a history of seagrass loss and recovery. In year one, 100 seeds were planted into three 9 x 1m^2 (100 seeds m^{-2}) plots assigned to one of three caging treatments; (i) uncaged (control), (ii) caged and (iii) half cage at 24 sites then monitored for survival at 1, 2.5, 4.5 6.5 months, and 1 year after planting. In year two, 5000 seedlings were broadcast into each of 3 x 25m^2 plots (200 seedlings m^{-2}) repeated at 9 sites and monitored for survival every month. In year 1, there were high rates of mortality across all treatments and all sites with most sites experiencing 100% mortality in the first month of development. However, seedlings that did establish in year one (0.07%) have persisted for 2 years. Seedling recruitment in the second experiment was also low (2-5% for 2 month survival), suggesting sites are not limited by the availability of seed. Seedling mortality appears to be driven by bottlenecks to recruitment: high biological (blue swimmer crab predation, bioturbation) and hydrodynamic activity (winter swell). Long term persistence of seedlings may be more a function of ‘a recruitment window of opportunity’ where lower levels of blue swimmer crab grazing, bioturbation and winter storms occur during the same year.

5.2 Dennis and Karen Holder – A Crab Fishing Journey

Dennis and Karen Holder,
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Dennis Holder started crab fishing in his early 20s at Ceduna on the Far West Coast in 1986 using a 5 metre fibreglass speedboat. By 2010 that journey had progressed to the project management and launch of the FV Silver Spectre a 24 metre purpose built crab fishing vessel (Figure 16). The talk by Karen and Dennis Holder details the boats in between, an overview of management arrangement to quota allocation in 1996 and a glimpse of prices achieved over the 15 year period. It concludes with information around the snapper event in Gulf St Vincent in the years 2011-2014, PIRSA response, and fisher's response and wraps up with some personal observations around management and science.

Figure 16. Commercial crab fishing vessels of Dennis Holder used in the 80s (above) and the FV Silver Spectre (below).

5.3 Assessing Bycatch in the South Australian Blue Swimmer Crab Pot Fishery

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In South Australia, annual or biennial fishery independent surveys conducted have been used to determine measures of relative abundance and size composition of blue swimmer crabs (*Portunus armatus)* for the Blue Crab Fishery (BCF). Surveys were undertaken using a standardised pot type alongside commercial gear at set survey locations. Additional information has been collected to provide the Commonwealth Department of Environment and Heritage with evidence on captures of incidental mortality of by-catch. By-catch in this study is defined as any catch other than blue swimmer crabs. Rock crabs and spider crabs are allowed to be commercially harvested within this fishery however are not readily marketed and often discarded with all other species and are therefore recorded as by-catch. The objectives of this study were to collect and monitor any changes in by-catch abundance and composition in comparison to blue crab catch rates in the fishery. Additionally, the current gear specifications were reviewed to assess the effectiveness of gear in minimising by-catch.

Since surveys first began in 2002, a total of 76 by-catch species have been recorded, dominated by crustaceans, fish and molluscs. This equates to 103,554 animals being captured from all pots during the sampling program. Three species have dominated captures, namely rock crab *(Nectocarcinus intigrifrons)*, spider crab (*Leptoithrax spp)* and Degen's leatherjacket (*Acanthaluteres spilomelanurus*). Marked differences exist in the composition of catch between the two gulfs and between the two types of fishing pots employed in the survey, however, there were no significant differences in by-catch over time. In Gulf St Vincent more species of by-catch were recorded compared to Spencer Gulf and there was a greater abundance of by-catch in Gulf St Vincent in all years, in particular 2013 and 2014. The rock crab was the most abundant species and comprised 81% of the total catch in both gulfs.

Comparisons of research and commercial pots demonstrated a higher frequency occurrence and abundance of by-catch in research pots in both gulfs. Research pots were dominated by rock crabs, however in Gulf St Vincent, there was a 33% increase in Degen's leatherjackets recorded in research pots in 2014. This coincided with a change to a larger mesh and larger diameter commercial pot which resulted in a 38% reduction in rock crabs abundance and a 64% increase in spider crab abundance in 2014.

In comparison to other fisheries, by-catch levels in the South Australian Blue crab fishery are considered comparatively low, in recent years the increase in mesh size and escape gaps in the fishery have provided decreases in by-catch abundances overall however continued monitoring of this is required to monitor future changes of by-catch levels.

5.4 Ecology and Infection Dynamics of *Hematodinium spp.* in Decapod Crustaceans: A Case Study and Potential Impacts to Fisheries

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Parasitic dinoflagellates of the genus *Hematodinium* are important pathogens of marine crustaceans, with outbreaks causing significant mortalities in a number of commercially and recreationally valuable stocks. Major fisheries which have been affected worldwide include commercial stocks of velvet swimmer crabs, *Necora puber*, American blue swimmer crabs, *Callinectes sapidus*, Norway lobster, *Nephrops norvegicus*, snow crabs, *Chionoecetes opilio*, and Tanner crabs, *C. bairdi*. Annual seasonal prevalence of *Hematodinium* spp. within some crab species can reach >80%, therefore these parasites have the capacity to regulate their host populations. The life cycle for the *Hematodinium* species infecting Norway lobsters and American blue swimmer crabs have been elucidated *in vitro* and include a series of unique asexual, and putatively sexual, reproductive stages that occur in the tissue and haemolymph of infected individuals. Development occurs within the crustacean host culminating in the production of numerous infective dinospores (densities can reach >1 million cells per ml of haemolymph in advanced stages of infection), which are generally released into the water column from moribund hosts via the gills. An overview of a US National Science Foundation – Ecology of Infectious Diseases grant project led by Professor Jeff Shields of the Virginia Institute of Marine Science, investigating *Hematodinium* infections blue swimmer crab, *Callinectes sapidus* on the east coast of the United States is presented. *Hematodinium* sp. infections have been reported in Australian blue swimmer crabs, *Portunus pelagicus*/ *P. armatus*, however the prevalence of the disease and potential impact to populations in Australia is unknown. Our understanding of the ecology and infection dynamics of *Hematodinium* sp. in juvenile and adult populations of *C. sapidus* provided by Prof Shields and his research team provides a solid foundation of knowledge and critical comparative data with which to begin exploring the impact of the *Hematodinium* infections in Australian crustacean fisheries.

5.5 CESSH Post-Harvest Research and Extension Update for the Blue Swimmer Crab

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Centre of Excellence for Science, Seafood and Health (CESSH), focuses on post-harvest projects with the aim to increase profitability for the Australian seafood industry. Two blue swimmer crab projects were discussed.

The first project (Seafood CRC 2010/770) was developed in response to end-user research that showed that chefs, hospitality staff and consumers were seeking more information/knowledge about seafood. A series of seven short videos have been produced on various seafood sectors including prawns, rock lobster, oysters, barramundi/snapper, sardines, crabs and cephalopods. The videos provide information on the species, the supply chain and seasonality, and tips on quality/storage (Pete Manifis), preparation (Josh Catalano) and cooking techniques (Don Hancey). The videos were integrated into the seafood training component for chef training qualifications at West Coast institute of Training and have also been distributed to the 250 other institutions in Australia that teach this course (Figure 17). In addition the videos have been taken up by the Home Economics Institute of Australia for their students, and the supply chain sections were re-edited into a single 10 minute video that was recently piloted in a one hour workshop on the seafood industry with 150 primary school students and their teachers.

The second project was Seafood CRC project: 2010/706 Accelerated Product Development: Blue Swimmer Crab Pilot. The project industry partner was Abacus Fisheries, a company involved in the catching, processing and marketing of blue swimmer crab products. The aim of the project was to develop a new series of value added Abacus crab products that have been researched, developed, costed, branded and trialled in the marketplace prior to further large financial commitment to facilitate production. This new accelerated product development methodology, building the products from desk-top to cook-top, and improving the likelihood of market success prior to large scale production, represented an innovative approach to seafood product development in smaller businesses.

Initially and during a four day collaborative ideation process, an ideation team of up to 15 chefs and food service distributors resulted in identification of over 90 possible product concepts from the Abacus Fisheries base ingredients, cooking liquor, crab mince and premium crab meat. These concepts were reduced to 19 following analysis by the technical team against parameters such as marketability, ease of preparation, and production constraints at the Abacus factory. The 19 products were prepared by a professional chef and the ideation team reconvened to assess the products against a number of criteria including value for money, texture, taste and general acceptability. This ideation/consultation process resulted in seven products being chosen for the next stage of the process.

Subsequently a commercial production trial for the seven products was conducted at a seafood processing facility in Brisbane. The trial utilised production methodologies, techniques, ingredients, recipes and packaging formats which would be applied to full scale production of the products. The products produced were assessed based on ability for cook top practices to be scaled to commercial production levels without impacting on product quality. As a result the test products were reduced to five: crab consommé, crab bisque, crab mousselline (presented as a boudin and timbale), crab rillette and crab cake protocols were finalised in the commercial production trials. These products were also subjected to analyses for shelf-life, packaging options, production costings and nutritional composition. HACCP plans for the products were also commenced.

The next stage of the process was an extended, secondary round of consultation/product assessment with >150 participants through one on one chef meetings and exposure at a trade shows. Following assessment of the results from this secondary chef consultation, the test product concepts were reduced to two (crab cake and crab bisque) and commercial trials at the Abacus facility were conducted.

Following successful completion of the trials, and Abacus factory modification to facilitate crab cake production, 16 pallets of crab cakes were produced (~288,000) and the product reached the market in September 2011. Production has continued and to date > 1.5 million crab cakes have been sold and a retail pack has just been launched.

The accelerated product development methodology developed in the project, loosely based on the stage gate methodology for new product development has been shown to be an alternative and feasible approach for new product development in the seafood industry.

Figure 17. WCIT students evaluate the videos (left) and Abacus crab cake packaging (right).

6 Session 5: Recreational Fishing and Surveys

Chaired by Karina Ryan, Senior Research Scientist, WA Department of Fisheries

6.1 National Perspective of Recreational Fishing for Blue Swimmer Crab

Karina Ryan, Steve Taylor, Crystal Beckmann, Daniel Johnson and Wayne Sumpton

While commercial catches are reported with statutory reporting, which provides an assumed census or true measure with no sampling error, it is often impossible or impractical to collect data from all recreational fishers. Survey sampling is the only feasible way of collecting data from large populations to provide information at lower costs. Importantly, surveys can be representative of the population when probability-based sampling designs are used. These designs can allow the potential forms of survey error to be minimised (see Figure 18), providing accurate and cost-effective data.

Although most states have a long history of recreational fishing surveys, the National Recreational Fishing Survey (NRFS, Henry and Lyle 2003) was the largest survey of its kind to be conducted in Australia. This survey has been described as concurrent state-wide surveys over the same time frame (1 May 2000—30 Apr 2001) using the same phone-diary survey methodology (with a cross-sectional screening to recruit diarists and a 12-month longitudinal phone-diary survey to collect detailed catch and effort information). Fishers were randomly selected from White Pages telephone directories and sample data expanded using Australian Bureau of Statistics (ABS) Estimated Resident Population.

The estimated total recreational catch of blue swimmer crab nationally in 2011/12 was 6,608,977 (by number), including 3,905,057 kept and 2,703,920 released. More than half the total catch was from Western Australia (57%), with catches also reported in South Australia (29%), New South Wales (11%), Queensland (4%) and the Northern Territory (<1%). The majority of catches were taken: by pots or traps (78%) compared with hand collecting, nets and line (22%); in estuarine habitat (52%) compared with coastal (46%) and offshore (2%); and by boat-based fishers (77%) compared with shore-based fishers (23%). Additionally 41% of catches were released, which was most likely in response to size limits and restrictions on harvesting females.

Estimates of the kept recreational catch by state (Table 4), with the exception of the Northern Territory, were considered to be robust in terms of the sample size and precision. The estimated average weight of individual blue swimmer crab kept by recreational fishers for each state were obtained from concurrent on-site surveys, previous surveys or 'best-guess' estimates where limited empirical data were available. The conversion of catch by numbers to weight indicated that catches kept by fishers exceeded 1,000 tonnes nationally.

The phone-diary survey methodology has been employed in state-wide repeat surveys in: New South Wales from 1 June 2013 to 31 May 2014 (in prep.); Queensland from 1 October 2010 to 30 September 2011 (Taylor et al. 2012) and 1 November 2013 to 31 October 2014

(Webley et al. 2015.); South Australia from 1 November 2007 to 31 October 2008 (Jones 2009) and 1 December 2013 to 30 November 2014 (*in prep*.); Tasmania from 1 December 2007 to 30 November 2008 (Lyle et al. 2009) and 1 November 2012 to 31 October 2013 (Lyle et al. 2014), the Northern Territory from 1 April 2009 to 31 March 2010 (West et al. 2012) and Western Australia from 1 March 2011 to 29 February 2012 (Ryan et al. 2013) and 1 May 2013 to 30 April 2014 (Ryan et al. 2015).

A current ABARES project aims to develop a Framework for a National Recreational Fishing Survey. It is likely this framework will recommend aligning state-wide surveys, with consideration of: different sampling frames, which is a household-based PSU from white pages sampling and person-based PSU from licence sampling; incomplete sampling frame coverage, including unlisted numbers and licence exemptions (potentially with dual frame designs); and reporting of inter-state fishing.

6.1.1 South Australia

The state-wide survey in South Australia has been repeated twice since 2000/01: from 1 November 2007 to 31 October 2008 (Jones 2009) and 1 December 2013 to 30 November 2014 (in prep). The phone-diary methodology used was consistent with the NRFS with sampling from the White Pages and expansion to ABS population profiles. The more recent surveys, however, included South Australian residents only, and were analysed using the R *recsurvey* package along with reanalysis of 2000/01 data (Lyle et al. 2010).

The estimated total recreational catch in South Australia by South Australian residents in 2007/08 was 1,876,490 (se=385,297) blue swimmer crabs, with 1,144,837 (se=268,749) kept and 731,653 (se=160,107) released, indicating 39% of catches were released (Jones 2009). The majority of the catch was from Gulf St Vincent and Kangaroo Island (58%) and the Spencer Gulf (39%), with minor catches from West Coast (3%) and Coorong Lagoon (<1%). The majority of catches were taken: by crab nets (hoop or drop nets) (~75%), by hand-held crab rakes, baited lines & other (surface dab netting, diving and spearing) (~25%); and by boat-based fishers (64%) compared with shore-based fishers (36%). The total number of blue swimmer crab caught increased by 20% from 1.56 million in 2000/01 to 1.88 million crabs in 2007/08, with the release rate increasing from 33% to 39%.

6.1.2 Queensland

The state-wide survey in Queensland has been repeated twice since 2000/01: 1 October 2010 to 30 September 2011 (Taylor et al. 2012) and 1 November 2013 to 31 October 2014 (Webley et al. 2015). The phone-diary methodology used was consistent with the NRFS with sampling from the White Pages and expansion to ABS population profiles. The more recent surveys, however, included Queensland residents only, and were analysed using the R *recsurvey* package along with reanalysis of 2000/01 data (Lyle et al. 2010).

Despite the fairly large gross sample in 2010/11 (11,200 diarists) compared with 2000/01 (7,900 diarists), fewer fishers caught blue swimmer crabs in 2010/11 and catches were highly variable. Estimates of recreational catch were considered to be highly unreliable. Overall fishing effort in 2010/11 was also considered to be fairly low, most likely as a consequence of the Brisbane Floods and Cyclone Yazi.

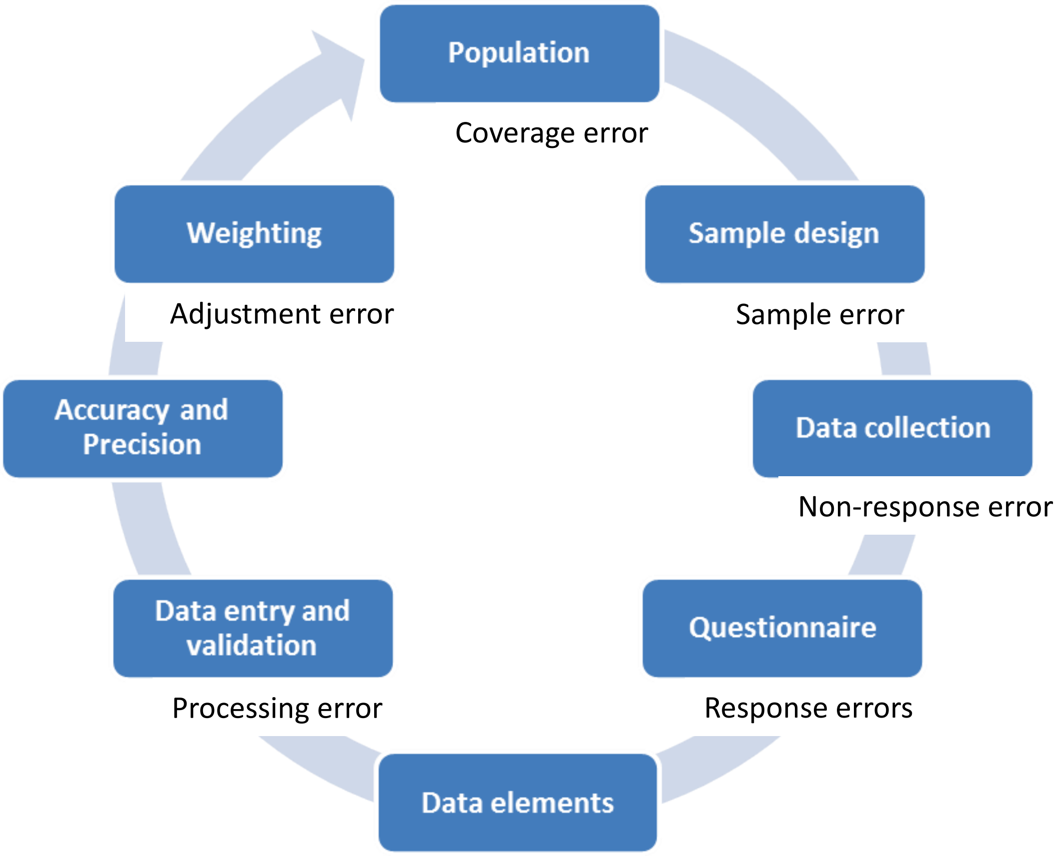

Figure 18. Flow chart of survey sampling methodology with potential sources of error.

Table 4. Estimated recreational catches of blue swimmer crab by state and survey period

State	Survey period	Catch by number (x 1000)	Standard error	Average weight (kg)	Catch by weight (t)	Reference
NSW	1 May 00—30 Apr 01	413	114	0.375	155	Henry and Lyle 2003
	1 Jun 13—31 May 14					
QLD	1 May 00—30 Apr 01*	118	33	0.333	39	Henry and Lyle 2003
	1 Oct 10—30 Sep 11	N/A	N/A	N/A	N/A	Taylor et al. 2012
	1 Nov 13—31 Oct 14					*in prep*
SA	1 May 00—30 Apr 01*	1,055	324	0.342	361	Henry and Lyle 2003
	1 Nov 07—31 Oct 08	1,145	269	0.248	284	Jones 2009
	1 Dec 13—30 Nov 14					*in prep*
WA	1 May 00—30 Apr 01	2,211	220	0.223	493	Henry and Lyle 2003
	1 Mar 11—29 Feb 12	424[B]	27	0.229	96[B]	Ryan et al. 2013
	1 May 13—30 Apr 14	285[B]	19	0.254	72[B]	Ryan et al. 2015
NT	1 May 00—30 Apr 01	<1				Henry and Lyle 2003

* Estimate reanalysed in subsequent publication
[B] Boat-based catch only

6.1.3 Challenges

Estimation

- accurate and precise estimates of recreational catch at spatial scales relevant to fisheries management, reliant of definitions of stocks/fishery
- Off-site surveys – e.g. large-scale surveys followed by spatial disaggregation, with robustness of estimates determined by sample size & uncertainty (relative standard error)
- On-site surveys – e.g. dedicated scoop netting survey for blue swimmer crab in WA

Average weight

- Average weight required for conversion of catch by number to catch by weight
- Subjective as it depends on the estimate of average weight, which is influenced by sample design, management and biological/environmental factors
- e.g. estimates of average weight for BSC reflect selectivity of sex distribution in the catch by fishers, protection of females & changes in the size distribution as cohorts move in to the fishery
- apply average weights in consultation with researchers and managers

Interpreting changes in point estimates over time - potential influences include:

- Changes to recreational bag limits
- Community interest in crabbing
- Environmental influences on crab abundance
- Environmental influences on fisher behaviour
- Other social and economic drivers

Other

- Communication of survey results
- Stakeholder engagement in research

6.1.4 Knowledge Gaps

Research

- Comparability between surveys due to differences in survey scope, e.g. proportion boat vs shore unknown
- Sex distribution in recreational catch
- Potential low level cost-effective monitoring, e.g. remote cameras

Management

- Alternative management strategies for recreational fishing (e.g. licence & catch card in US)
- Social-economic dimensions

6.2 Monitoring State-wide and Bioregional Catch of Blue Swimmer Crab in Western Australia Using Off-Site Survey Techniques

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Blue swimmer crab is a popular species among recreational fishers in Western Australia, with the lower West Coast fishery identified for Integrated Fisheries Management and Marine Stewardship Certification, requiring robust estimates to inform sustainable management decisions, resource allocations and monitoring resources. The introduction of a Recreational Fishing from a Boat Licence (RFBL) in Western Australia in March 2010 has allowed consideration of cost-effective, spatially and temporally comprehensive survey methods. An integrated approach was designed to provide estimates of recreational catch and effort by boat-based fishers at state-wide and bioregion levels. Survey components include: (i) phone-diary survey to obtain catch and effort data; (ii) boat-ramp surveys to collect size/frequency data for key species; and (iii) remote video survey to monitor launches and retrievals at key boat ramps. The phone-diary methodology is consistent with the NRFS, but with sampling from the RFBL (~140,000 licences are issued annually). Sample statistics from 'raw' person-based sample data is 'expanded' to population parameters using the R survey package, which creates point estimates and standard errors at various species, spatial and temporal aggregations. The state-wide survey has been conducted from 1 March 2011 to 29 February 2012 and 1 May 2013 to 30 April 2014.

In both surveys, blue swimmer crab was the most commonly caught species, and the most common invertebrate in each bioregion. The majority of catches were from the West Coast bioregion; from estuary habitat (72%), and also nearshore (27%); taken in summer (66%) compared with autumn (23%), winter (4%) and spring (7%); and by pots (including drop nets) (99%). Estimates of the average weight increased from 0.229 kg in 2011/12 to 0.254 kg in 2013/14 allowing conversion of estimated recreational catch by numbers to weight. The estimated total recreational catch state-wide was consistent between the two surveys; the kept catch decreased from 96 t in 2011/12 to 72 t in 2013/14, while the release rates increased from 51% to 68%. In the West Coast bioregion, the kept catch decreased from 85 t to 64 t, but the released catch increased from 95 t to 148 t with release rates increasing from 53% to 70%. The estimated total recreational catch in the West Coast bioregion increased from 181 t to 212 t. High release rates were mostly from releases of crabs below the legal size limit, explaining 71% of all releases in 11/12 and 80% in 13/14. Differences in point estimates over time can be attributed to changes in: management regulations (e.g. recreational bag limits); community interest in crabbing; environmental influences on crab abundance; environmental influences on fisher behaviour; and other social and economic drivers.

The spatial resolution of monitoring recreational fishing needs to be matched to the spatial scale at which fisheries are managed. Spatial disaggregation of data from the state-wide survey can provide samples with sufficient samples sizes and adequate precision for key fisheries of Peel-Harvey Estuary, Cockburn Sound, Swan-Canning Rivers and Geographe Bay. These combined fisheries contributed over 80% of the state-wide recreational catches and have been periodically surveyed in the past: Peel-Harvey Estuary 1998/99 and 2007/08 (Lai et al. 2014); Cockburn Sound 1996/97, 2001/02 and 2005/06 (Sumner and Lai 2012); Swan-Canning 1998/99 (Smith 2006); and Geographe Bay 1996/97, 2001/02 and 2003 (Bellchambers et al. 2006). Fishing activity considered to be in-scope during these on-site surveys has varied, with some surveys including both boat- and shore-based fishing, others just boat-based fishing; some surveys are based around key access points and most surveys conducted during daylight hours. Although recreational fishing for blue swimmer crab occurs across numerous, widespread access points with fishing from multiple platforms (including boat, shore, bridges/jetties), the state-wide phone-diary survey provides estimates, and allows comparison over time, of the boat-based sector using consistent methodology. While there is no specific recreational fishing licence for blue swimmer crab that can be used as a sampling frame to cost effectively contact fishers, the RFBL provides access to boat-based recreational fishers. The state-wide survey has proven to provide cost-effective data to support regular, robust estimates over large spatial scales, and also allows disaggregation at smaller spatial scales.

6.3 Estimating the Recreational Catch of Blue Swimmer Crab in Peel-Harvey Estuary: Trends, Challenges and Opportunities

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Blue swimmer crab (*Portunus armatus*) is highly sought after by recreational fishers and the protected waters of the Peel-Harvey Estuary are one of the most popular areas for recreational blue swimmer crab fishing in the south-west region of Western Australia. This estuary is easily accessible to fishers residing in Mandurah, Perth and Bunbury. Most crabs are caught using baited drop nets (set from boats, bridges, jetties and canal houses) and scoop nets, although fishers are also permitted to catch crabs by hand or using a blunt wire hook.

Estimating the recreational catch of blue swimmer crab in Peel-Harvey Estuary is challenging and expensive due to the large number of recreational fishers, the variety of fishing platforms, and the lack of a sampling frame for shore-based fishers. Estimates of boat- and shore-based blue swimmer crab catches in the estuary are available from two dedicated recreational fishing surveys undertaken in 1998/99 and 2007/08. The first survey estimated that the total retained recreational catch of blue swimmer crab between August 1998 and July 1999 was approximately 289 tonnes; however, a revised estimated range of 251 – 377 tonnes was recently produced. Applying the same method to analyse the data collected during the second survey, the total retained catch between November 2007 and October 2008 was estimated as 107 – 193 tonnes. In both surveys, the majority of the catch (approximately 70%) was taken by boat-based fishers, although not all platforms and time periods (e.g. fishing at night) were included in these estimates.

The state-wide survey of boat-based fishing was implemented in 2011/12 and provides state-wide and bioregion estimates for blue swimmer crab on a biennial basis. This survey also provides smaller-scale catch estimates (e.g. Peel-Harvey Estuary) for some species depending on the precision. Between March 2011 and February 2012, the total retained catch for Peel-Harvey Estuary was estimated to be approximately 51 tonnes. This estimate relates to the boat-based catch and does not include the retained catch from shore-based fishers. To improve knowledge on shore-based fishing, new technology thermal imaging cameras have recently been deployed at various locations around Peel-Harvey Estuary. These cameras are providing information on the 24 hr distribution of shore-based activity. An improved understanding of day vs. night patterns of shore-based fishing may help assess the potential underestimation of catch from previous on-site surveys and will assist in estimating the catch in future on-site surveys. In the absence of a sampling frame, it is likely that future estimates of the total recreational catch in Peel-Harvey Estuary will need to be derived from separate surveys. Corroboration through the comparison of different survey estimates and reanalysis of past data will assist in providing management with accurate information on recreational fishing.

6.4 Where the Crab is King……Investigating Recreational Crab Fisheries in Southwest Western Australia

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Blue swimmer crabs represent one of the most important recreationally fished species in terms of catch and participation rate in southwest Western Australia. The South-west Recreational Crabbing Project provides a valuable opportunity for the WA Department of Fisheries (DoF) to engage with the local crabbing community to develop ongoing, cost-effective programs that will deliver annual information on recreational crabbing and stock dynamics in the recreationally important blue swimmer crab fisheries of the Swan-Canning Estuary (SCE), the Leschenault Estuary and wider Bunbury area (LE) and Geographe Bay (GB). This information could not otherwise be collected by DoF, as these areas do not have substantial commercial fisheries like Cockburn Sound and the Peel-Harvey Estuary, where information is available to assess the annual status of these stocks. Funding for the project comes from Recreational Fishing from Boat Licence (RFBL) fees, via the Recreational Fishing Initiatives Fund which is overseen by RecFishWest.

Specifically, the project aims to:

1. Establish a program for providing recreational crabbing information on SCE, LE and GB by implementing a Recreational Angler Program (RAP) daily logbook to be completed by targeted recreational crabbers;
2. Develop methods for the ongoing assessment of blue swimmer crab recruitment and breeding stock in SCE, LE and GB; and

3. Determine the effectiveness of tagging methods to provide information on the movement of blue swimmer crabs that occurs between SCE, LE, GB and their adjacent marine environments (including Cockburn Sound and Koombana Bay).

There are currently 85, 36 and 57 recreational crabbers involved in the RAP program from SCE, LE and GB respectively. During the first year of the project (June 2013 to May 2014) 25 SCE crabbers submitted catch and effort records, compared with 12 crabbers from LE and 13 crabbers from GB. Similar numbers of crabs were captured by logbook participants in each of the three fisheries during this period, with drop netting representing the primary form of crabbing in each area (Figure 19). However, significantly more crabs were retained in SCE (70%) than either LE (22%) or GB (39%) where the majority of the captured crabs were either undersize or berried females (Figure 20). Most crabs were caught in the summer months in SCE and LE, compared with winter and spring in GB (Figure 20). Despite more crabs being retained in SCE, they required more effort to catch in this fishery with crabbers retaining on average 1.2 crabs for every 10 drop net pulls (Figure 21). This compared with 1.7 and 2.6 retained crabs per 10 drop net pulls in LE and GB respectively (Figure 21).

Fishery-independent spawning stock surveys were undertaken in October and November of 2013 and 2014 in each of the three fisheries, with sexually mature female crabs captured during all surveys (Figure 22). Recruitment pulses were identified from beach seines during recruitment surveys conducted in SCE and LE in March, April and May in 2014. However, the method was found to be unsuitable for catching juvenile crabs in GB and research hourglass traps are now preferred for this fishery. Recruit pulses were again recorded in LE in March, April and May during 2015, however, this has not been the case in either SCE or GB. Consequently, further surveys will be conducted in these fisheries in June 2015 to determine if there is a late recruitment.

It should be noted that these results are preliminary, and as the research will continue for another 12 months it is not possible to draw definitive conclusions regarding trends at this point (see Harris et al. 2016 for full report)

Two tank trials (January – March 2014 and 2015) have been run to assess the suitability of a modified T-bar tag for the long-term tagging of blue swimmer crabs. Despite some success, the level of crab mortality during the trials was unacceptable. Conversely, an *in situ* glue-on tag trial (September 2014 – February 2015) run in parallel with the tank trials was very successful, with recaptures of more than 10% of the 1125 crabs tagged in SCE reported in the three months before the crabs moulted and the tags were lost. The success of this trial has allowed for assessment of the T-bar tag *in situ*, with a current trial in SCE involving tagging half of all captured crabs with the glue-on tag only and the other half with the glue-on tag and a T-bar tag. Comparison between recapture rates of each will be used to determine if the mortality experienced during the tank trials was due to the T-bar tag or the tank environment. To date, 559 crabs have been tagged with recaptures of 18 glue-on only tagged crabs and 14 double tagged crabs reported.

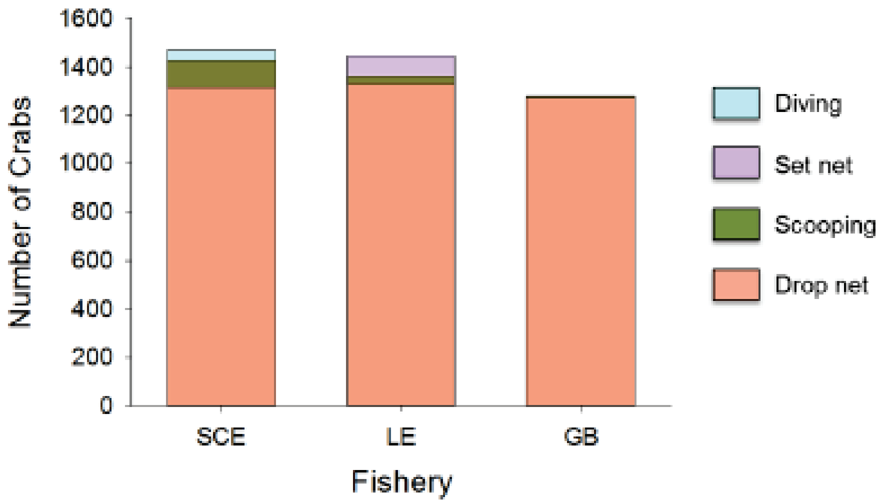

Figure 19. Total number of crabs captured by logbook participants by method the Swan-Canning Estuary (SCE), Leschenault Estuary (LE and Geographe Bay (GB) between June 2013 and May 2014 inclusive.

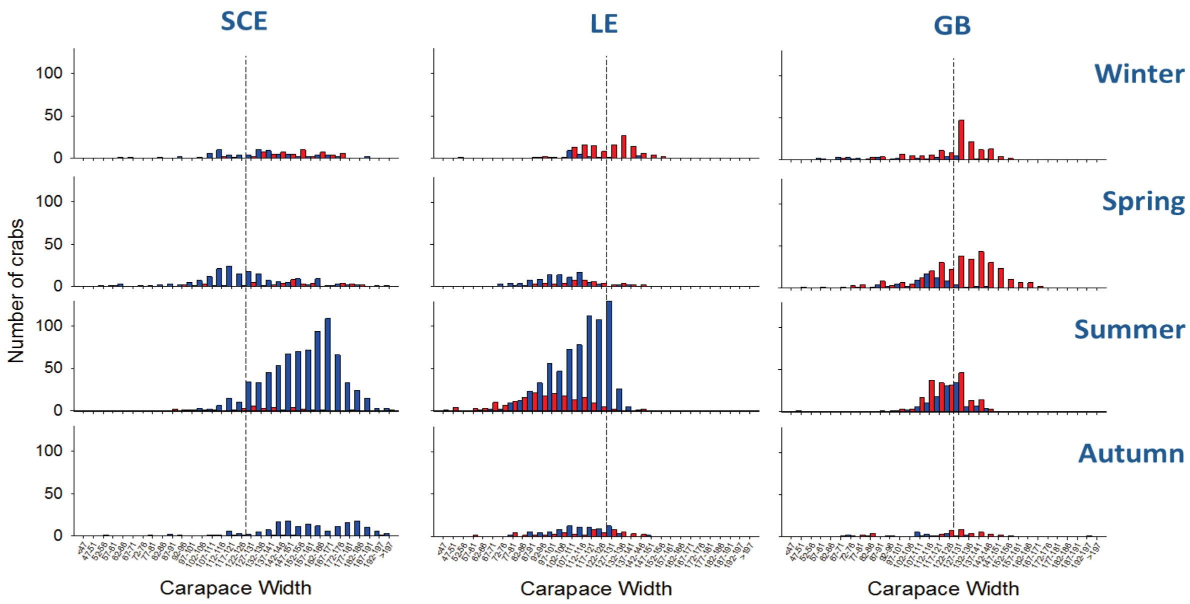

Figure 20. Length frequency histograms of male (blue) and female (red) blue swimmer crabs captured by logbook participants by season in the Swan-Canning Estuary (SCE), Leschenault Estuary (LE and Geographe Bay (GB) between June 2013 and May 2014 inclusive. --- recreational size limit (127 mm CW).

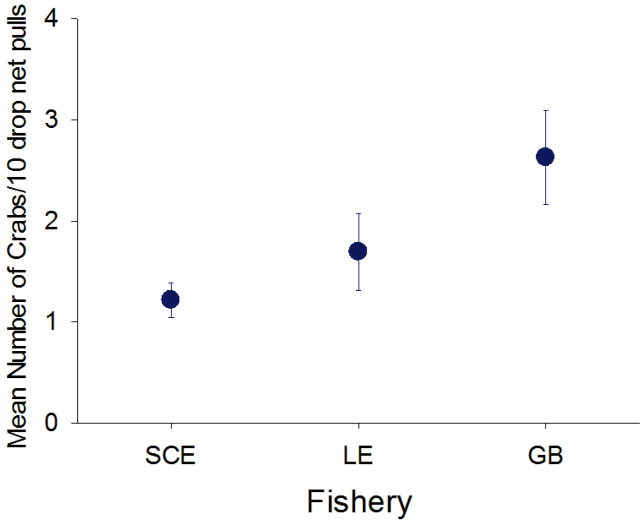

Figure 21. Mean catch rate of retained blue swimmer crabs per 10 drop net pulls by logbook participants in the Swan-Canning Estuary (SCE), Leschenault Estuary (LE and Geographe Bay (GB) between June 2013 and May 2014 inclusive.

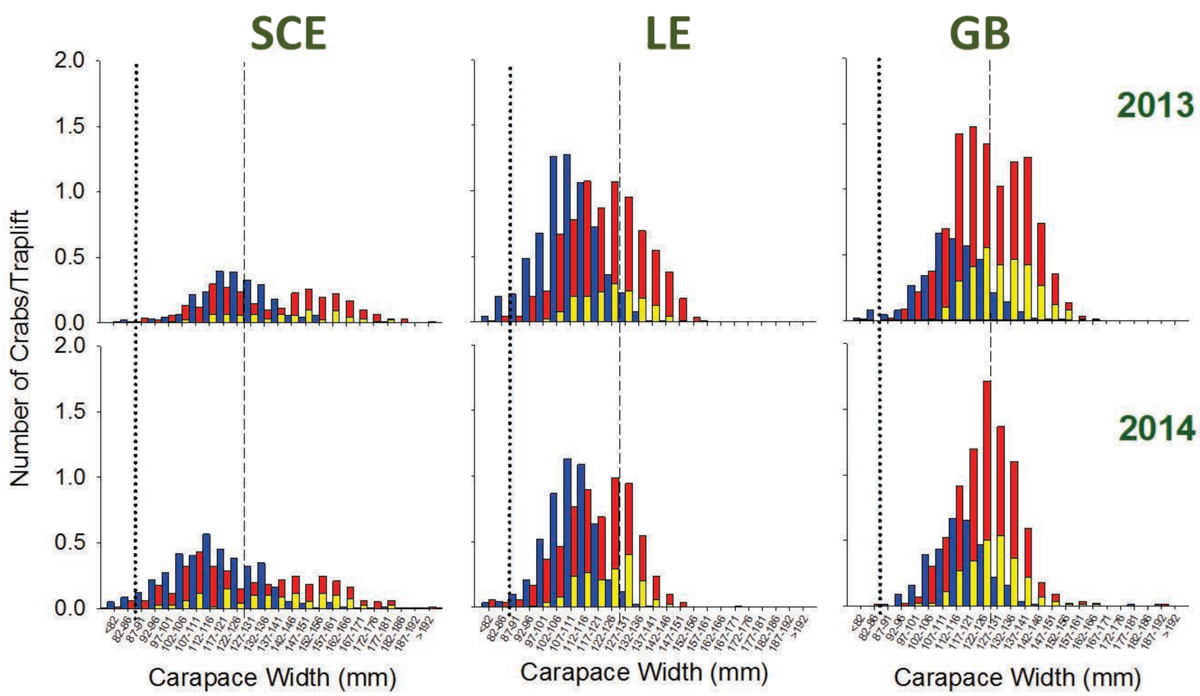

Figure 22. Mean length frequency histograms of male (blue), female (red) and berried female (yellow) blue swimmer crabs captured during fishery independent breeding stock surveys in the Swan-Canning Estuary (SCE), Leschenault Estuary (LE) and Geographe Bay (GB) in October and November 2013 and 2014. ••• sexually mature female size limit (86 mm CW); --- recreational size limit (127mm CW).

6.5 Estimating the Recreational Catch of Blue Swimmer Crabs in NSW

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The annual recreational harvest of blue swimmer crab in NSW is likely to lie between 150 and 310 tonnes. This estimate is based upon the results of the off-site National Recreational and Indigenous Fishing Survey of 2000/01 (NRIFS) and on-site surveys undertaken by Fisheries NSW. On-site recreational fishing surveys of the boat-based fishery in Lake Macquarie estimated that the recreational harvest exceeded 50 tonnes per-annum in this estuary alone.

However, since the 2000-01 NRIFS survey there have been many changes to recreational fisheries in NSW. For example, changes to bag and size limits, introduction of Recreational Fishing Havens and the growth in new fishing technologies have led to a different recreational fishery to that of over a decade ago. In 2013-2014, Fisheries NSW completed a state-wide survey of recreational fishing in NSW and the ACT. The survey measured the number of NSW/ACT residents who go recreational fishing, where and how often they fish and what they catch. The survey is designed to provide reliable estimates of: 1) fishing participation rates among various subgroups (e.g. age and gender; 2) state-wide and regional annual catch (harvest and release), fishing effort (days and hours fished) and catch rates for many popular species; 3) other recreational fishing-related information and 4) fishers' awareness and opinions on various fisheries-related issues. High rates of co-operation have been achieved with more than 2,250 households completing a Diary Survey that collected information on fishing events. A total of 26,250 person-based fishing events were completed for the 12 months surveyed. It is expected that robust estimates of blue swimmer crab harvest will be available from this survey. Full analysis and reporting of the survey data is not due for completion until August 2015.

7 Session 6: Management, Policy and Industry Perspectives

Chaired by Jim Penn, Emeritus Research Director, WA Department of Fisheries

A wide range of management strategies are applied for blue swimmer crabs across Australia and each has its merits and challenges. Presenters in this session covered; the role of scientists and managers in maintaining monitoring programs, research data integrity, communicating and implementing effective changes and addressing environmental uncertainty, dealing with change in government priorities and conflict around resource allocation amongst sectors. Primarily a common issue was being asked to do more with fewer resources to achieve both sustainability and economic objectives.

NSW highlighted the following management challenges which are being addressed and reviewed in a commercial fisheries reform program (http://www.dpi.nsw.gov.au/fisheries/commercial/reform/sarc-draft-recommendations) being put forward to the state Minister (outcomes to be released late 2015):

- High level of excess capacity
- High level of latent effort
- Lack of social license to operate
- Limited succession planning
- Data poor fisheries
- Shares (allocation) have little meaning and value

Similarly, the key management and industry issues facing QLD blue swimmer crab fisheries that were raised included;

- Lack of an effective voice and representation
- Ensuring profitability in a dynamic biological, economic, social and political environment
- Providing accurate and precise catch and effort information
- Survival of inshore, multi-endorsed mixed fisheries
- Review of current reference levels and the need to move towards a formal harvest strategy

The management of all QLD fisheries has currently undergone a review and recommendations were proposed for all fisheries including blue swimmer crabs (https://www.daf.qld.gov.au/fisheries/consultations-and-legislation/reviews-surveys-and-consultations/fisheries-management-review).

The value of "male only" fisheries on the east coast was discussed in the light of the productivity of the SA and WA fisheries where both sexes are taken, however in the presence of high and largely uncontrolled fishing pressure from both recreational and commercial fishing in the Qld and NSW fisheries, there was a general view that any proposals to change management strategies should be undertaken with caution.

In WA, despite the large body of research knowledge acquired across all its crab stocks there is a large variation in the performance of the fisheries which require intensive management. Better understanding of the relationship between a fishery and the stock is needed for better management and what is known about stock connectivity is not easily transferable into the management of the stock.

In SA, the harvest strategy and the decision rule framework in the management plan is currently being reviewed (driven by the adjustment of quota in the GSV fishery) in an aim to:

- Allow decision making to be more timely in relation to the research that is undertaken since currently there is a 12month lag between issues identified by research and the commercial season
- More explicit decision rules to allow certainty – too many implications that led to individual interpretations of the decision making process and lack of transparency
- Better utilise all data that is collected in the fishery
- Ability to adjust quota – increase and decrease
- High level of non-compliance with size and bag limits in the recreational sector
- Ongoing conflict between recreational and commercial sectors over temporal and spatial closures
- Developing a framework of co-management that supports a shift of management to a shared role with greater operational responsibility by industry

Challenges raised for WA include;

- Crab stocks are managed from tropical to temperate environments with good understanding of some stocks and limited understanding of others including stock connectivity – it is unclear if multiple fisheries are managed within a single stock
- Fisheries managed individually rather than at the whole-of-stock level hence while common rules occur across all fisheries there are also myriad of different rules
- Resource is highly valued by both recreational and commercial sectors and vulnerable to increasing fishing pressure over time
    - Commercial fisheries are limited entry
    - Recreational fisheries are open access
- MSC assessments test Department's EBFM credentials – knowledge of retained, bycatch, ETP, effectiveness of management framework and capacity to manage for, and respond to change (through harvest strategies). A very open and very public process and has capacity to change Departmental priorities and resourcing.
- Both commercial and recreational sectors have entered into the MSC process to have blue swimmer crabs in Peel Harvey assessed. Assessment of the recreational fishery is a world first. Process will raise the profile of these fisheries but will also generate further work for the Department and the sectors.
- Resource sharing – Integrated Fisheries Management (IFM) policy is an ongoing challenge as demonstrated by Shark Bay crab fishery.
- Is a TAC the most appropriate management system for blue swimmer crabs?
- MER – Minimum effective regulation
- Need for a recreational fishing crab licence (for shore based catch estimates)

7.1 Management Approaches and Challenges for South-west WA Crab Fisheries

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The blue swimmer crab resource in the south west of Western Australia is of great importance to commercial and recreational fishers and the broader south west community. Based on the current management arrangements, the south west blue swimmer crab resource is traditionally partitioned into and managed as 7 separate fisheries: Swan/Canning, Cockburn Sound, Warnbro Sound, Comet Bay/Mandurah to Bunbury, Peel/Harvey, Leschenault Estuary and Geographe Bay. While all part of the same resource, each of these fisheries has its own set of characteristics, with some being multi sector fisheries and others accessed by only a single sector.

The level of monitoring regarding fishing catch and effort and the understanding of each fishery and its stock is also very different between each of the fisheries. Accordingly, many of the fisheries have their own management arrangements and there is little consistency between the arrangements for each of these fisheries.

Despite the Department of Fisheries having undertaken a considerable amount of work to monitor and assess the status of, and understand the dynamics of, south west blue swimmer crab stocks, in recent years the performance of some of these fisheries has been very variable. This variability has led to a dynamic management approach, requiring expensive in-season monitoring and responsive management, including in some cases the closure of fisheries. Together these things have created significant stakeholder uncertainty and dramatically increased the resourcing required to manage these fisheries.

Given this, and in the context of fisheries and aquatic management policy drivers such as Ecosystem Based Fisheries Management, Integrated Fisheries Management, the Department's Marine Stewardship Council fisheries certification project and the Aquatic Resources Management Bill 2015 it is time for the Department to undertake a strategic review of the south west crab resource and fisheries.

Focussed at the resource level, the Review will take a science and risk-based approach and, working closely with the sectors, seek to develop a set of simple and consistent management arrangements that provide necessary protection to breeding stock while also making south west crab fishery performance more reliable.

7.2 Shark Bay Crab Fishery - Management Approaches and Challenges

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The Shark Bay blue swimmer crab resource has been commercially fished since the 1960s by the trawl sector, then from about 1980 by the trap sector. The current recreational blue swimmer crab catch is thought to be about 1% of the total catch.

The commercial blue swimmer catch level remained below 100 tonnes per year until about 1998 when the Carnarvon Experimental Crab Trap Fishery was established. The combined catch of both the trap and prawn trawl sectors then grew to a high of 828 tonnes in 2010. The Department of Fisheries became uncomfortable with the catch level in 2007 when it reached 700 tonnes. Noting that, in the Department's view there was insufficient research data upon which to predict a sustainable harvest level at that time and therefore the increasing catch level represented an unacceptable risk to stock sustainability.

The single biggest challenge to sustainably managing the blue swimmer crab resource in Shark Bay has been allocating commercial sector access to the resource. Not having "allocation" determined prevented industry reaching agreement to voluntarily limit the catch to 700 tonnes between 2007 and 2010.

In 2013, the then Minister determined commercial sector allocation and approved the development of an integrated blue swimmer crab management plan to include the trap, prawn trawl and scallop trawl sectors under one Individual Transferable Quota system. Following the Minister's sectoral allocation decision, allocation within the prawn trawl sector has continued to be a divisive and intractable issue that has impeded the ongoing development of the new management plan.

As the new plan nears completion during 2015, with a target date of 12 November for implementation, prawn trawl sector allocation continues to cause angst within industry. The Director General has commissioned independent advice on the matter ahead of providing a final draft management plan to the Minister in July 2015. The Minister's decision regarding allocation will come into effect when the new plan is published in the Government Gazette and comes into effect.

The key message out of this process is – sustainable fisheries management is the easy bit, once the thorny issue of "allocation" of entitlement to a resource can be resolved.

7.3 Socio-Economic Significance of Commercial Blue Swimmer Crabs in Shark Bay

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The small-scale Shark Bay trap and trawl crab fishery reopened in late 2013 after a 20 month closure. The fishery is now implementing substantial management changes including a TACC that are particularly challenging due to continued low crab abundance in Shark Bay. A set of socio-economic criteria were developed to assess current performance, and to identify risks and opportunities for the future. The criteria are: 1. Gross Value of Production (GVP), 2. Profitability, 3. Supply chain and 4. Employment and flow on benefits. These criteria were estimated using catch data obtained from WA fisheries and price data and other catch related information from ABARES and fisher interviews. The interviews also provided information on the structure of the crab supply chain. Participation in the study was high and represented all trap vessels and 17 of the 18 prawn trawl vessels active in 2013/14 season, as well as the two major processors (see Daley and van Putten 2017 for full study)

The daily logbook catch data are verified by landings and are considered reliable. Catches peak in winter for both trap and trawl crab sectors. Catch volume in the season following the closure (2013/14) was 372 t. This post closure catch volume is much lower than the 838 t caught in the season 09/10 preceding the closure. Even though catches are highest in winter, domestic prices are highest in summer. For the 2010/11 fishing season the average price was estimated at $4.25 per kilo by ABARES. The price for the 13/14 fishing season was estimated to be higher at $5.24 per kilo. GVP for the 13/14 season is estimated at $1.62 million, compared to $3.37 million prior to the closure (10/11). The estimated GVP foregone during the closure was estimated at greater than $2 million. Due to inconsistencies in available historical price data, a long-term estimation of GVP was not possible as either over or underestimation would likely result.

A detailed profitability analysis estimated that a trap fishing businesses is likely to have a positive gross margin in the short-term but in the longer term economic profitability (taking into consideration capital cost) is likely to be negative (assuming average prices per kilo and costs per vessel). The threshold catch for the trap fishery at which economic profit is zero (assuming a price of $5.24/kg) is 123 tonnes of crabs per trap vessel. If catches are assumed to be at the current average level of 89 tonnes, the threshold price at which economic profit is zero is $7.26/kg. For the trawl sector at the current price of $5.24, the catch of crabs would need to be 19.7 tonnes per annum per vessel for the sector’s economic profit to break even. Neither fishery achieved these thresholds in 2013/2014. If no economic profit is achieved the trap and trawl fisheries operators will not be able to afford to replace ageing vessels and other capital equipment. This may be particularly pertinent in the trawl fleet as many vessels may be due for replacement in the near future.

Scenario analysis explored three options for achieving economic sustainability: 1. increasing the price of crab, 2. increasing volume per vessel or, 3. reducing costs. Achieving a price increase may be challenging due to cheap imports of the same or similar product. Quota trading may provide some operators with the opportunity to increase catch volumes (i.e. pursue option 2). The opportunity to pursue option 3 may be different for the trawl and trap fisheries as their fixed costs differ significantly. Prawn trawl has higher fixed costs than trap but these are offset against returns from the target species (prawns). This means any increase in crab catch has a positive effect on returns, without substantial additional costs. A reduction in fuel price could provide relief for either fishery.

The trap and trawl fisheries are each characterised by their own supply chains, which are separate. It is evident that the two year closure has had had a significant impact on both sectors and this change may be difficult to reverse. In both supply chains there are points where 85–100% of volume is processed or transported making the supply chain vulnerable to, for instance, changes in volume. There have also been flow on effects from changes in the structure of the supply chains with direct expenditure on labour in the trap sector falling from around \$713K per annum to by an estimated \$327K per annum and indirect labour spending is estimated to have halved to an estimated \$563K. The social cost of the associated skills that were lost is likely to have long-term impacts.

Aside from the challenges faced by the two crab fishery sectors due to the past fishery closure and current low catches, new management arrangements may provide some opportunity for strengthening individual businesses that can capitalise on quota trading. To ensure ongoing accuracy of GVP estimates it is essential for the fishery to establish a consistent and reliable process to collect price data for both the trap and trawl sectors.

7.4 Marine Stewardship Council (MSC) Certification - What Does it Mean for Crab Fisheries

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Marine Stewardship Council (MSC) certification process involves independent third-party assessments of a fishery based on evaluations made against three broad principles; P1 - assessment of target species, P2 - ecological and environmental impact of the fishery and P3 - governance and management of the fishery. Each Principle consists of a series of performance indicators (PIs) against which the fishery is allocated a score out of 100. If any PI receives a score of less than 60, the fishery automatically fails. A score of 60 – 79 represents a conditional pass, where additional corrective measures are required in order to meet the criteria. A score of 80 – 100 is an unconditional pass i.e. the fishery is considered to currently meet the MSC criteria. In addition, to scoring above 60 for each of the PIs a fishery must pass each of the three principles individually (i.e. scores cannot be averaged across principles) to successfully obtain MSC certification.

Since 2000, the MSC program has expanded rapidly with 255 fisheries certified worldwide and an additional 121 fisheries in assessment. Worldwide there are six MSC certified crab fisheries; Louisiana Blue crab fishery (*Callinectes sapidus* - blue crab), Oregon Dungeness crab (*Cancer magister),* Shetland inshore brown & velvet crab, lobster and scallop fishery (*Cancer pagurus* -brown crab , *Necora puber* - Velvet crab), Gulf of St Lawrence snow crab trap (*Chionoecetes opilio - Snow crab),* Newfoundland & Labrador snow crab – (*Chionoecetes opilio-Snow crab),* Scotian shelf snow crab trap (*Chionoecetes opilio -Snow crab).*

Across the certified crab fisheries there are some PIs in each Principle that are more likely to receive conditions and therefore may require extra attention where preparing for assessment these are;

Principle 1 - Reference points (B_{MSY}) and Harvest strategy and harvest control rules and tools

Principle 2 - Information PIs, particularly for retained, bycatch and Endangered Threatened and protected species

Principle 3 - Fishery specific objectives (both long- and short-term)

In early 2012, the Western Australian State Government announced the allocation of approximately AUS $14 million for third party certification of the state's commercial fisheries. Approximately 47 fisheries are undergoing pre-assessment after which fisheries can voluntarily enter full assessment. The Western Australian Government is committed to funding the costs of pre-assessment for all fisheries and the first full assessment and surveillance audit for fisheries going to full assessment.

Pre-assessments for four bioregions have been completed, with last one expected to be completed by late 2015. In addition, Exmouth Gulf Prawn Managed Fishery, Shark Bay Prawn Managed Fishery, West Coast Deep Sea Crustacean Managed Fishery and The West Coast Estuarine Managed Fishery (Area 2: Peel-Harvey Estuary; which includes commercial fisheries for blue swimmer crab and sea mullet) and the Peel-Harvey Estuary Blue Swimmer Crab Recreational Fishery are all in full assessment (Johnston et al. 2015). Taking the number of Western Australian fisheries, including the Western Australian rock lobster fishery, either MSC certified or in assessment to six.

7.5 Overview of the South Australian Blue Crab Fishery

Neil MacDonald on behalf of Keith Rowling
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The Fishery

- Commercial pot fishery for Blue Swimmer Crabs established in 1996
- Limited entry and individual transferable quota (ITQ) management system
- The total allowable commercial catch (TACC) is set on an annual basis for each zone of the fishery
- Management History – Proceedings 1st National Blue Crab Workshop 1997
- Management plan for the Blue Crab Fishery was finalised in early 2012. The objectives of the plan include
- Ensuring sustainable harvests of the Blue Swimmer Crab resource
- Allocation of the resource to achieve optimal utilisation and equitable distribution to the commercial, recreational and Aboriginal traditional fishing sectors; and
- Minimising impacts of the fishery on the ecosystem
- Cost effective and participative management of the fishery
- Management response to changes in the Gulf St Vincent fishery identified limits of the current management processes
- The harvest strategy in the management plan is currently being reviewed in an aim to
- Allow decision making to be more timely in relation to the research that is undertaken
- More explicit in the decision rules to allow certainty
- Better utilise all data that is collected in the fishery
- Ability to adjust quota – increase and decrease

Allocation

- The Act provides that, in determining the share of aquatic resources to be allocated to a particular fishing sector under the first management plan for an existing fishery
- The current allocation on the Blue Crab Fishery is 70% commercial, 29% recreational and 1% Aboriginal traditional
- The information used to allocate shares of aquatic resources in this management plan is derived from the following sources
- 2007/08 South Australian Recreational Fishing Survey (Jones, 2009)
- Blue Swimmer Crab Fishery 2007/2008. Stock Assessment Report to PIRSA Fisheries (Dixon and Hooper, 2009)

Compliance

- There is concern with the level of non-compliance with size and bag limits in the recreational sector

By-catch

- There is very little gear interaction and by-catch issues in the pot fishery
- The management plan allocation framework provides for review if there is more information available or mortality of Blue Swimmer Crab by-catch by the prawn fisheries has significantly increased
- Such a review would consider whether mortality caused by the prawn fisheries needed to be explicitly allocated a share of the resource as a 'by-catch' allocation only. This would not be a reallocation of the quantum of the shares but an additional allocation, to recognise mortality of the resource by the prawn fisheries
- Prawn fisheries are actively mitigating by-catch through gear development

Socio-Economic issues

- The issue of access to Blue Swimmer Crabs in popular recreational fishing areas in Gulf St Vincent has been ongoing over many years
- In 2014 the commercial access along the Adelaide metropolitan coastline was temporarily closed over summer to give recreational fishers greater opportunities to catch Blue Crabs
- In 2015 additional pressure extended the temporary closure based on Industry Code of Practice (endorsed by PIRSA & the Minister) through January and February 2016 and over Easter. The closure covered two specific areas along the Adelaide Metropolitan coast: St Kilda Beach to the northern Outer Harbor breakwater; and the southern Outer Harbor breakwater to Marino Rocks and a key area on upper Yorke Peninsula (eastern side of GSV)
- Industry actively worked with the recreational fishing body to identify areas and the underlying issues. The Government worked co-operatively with the South Australian Blue Crab Pot Fishers Association in developing the closures

Management challenges

- Provision and delivery of services under a "fully" cost recovered licence fee model. 2015/16 - $284k
- Continued pressure to extend the temporary closure based on regulated closures rather than Industry Code of Practice
- Linking quota and pots
- Lack of access security
- Closed Season for commercial operators
- Co-management framework – process for devolving management responsibility and decision making, corporate knowledge, history retention, developing an industry governance framework that supports the management shift to a shared role with greater operational responsibility by industry
- Industry creating and maintaining an effective relationship with government management and research agencies
- Maintaining industry capacity to effectively participate in the management processand accessibility

7.6 Management and Industry Challenges for Ensuring a Sustainable and Profitable Inshore Commercial Fishing Industry in Queensland

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Management of the blue swimmer crab fishery in Queensland has been under review for several years and the Queensland Department of Agriculture and Fisheries (DAF) is currently considering the recommendations of a recently completed independent review of broader fisheries management in Queensland. There are many recommendations in that review which could significantly affect the management of the blue swimmer crab fishery but at this stage all recommendations are still under consideration.

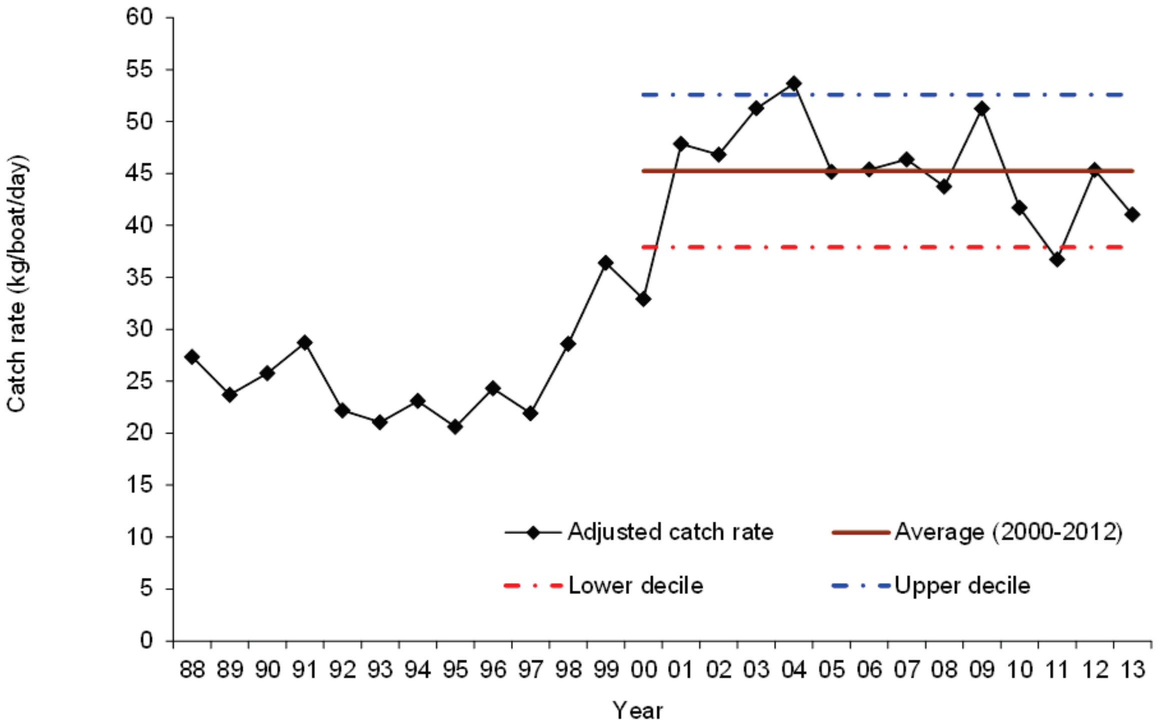

Figure 23. Average standardised blue swimmer crab catch rates for commercial pot fishers over all fishery areas in Queensland from 1988 to 2013.

Queensland has adopted the National Status of Australia Fish Stocks (SAFS) framework for categorising fisheries sustainability and currently conducts annual stock status workshops where the performance of the blue swimmer crab fishery is assessed and categorised within the SAFS framework. Currently, the fishery is assessed as sustainable in all fisheries regions within Queensland.

Current reference points are based on catches and standardised catch rates (Figure 23). The fishery currently has a stock assessment which was completed at the end of 2014 and as such can be regarded as a Tier 1 Fishery under the Commonwealth Harvest Strategy Policy.

However, the harvest strategy currently does not have explicit harvest control rules which trigger specific management actions when the fishery reaches threshold reference points.

In the past Management Advisory Committees were important in managing the fishery but these have not been in operation in Queensland for some years, although other less formal consultative mechanisms have ensured stakeholder engagement. The current MRAG review also recommended the formation of Fisheries Councils which could possibly have similar roles to the previous MAC's

There are few by-catch issues in the Queensland pot fishery as traps are widely regarded as one of the most environmentally sustainable fishing practises. There is a high degree of spatial and temporal complexity to the species composition of the bycatch in the pot fishery but bycatch levels are low by international standards. Interactions with turtles are recognised as an issue in this fishery

The trawl fishery for blue swimmer crabs is not generally regarded as a target fishery with the main species of interest to trawl fishers being prawns and scallops but the well-established bycatch concerns of trawl fisheries are still relevant with respect to catching blue swimmer crabs.

Entanglement of cetaceans such as whales is an issue in other parts of the world and has been highlighted as a potential risk factor in the blue swimmer crab fishery (particularly in offshore waters) given the increasing migratory population of humpback whales on the east coast of Australia.

The main compliance issues for this fishery relate to over-potting – In the past this has been difficult to detect in the commercial pot fishery as apparatus can be spread out over a very large area, and as pots are often individually buoyed it can be difficult to detect excess pot use.

Product and gear theft have been a problem in the fishery for many decades with both commercial and recreational fishers reporting a relatively high rate of theft and gear loss in some areas. Recent advances in detection and compliance technology may see an improvement in this situation. Compliance records have shown that taking undersized or female blue swimmer crabs have not been problem issues for a number of years with regulation compliance not declining over time.

Sections of the commercial fishing industry view poor economic performance in this fishery as being a significant impediment to ongoing sustainability. The widely varying structure of fishing businesses that access blue swimmer crab stocks complicates effective management due largely to the difference in size of fishing operations and the extent to which fishers rely on blue swimmer crabs for their income. There is a very limited charter industry for blue swimmer crabs and the recreational crab fishery has declined in recent years.

7.7 Commercial Fishery Management Approaches and Challenges in NSW

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The Estuary General Fishery (EGF) accounts for the majority (approximately 90%) of the commercial harvest of blue swimmer crabs in NSW. The fishery is a diverse multi-species multi-method fishery that may operate in 76 of the state's estuarine systems and comprises approximately 590 fishing businesses authorised to utilise 17 types of fishing gear. The fishery is an input controlled share management fishery and is divided geographically into seven regions from the Far North Coast to the Far South Coast of NSW.

There are 63 classes of share available in the fishery (hence 63 types of endorsement), comprised of 9 classes of share for each of the 7 regions. The classes of share correspond to the type of endorsement available in the fishery and the region in which that endorsement holder may take fish. Specifically, licensed commercial fishers must hold sufficient shares (generally 125) to be eligible for an endorsement, and each endorsement authorises the use of specific methods to take permitted species from certain waters.

The blue swimmer crab is a primary species of the EGF with annual landings ranging between 50 and 200 t over the past 15 years. The species is targeted by two endorsement types using traps and meshing nets, with a small proportion of the total catch caught incidentally in seine nets by a third endorsement type. The primary management controls in the EGF include a limit on the number of fishers authorised to operate in the fishery, temporal and spatial closures, gear restrictions (i.e. mesh sizes and net lengths), conditions on the use of gear, minimum size limit (60 mm carapace length) and a prohibition on the retention of berried females.

Some of the main issues faced by the EGF include high levels of fishing capacity and latent effort, lack of social licence to operate, limited succession, data paucity and fishery entitlements (shares) have little meaning and value. A reform program is currently underway that aims to rectify some of these issues. The structural adjustment component of the reform program has included discussions with industry on the implementation of individually transferable catch and/or effort quotas for the blue swimmer crab harvesting sector of the EGF.

8 Appendices

8.1 Appendix A : List of participants and Attendees

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- George Ebbett (georgeebbett@SOUTHERN PHONG.COM.AU) - Industry stakeholder
- Stephen Peters (Peters.SL@BingPond.com) - Industry stakeholder
- Matt Gillett (matt@recfishwest.org.au) – RECFISHWEST
- Felicity Horn (felicity@wafic.org.au) – WAFIC
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South Australia

- Crystal Beckmann (crystal.beckmann@sa.gov.au) - SARDI
- Graham Hooper (graham.hooper@sa.gov.au) - SARDI
- Neil MacDonald (neil@nmac.com.au) – SABCPFA
- Gary Barnes (garrybarnes3@outlook.com) – SABCPFA
- Dennis Holder (silverspectre2010@gmail.com) - SABCPFA
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New South Wales

- Daniel Johnson (daniel.johnson@dpi.nsw.gov.au) – NSW DPI
- Darren Reynolds (darren.reyonlds@dpi.new.gov.au) – NSW DPI

Queensland

- Wayne Sumpton (wayne.sumpton@daf.qld.gov.au) – QLD DAF

Tasmania

- Ingrid van Putten (Ingrid.vanPutten@CSIRO.au) – CSIRO
- Ross Daley (rossk.daley@gmail.com) – Horizon Consultancy

8.2 Appendix B: Workshop Agenda

3rd National Workshop on Blue Swimmer Crab

Department of Fisheries, Western Australia

The Western Australian Department of Fisheries welcomes you all and hopes this workshop provides a forum for blue swimmer crab scientists, fisheries managers, and industry stakeholders to review, exchange and discuss the current biological, management and economic issues facing the different jurisdictions and hopefully we can find synergies and solutions in moving forward.

Wednesday 3rd June 2015 – DAY 1 *(coffee and tea served from 8:30 am)*

09:00 – 09:05	**Welcome address** Lindsay Joll, *Acting Deputy Director General, DoF WA*
09:05 – 09:15	**Introduction and expected outcomes** Mervi Kangas, *Principal Research Scientist, DoF WA*
	Session 1 : State overview of blue swimmer crab commercial fisheries ***Chaired by Jim Penn***
	Overview of Western Australia's blue swimmer crab fisheries Danielle Johnston, *Senior Research Scientist, WA DoF*
	The rise, the fall and recovery of the Shark Bay crab fishery Arani Chandrapavan, *Research Scientist, WA DoF*
	Overview of the South Australian Blue Crab Fishery Crystal Beckmann, *Research Officer, SARDI*
	The evolution of blue swimmer crab fisheries in Queensland Wayne Sumpton, *Senior Fisheries Biologist, DAF*
	Stock status and fishery for blue swimmer crabs in NSW Daniel Johnson, *Scientific Officer, NSW Fisheries*
11:00 – 11:30	**MORNING TEA BREAK**
	Session 2 : Monitoring, Stock Assessment and Harvest Strategy ***Chaired by Mervi Kangas***
	Long term monitoring and results of the recent stock assessment of blue swimmer crabs in southern Queensland Wayne Sumpton, *Senior Fisheries Biologist, DAF*
	The South Australian Blue Crab Fishery Research Program Crystal Beckmann, *Research Officer, SARDI*
	Stock recovery and development of a new harvest strategy for Shark Bay crab fishery Arani Chandrapavan, *Research Scientist, WA DoF*
	Western Australia – South west coast crab fisheries Danielle Johnston, *Senior Research Scientist, WA DoF*
13:00 – 14:00	**LUNCH BREAK**
	What factors influence the vulnerability of the Cockburn Sound crab stock to fishing mortality Alex Hesp, *Senior Research Scientist, WA DoF*
	DISCUSSION of SESSION 2 **Identify synergies, challenges and knowledge gaps from the issues raised**
	Session 3 : Environmental drivers and Climate change ***Chaired by Nick Caputi***
	Overview of oceanographic processes associated with summer 2011 marine heat wave Alan Pearce, *Principal Research Oceanographer , WA DoF*
	Environmental drivers of recruitment of crabs in Western Australia Nick Caputi, *Supervising Scientist, WA DoF*
	Genetic determination of the stock structure of blue swimmer crabs in Australia Jennie Chaplin, *Senior Lecturer, Murdoch University*

15:30-15:50	**AFTERNOON TEA BREAK**
	Biophysical management tool for the South Australian Blue Crab Fishery **Crystal Beckmann, *Research Officer, SARDI***
	Environmental and other "non-fishing " factors affecting blue swimmer crabs in Moreton Bay Queensland **Wayne Sumpton, *Senior Fisheries Biologist, DAF***
	DISCUSSION of SESSION 3 **Identify synergies, challenges and knowledge gaps from the issues raised**
17:15	**END OF DAY 1**

3rd National Workshop on Blue Swimmer Crab

Department of Fisheries, Western Australia

Thursday 4th June 2015 – DAY 2 *(coffee and tea served from 8:30 am)*

09:00 – 09:05	**Introduction and recap of Day 1** **Mervi Kangas, *Principal Research Scientist, DoF WA***
	Session 4 : Blue swimmer crabs….from the sea to the plate ***Chaired by Danielle Johnston***
	Blue swimmer crabs impact recruitment success of *Posidonia australis* seedlings in a degraded seagrass ecosystem **John Statton, *Marine Restoration Ecologist, UWA***
	Dennis and Karen Holder – a crab fishing journey **Dennis and Karen Holder, *Licensee, DM and KL holder P/L***
	Assessing bycatch in the South Australian blue swimmer crab pot fishery **Graham Hooper, *Research Officer, SARDI***
	Ecology and infection dynamics of *Hematodinium* spp. in decapod crustaceans: a case study and potential impacts to fisheries **Terry Miller, *Senior Research Scientist, WA DoF (Fish Health)***
	CESSH Post-harvest research and extension update for the blue swimmer crab **Janet Howieson, *Senior Research Fellow, Curtin University***
	DISCUSSION of SESSION 4 **Identify synergies, challenges and knowledge gaps from the issues raised**
11:00 – 11:20	**MORNING TEA BREAK**
	Session 5 : Recreational Fishing and Surveys ***Chaired by Karina Ryan***
	Monitoring State-wide and Bioregional catch of blue swimmer crab in Western Australia using off-site survey techniques **Karina Ryan, *Senior Research Scientist, WA DoF***
	Estimating the recreational catch of blue swimmer crab in Peel-Harvey Estuary: trends, challenges and opportunities **Steve Taylor, *Research Scientist, WA DoF***
	Where the Crab is King……investigating recreational crab fisheries in Southwest WA **David Harris, *Research Scientist, WA DoF***
	Estimating the recreational catch of blue swimmer crabs in NSW **Daniel Johnson, *Scientific Officer,, NSW Fisheries***
	DISCUSSION of SESSION 5 **Identify synergies, challenges and knowledge gaps from the issues raised**
13:00 – 14:00	**LUNCH BREAK**

Session 6 : Management, Policy and Industry Perspectives *Chaired by Jim Penn*
Management approaches and challenges for South-west WA crab fisheries Tim Nicholas, *Fisheries Manager, WA DoF*
Shark Bay crab fishery - management approaches and challenges Shane O'Donoghue, *Fisheries Manager, WA DoF*
Socio-economic significance of commercial blue swimmer crabs in Shark Bay Ingrid van Putten and Ross Daley, *Consultants*, *Horizon Consultancy*
Marine Stewardship Council (MSC) Certification - What does it mean for crab fisheries Lynda Bellchambers, *Principal Research Scientist, DoF WA*
15:30-15:50 AFTERNOON TEA BREAK
Overview of the South Australian Blue Crab Fishery Neil MacDonald, *SABCPFA*
Management and industry challenges for ensuring a sustainable and profitable inshore commercial fishing industry in Queensland Wayne Sumpton, *Senior Fisheries Biologist, DAF*
Commercial fishery management approaches and challenges in NSW Darren Reynolds, *Senior Fisheries Manager, NSW Fisheries*
DISCUSSION of SESSION 6 **Identify synergies, challenges and knowledge gaps from the issues raised**
Workshop wrap-up discussion ***Chaired by Mervi Kangas and Nick Caputi***

8.3 Appendix C: References and Suggested Reading

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