Population monitoring of Glenelg Spiny Crayfish (*Euastacus bispinosus*) in rising-spring habitats of lower south east, South Australia

Nick Whiterod and Michael Hammer

Aquasave Consultants, Adelaide

May 2012

Report to Friends of Mt Gambier Area Parks (Friends of Parks Inc.)

Citation

Whiterod, N. and Hammer, M. (2012). Population monitoring of Glenelg Spiny Crayfish (*Euastacus bispinosus*) in rising-spring habitats of lower south east, South Australia. Report to Friends of Mt Gambier Area Parks (Friends of Parks Inc.). Aquasave Consultants, Adelaide. p. 27.

Correspondence in relation to this report contact

Dr Nick Whiterod
Aquasave Consultants
Tel: +61 409 023 771
Email: nick.whiterod@aquasave.com.au

Cover (clockwise from top): underwater view of aquatic vegetation in the Ewens Pond system; female Glenelg Spiny Crayfish with eggs (in berry); and Glenelg Spiny Crayfish amongst aquatic vegetation.

Table of Contents

1.0 Introduction

Glenelg Spiny Crayfish (*Euastacus bispinosus* Clark) is one of the world's largest freshwater crayfish. They are a slow-growing, long-lived and late-maturing species with a naturally limited distribution across south east South Australia and south west Victoria (Zeidler 1982; Honan 2004; Hammer and Roberts 2008). Across its natural range, the species has undergone dramatic reductions in distribution and abundance and, nowadays, has a considerably restricted geographical range (total extent of occurrence, 12 700 km^2) (Zeidler 1982; Morgan 1986; Furse and Coughran 2011a). These declines have been attributed to wide ranging biological (fishing pressure, genetic isolation), habitat (riparian clearing and bank erosion, water quality), hydrological (declining water availability, flow regulation) and catchment (agriculture) threats (Honan 2004; Hammer and Roberts 2008; Sweeney and Dickson 2011). Of particular concern is the South Australian population of the species, which has a small core area of occurrence (24 km^2) in the westerly extent of the natural range of the species (Hammer and Roberts 2008). The SA population is largely restricted to five rising-spring habitats (although presumed translocation sub-populations exist elsewhere), which are characterised by cool water containing little or no suspended solids, which is thick with aquatic vegetation and a rich array of aquatic fauna (Hammer 2002; Hammer and Roberts 2008). Threats specific to the SA population relate to hydrology and extensive habitat modification and fragmentation, with the declining quantity (i.e. reduced discharge) and quality (i.e. increased nutrient content) of the aquifer water source feeding these rising-spring habitats a recent concern (Hammer and Roberts 2008; Sweeney and Dickson 2011).

The regional conservation and management of the species is hampered by a limited understanding of demographics of the SA population in contrast to the well-studied Victorian population (Honan and Mitchell 1995a; Honan and Mitchell 1995b; Honan and Mitchell 1995c; Johnston *et al.* 2008; Johnston and Robson 2009). A published study focusing on the SA population, from one small sub-population from a spring fed creek that is now dry, observed females maturing at smaller mean sizes and more individuals with gonopore aberrations (i.e. individuals with both male and female sex organs) compared to the Victorian population (Honan and Mitchell 1995a). In 2006, the first assessment to monitor the species across its SA range highlighted low abundance, a notable sex bias towards females, a large proportion of aberrant individuals and a conservative population estimate of less than 500 individuals across the restricted core area of occurrence (Hammer and Roberts 2008). From this assessment it concluded that species is 'Critically Endangered' in South Australia, indicating an extremely high risk of extinction in the wild. Broader conservation assessment has elevated the species to 'Endangered' nationally (under *EPBC Act* 1999) and 'Vulnerable' globally (under IUCN) and led to the closure of the recreational fishery across its entire range (Furse and Coughran 2011b).

Some threats to the SA population have diminished (e.g. closure of recreational fishery) since these listings, but many threatening processes remain and therefore the future of Glenelg Spiny Crayfish remains uncertain (Sweeney and Dickson 2011). From the recent national conservation assessment it was concluded that population monitoring is needed to evaluate the trends in recovery or decline across the range (Furse and Coughran 2011b; Furse and Coughran 2011c) and it is therefore pertinent to investigate the SA population as it is at high risk of extinction.

The aim of the present study was to continue and expand the monitoring of the SA of population of Glenelg Spiny Crayfish by:

- Conducting winter and summer monitoring across the core area of occurrence,
- Assessing population demographics of sampled crayfish (abundance, sex ratio, length-frequency distributions, size of onset of sexual maturity, gonopore aberrations), and
- Exploring additional rising-spring habitats outside of the core area of occurrence as part of range mapping of the species.

These objectives aim to provide the information necessary to make an updated conservation assessment to inform the management of Glenelg Spiny Crayfish within rising-spring habitats of south east South Australia.

2.0 Methods

2.1 Study region

Glenelg Spiny Crayfish has a restricted distribution across south east South Australia and south west Victoria (Figure 1). The core area of occurrence of the SA population of Glenelg Spiny Crayfish is restricted to sites across five of these rising-spring habitats in the lower south east region of South Australia (Hammer and Roberts 2008). Rising-spring habitats are the result of karst activity that produced numerous depressions, some of which form spring pools or ponds ('drowned sinkholes'). These unique habitats are fed by cool groundwater rising to the surface and discharge via modified creeks (some are now man-made drains) to the sea (Allison and Harvey 1983). While once likely hydrologically linked naturally through the seasonal inundation of the surrounding fen environment, landscape change through drainage and clearance has disrupted connectivity and ensures individual rising-spring habitats are now largely isolated (Sweeney and Dickson 2011). Each fragmented rising-spring habitat (and all connected sites within) where the species occurs was defined as sub-populations of the SA population (i.e. the Eight Mile Creek sub-population consists of individuals from Ewens Ponds, Eight Mile Creek sites and Spencer Pond). Seasonal (winter, 21-27 August 2011; summer, 5-10 December 2011) monitoring focused on 22 sites across the core area of occurrence as well as three dedicated 'range mapping' sites (Table 1 and Figure 5).

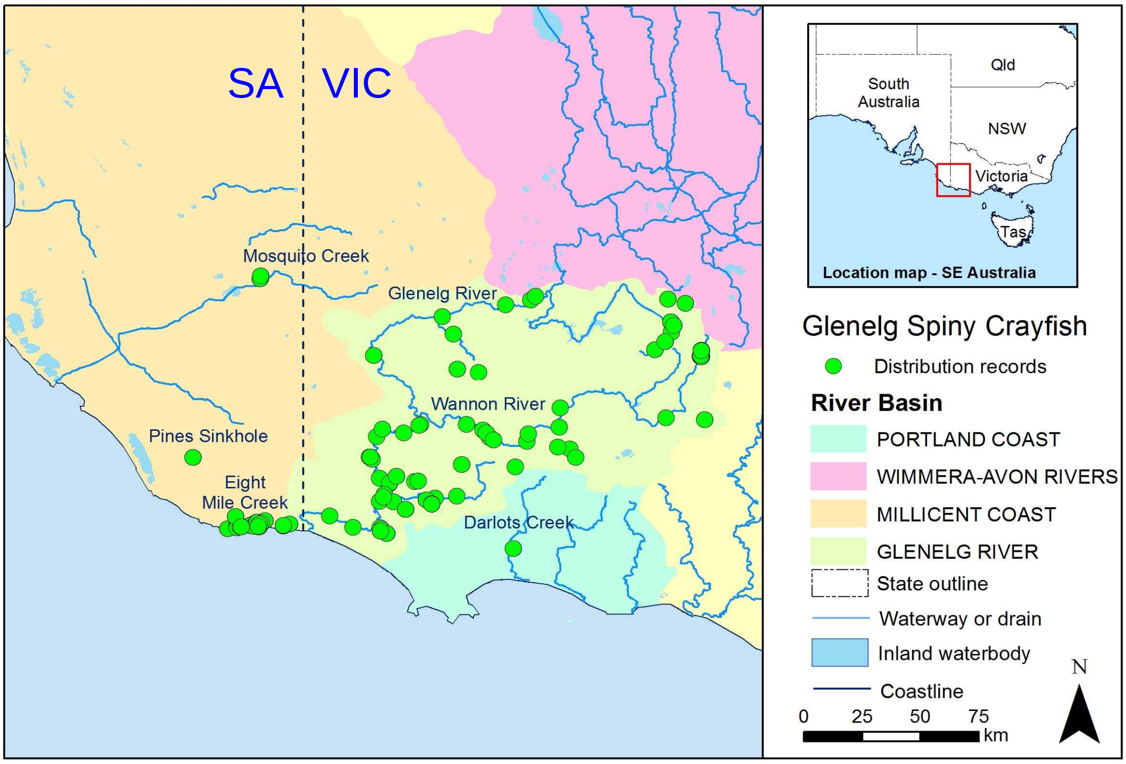

Figure 1. Distribution records of Glenelg Spiny Crayfish (*Euastacus bispinosus*), collated from Hammer and Roberts (2008) including SA Museum records; Johnston et al (2008); Victorian Environment Protection Authority and Victorian Department of Sustainability and Environment unpublished data including Museum Victoria records; and David Mossop unpublished data.

Table 1. Summary of sampling sites, survey effort and methods for Glenelg Spiny Crayfish in lower south east of South Australia.

Waterway	Site	Site Code	Easting	Northing	Munyana (nets)	Opera (nets)	Efishing (sec)
Clarke Park	Dingy Dell & Spring	SC11-21	472110	5789120			334
	ds SA Water pump shed	SC11-20	471878	5788288			414
		SC11-41					377
	Sea Parade	SC11-22	472355	5787890	2	3	
Cress Creek	Bubbling spring	SC11-17	474927	5789930	5	5	
		SC11-38			5	4	
	ds bubbling spring	SC11-18	475029	5789859	3	2	
		SC11-39			4	2	
	EMC Road Bridge	SC11-19	474975	5788599			1187
		SC11-40					700
Jerusalem Creek	Little Piccaninnie	SC11-13	476082	5789118	9	9	
		SC11-36			6	5	
	Rising spring close to LP	SC11-14	476320	5789320	3	3	
Deep Creek	54ft Pond	SC11-10	480990	5789909	4	4	
		SC11-33			5	5	
	EMC Road Bridge	SC11-12	480803	5789286			1288
		SC11-35					1072
	Stratmans Pond	SC11-09	479928	5789917	9	7	
		SC11-32			9	6	
	us Wooden Bridge	SC11-11	480481	5789364	4	4	
		SC11-34			4	4	
Eight Mile Creek	ds Drain 5	SC11-07	482373	5740026	9		
		SC11-30			3	3	
	Edge of Conservation Park	SC11-06	481985	5790877	10		
		SC11-29			6	6	
	Pond 1	SC11-03	481618	5791270	10	9	
		SC11-26			9	8	
	Pond 2	SC11-02	481622	5791272	11	10	
		SC11-25			9	8	
	Pond 3	SC11-04	481825	5791074	9	9	
		SC11-27			10	8	
	Spencer Pond	SC11-05	483054	5790772	10	10	
		SC11-28			10	10	
	Drain 5 us EMC junction	SC11-01	482450	5790350			1144
		SC11-24					830
	us EMC Road bridge	SC11-08	482171	5789412			1122
		SC11-31					930
Hitchcox Drain	Bones Pond	SC11-15	484464	5791710	7	8	
		SC11-37			7	7	
	Dead Pond	SC11-16	484800	5791710	2	2	
Isolated	Nene Valley	SC11-23	460550	5790680			1211
	Tea-tree Sinkhole	SC11-43	492890	5790450	2	1	
	Horse & Cart Sinkhole	SC11-42	492853	5790387	1	1	

2.2 Environmental descriptors

Location (description and GPS- WGS 84 datum), waterway, weather, land use, potential impacts and environmental characteristics were recorded for each sampling site to assist with the interpretation of results and future replication. Digital photos were also taken of all sites. Environmental characteristics included details of aquatic and interlinked riparian condition under the following categories:

General descriptors:

- Habitat type (i.e. stream, pool)
- Pool size as an estimate of surface area: small (<100 m^2), medium (100-199 m^2), large (200-299 m^2), very large (300-399 m^2) and open water (>399 m^2)
- Bank slope (e.g. steep = 45º, vertical 90º)
- Depth (maximum and average)
- Substrate type (e.g. sand, gravel, mud)

Flow environment:

- A temporal measure of connectivity based on seasonal conditions and local landholder input (e.g. ephemeral, six months flow connection, or permanently connected), plus comments such as whether the area is spring fed.

Pool condition and flow:

- A measure of water level in comparison to the normal bank level of a pool (e.g. concentrated, bank level, in flood) and
- Estimate of flow at the time of sampling ranked relative to magnitude: low <10 L sec^{-1}; medium = 10-100 L sec^{-1}; high = 100-200 sec^{-1}; very high > 200 L sec-^{1}.

Contributions to cover (% of volume occupied and type):

- Submerged – physical (e.g. snags, leaf litter, rock),
- Submerged – biological (e.g. aquatic plants, Chara, other algae),
- Emergent (e.g. reeds, rushes and sedges, tea tree),
- Fringing vegetation within 2 metres of the water's edge (particular note of small amphibious species on the bank such as Crassula, Centella, Ranunculus).
- Canopy – measure of overhanging vegetation (shade),
- General surrounding terrestrial vegetation cover.

Water quality:

- TPS WP-81 meter taken at 0.2m depth recording (a) temperature (°C), (b) conductivity (k=10 probe, range 200-200,000 µS cm-1), (c) dissolved oxygen (mg L-1) and (d) pH,
- Water transparency measured in situ against a white object with comments on contributions to low values such as natural tannin or algae.

A detailed database of environmental descriptors is maintained by Aquasave Consultants for more specific information and future comparison. A summary of environmental descriptors for each sampled site are provided in Appendix 1.

2.3 Glenelg Spiny Crayfish sampling

Following the previous monitoring of Hammer and Roberts (2008), sampling involved standardised overnight netting as well as targeted juvenile assessment and range mapping using backpack electrofishing (Smith-Root LR24). For the overnight netting, two gear types were employed to target Glenelg Spiny Crayfish:

- Fine meshed opera house nets (635x445 mm base, 220 mm deep (retractable), 60 mm entrances and 5 mm stretch mesh) – to target adult and juvenile crayfish.
- Munyana nets (60 mm stretch mesh, 0.76m diameter steel hoops with two eye shaped 0.18x0.12 m flexible entrances) – to target larger crayfish. These nets are a type of mud crab net employed successfully for studying Murray Crayfish (McCarthy 2005).

Both net types allow capture rates to be standardised on time period set (consistent effort) and can be set and left allowing higher replication. Nets were set in deep pool and upper creek sites, baited with ox liver, covered with shade cloth, and had short lengths of PVC added as cover. Nets were set in the afternoon (1600-1900) then retrieved the following morning (0700-1100). Nets were set by kayak allowing even spatial coverage of habitats, with one of either net type set to cover a surface area of ~5 m^2. Records were kept of net position (edge, outer edge, middle), depth and dominant habitat type or features to provide a basic assessment of occupied habitat. Additionally, opportunistic collection (by hand whilst snorkelling) was undertaken during net retrieval. At the shallower and faster-flowing sites, targeted assessment of juvenile Glenelg Spiny Crayfish was undertaken using back pack electrofishing with (settings: 250-300V, 70Hz, 7% duty cycle and ~1000 seconds (less for sites with limited habitat).

Glenelg Spiny Crayfish biological data that was collected included occipital carapace length (OCL) (measured from the rear of the eye socket to the middle of the rear of the carapace to the nearest 0.1 mm: Figure 2), weight (to nearest gram), sex, stage of female maturity, presence of adult females with eggs (in berry) and presence of gonopore aberrations (atypical sexual features). From all sampled individuals (>35 mm), a small (5 mm^2) clip of a uropod (part of the tail) was taken for subsequent identification and genetic assessment (Figure 3). Staging of female maturity was achieved using the modified criteria of Honan and Mitchell (1995a) (Figure 4). Gonopore aberrations are a feature of Glenelg Spiny Crayfish populations and following Honan and Mitchell (1995c) all aberrant individuals were classified as ‘pseudo-female’ males, as male gonopores were always dominant.

All sampling was conducting in accordance with relevant permits (DENR Wildlife Research permits: U25318 and E25963-1, PIRSA Fisheries permits: 9901926 and 9902414).

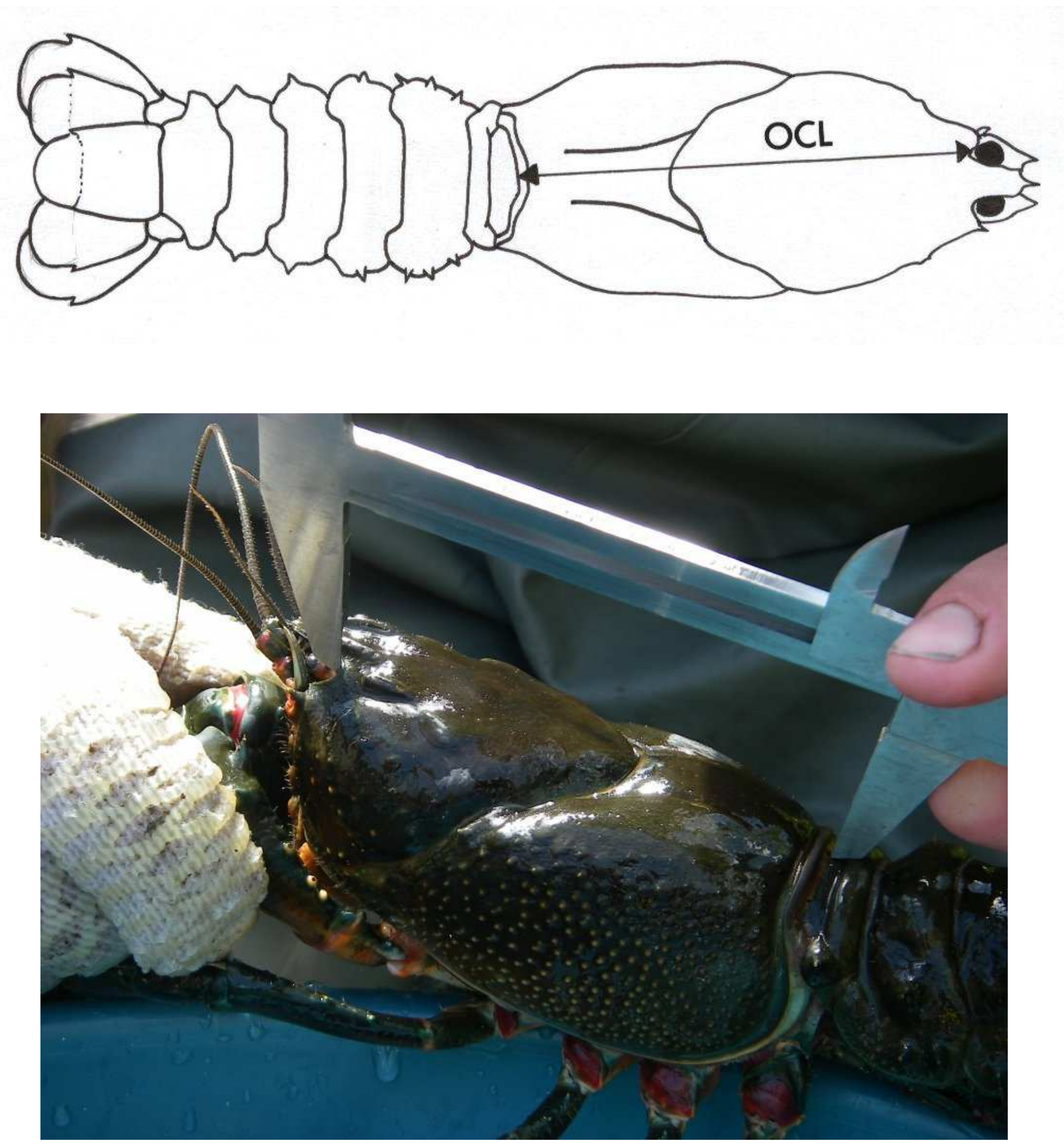

Figure 2. Measuring occipital carapace length (OCL).

Figure 3. Recaptured Spiny Crayfish showing distinctive tail clip used for identification (and genetic assessment).

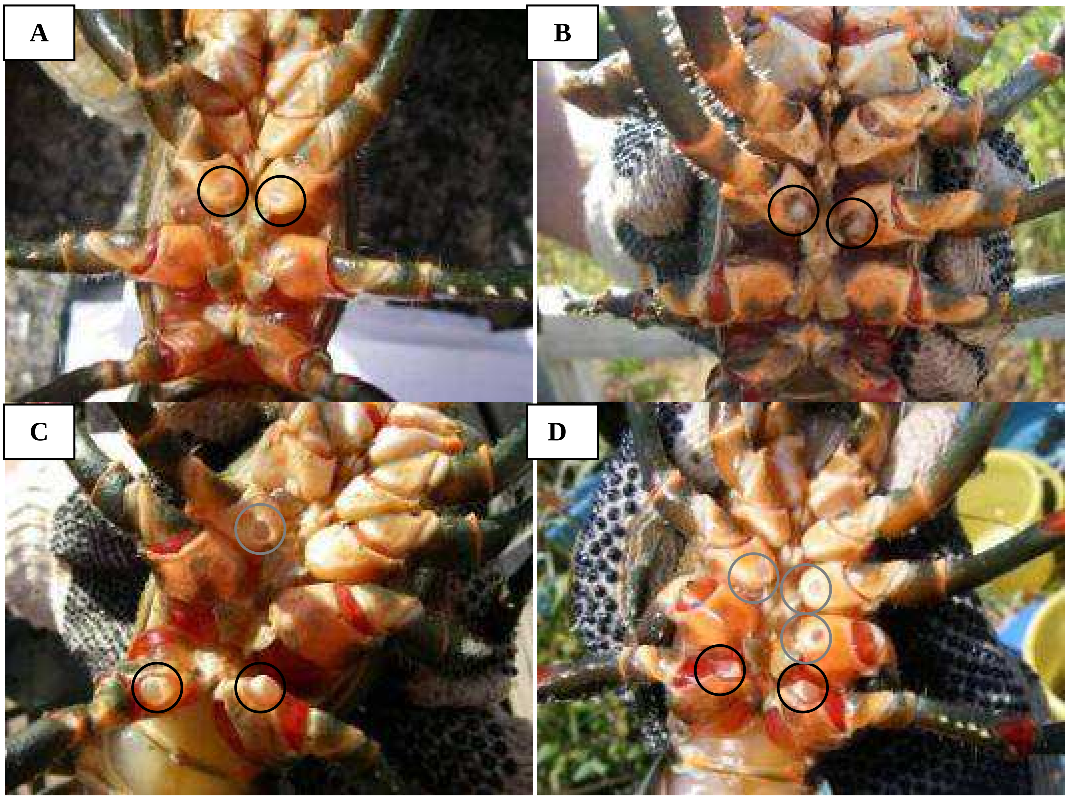

Figure 4. Images showing sexing of Glenelg Spiny Crayfish including (A) immature female (black circles on 3rd legs), (B) mature female (black circles), (C) male (black circles on 5th legs), aberrant with one additional (pseudo-female) (grey circle) gonopore, and (D) male (black circles), aberrant with three additional (grey circles) gonopores (see Honan and Mitchell 1995a).

2.4 Data analysis

The population demographics of Glenelg Spiny Crayfish were described for sub-populations as well as the overall SA population. Total captures are reported to provide indication of the number of Glenelg Spiny Crayfish present, but is best standardised relative to net catch and related effort (both are presented) as effort influences total catch. Net catch was analysed with respect to per unit sampling effort or catch per unit effort (CPUE), which was defined as the number of individuals per net night. This allows comparison both of relative abundance across sites and comparisons between past and future surveys. Electrofishing catch was evaluated based on an approximate time required to cover 5 m^2 as to be roughly comparable with netting (i.e. total seconds/60). For sampled individuals, length-frequency distributions were developed using 5-mm-OCL size classes. The distribution of sexually mature (stage 3) females across the 5-mm-OCL size classes was used to estimate the size at onset of sexual maturity (SOM) according to the following logistic equation (Hobday and Ryan 1997):

$$M = 100 / [1 + (OCL / SOM_{50})^{b}]$$

Where M is the percentage of females in a size class, OCL is the occipital carapace length (mm), SOM_{50} is the length at which 50% of females are sexually mature (mm) and b is a constant.

3.0 Results

3.1 Distribution

Glenelg Spiny Crayfish sub-populations were observed in the five known rising-spring habitats previously sampled by Hammer and Roberts (2008). Additionally, individuals were observed at Bones Pond (representing a new sub-population) as well as the upper Cress Creek (Bubbling Spring and downstream of Bubbling Spring), within the present core area of occurrence. No individuals were recorded outside the core area of occurrence. In summary, Glenelg Spiny Crayfish were recorded from 19 of the 25 sampled sites (Figure 5).

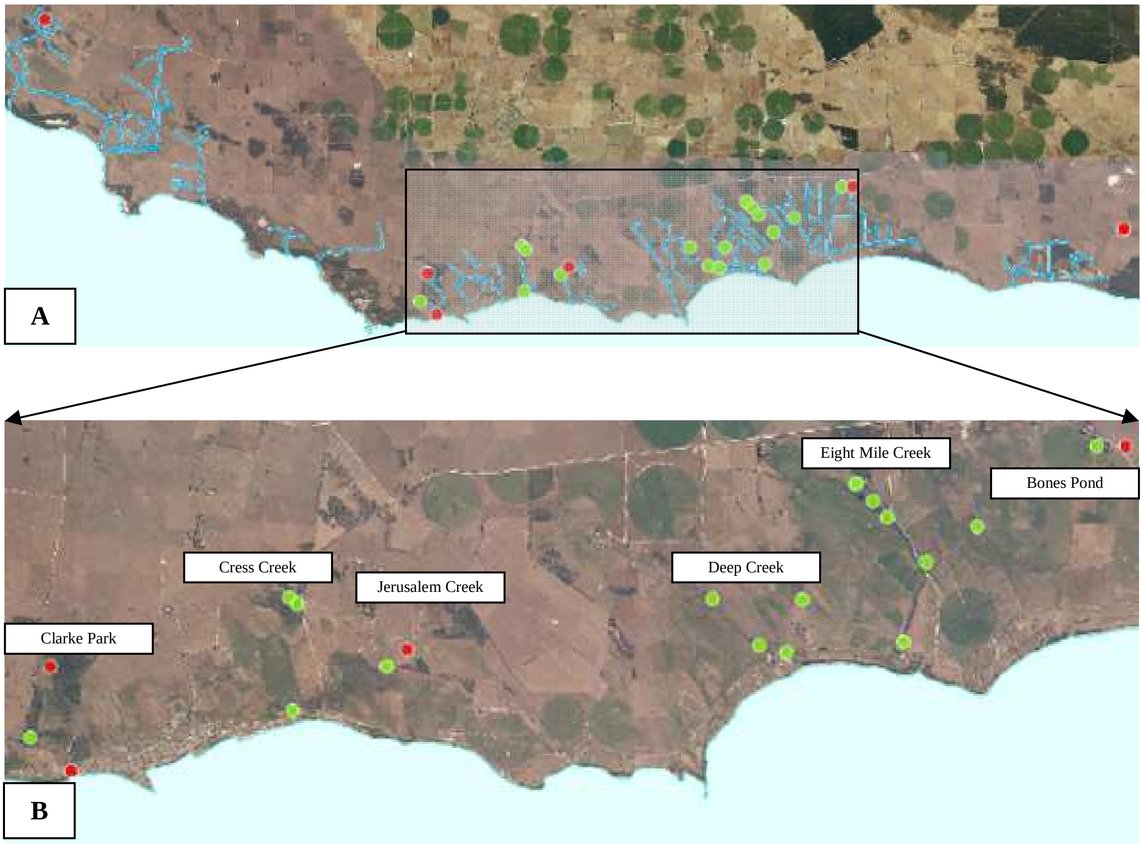

Figure 5. Presence (green) and absence (red) of Glenelg Spiny Crayfish at sampling sites across (a) study area and (b) core area of occurrence.

3.2 Population demographics

A total of 225 Glenelg Spiny Crayfish were recorded during the winter and summer sampling. Slightly fewer individuals were sampled during winter (96) as opposed to summer (124), with seven individuals marked in winter included in the summer data as recaptures. Sampled individuals ranged from 5–112 mm OCL and 3–850 g and included 95 males and 106 females (ratio 0.9:1) with 19 juveniles defined as individuals not possessing identifiable gonopores. Of males, 39% were aberrant. Across all sites, the CPUE (netting) was 0.85 individuals per net night and CPUE (efishing) was 0.22 per unit effort. When CPUE is compared between 2006 and 2011 it is evident that relative catch has declined across the majority of sites in the core area of occurrence. For instance, declines in CPUE were realised at Spencer Pond (CPUE nets, 1.9→1.1) and Stratmans Pond (CPUE nets, 0.6→0.19) deep pools typically preferred by adults, but also at lower creek sites such as Cress (CPUE efishing, 2.8→0.35) and Deep Creek (CPUE efishing, 0.6→0.35) where juveniles are typically observed. There were positive signs at some sites in Eight Mile Creek, with CPUE remaining consistent, or increasing (Ewens Pond 3, CPUE nets, 0.3→0.81; edge of conservation park, CPUE nets, 0.0→0.18).

Table 2. Summary of the population demographics of Glenelg Spiny Crayfish in lower south east, South Australia. Waterway totals in bold. Numbers in brackets in total catches indicate recaptures and percent change in CPUE (nets/efishing) represented by ±10 (grey), >10% (green), -10 to -50% (orange) and >50% (red).

Waterway (site)	**Total catch** (recaptures)	**CPUE** (nets)	**CPUE** (efishing)	**Sex ratio** (M:F)	**Aberrant individuals** (%)	2006 survey	
						CPUE (nets)	**CPUE** (efishing)
Clarke Park	6	0	0.46	0	0		
Crossroads (Dingy Dell & Spring Rd)	0	0	-	-	-	-	-
ds SA Water pump shed	6	-	0.46	0	0	-	1.2
Sea Parade	0	0	-	-	-	-	-
Cress Creek	38 (2)	0.83	0.35	1.4:1	53		
Bubbling spring	16 (1)	0.79	-	2.5:1	60	-	-
ds bubbling spring	11 (1)	0.91	-	0.7:1	75	-	-
EMC Road Bridge	11	-	0.35	1.5:1	0	-	2.8
Jerusalem Creek	3	0.10	0	2:1	0		
Little Piccaninnie	3	0.10	-	2:1	0	0.3	-
Rising spring close to LP	0	-	0	-	-	-	-
Deep Creek	41 (1)	0.43	0.38	0.7:1	31		
54ft Pond	7	0.39	-	0.4:1	50	0.6	-
EMC Road Bridge	15	-	0.38	0.6:1	0	-	0.6
Stratmans Pond	7(1)	0.19	-	2:1	50	0.6	-
us Wooden Bridge	12	0.75	-	0.5:1	25	0.1	-
Eight Mile Creek	126 (2)	0.60	0.18	1:1	40		
ds Drain 5	1	0.07	-	0	0		
Edge of Conservation Park	4	0.18	-	0.3:1	100	0.0	-
Pond 1	30 (1)	0.81	-	1.2:1	33	0.9	-
Pond 2	5	0.13	-	0.7:1	0		
Pond 3	29	0.81	-	0.8:1	33	0.3	-
Spencer Pond	45 (1)	1.1	-	1.4:1	44	1.9	-
Drain 5 us EMC junction	7	-	0.21	1:1	67	-	0.4
us EMC Road bridge	5	-	0.15	0.5:1	0	-	0.2
Hitchcox Drain	11(2)	0.56	-	0.3:1	0	-	-
Bones Pond	11(2)	0.64	-	0.3:1	0	-	-
Dead Pond	0	0	-	-	-	-	-
Horse & Cart Sinkhole	0	0	-	-	-	0	-
Nene Valley	0	-	0	-	-	-	-
Tea-tree Sinkhole	0	0	-	-	-	-	-
Total	225	0.85	0.22	0.9:1	39		

Length-frequency distributions for each sampling trip (winter and summer) reveal bimodal biases toward (a) larger adults (>60 mm), and (b) small juveniles (<30 mm), including a strong peak of presumed recent recruitment (~10 mm) in the summer sampling across the SA population (Figure 6). The 30-60 mm OCL size classes were under sampled during both sampling trips, but to a greater degree during winter.

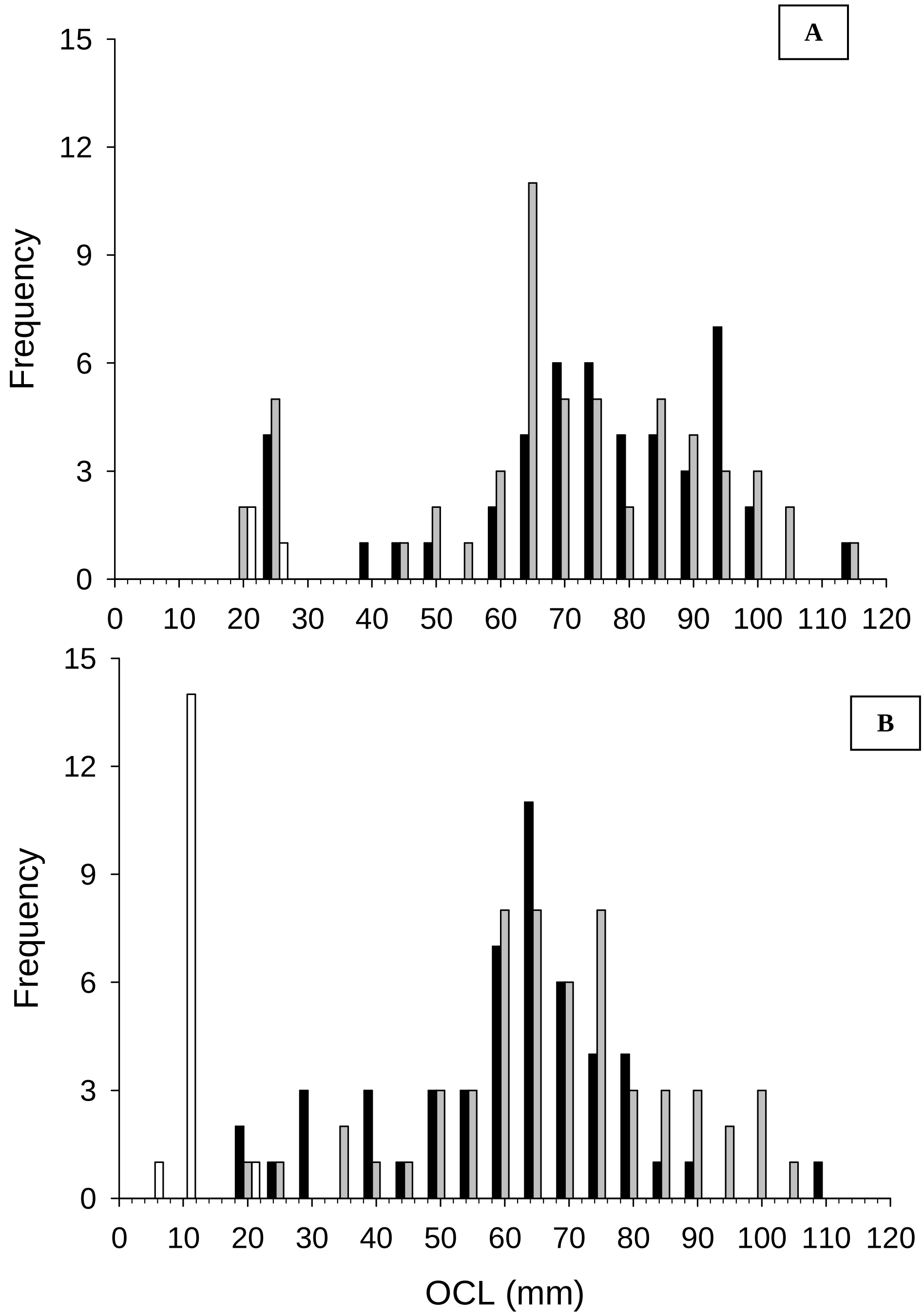

Figure 6. Length-frequency distribution of female (grey), male (black) and juveniles (white) from (a) winter and (b) summer population monitoring of Glenelg Spiny Crayfish in rising-spring habitats of south east of South Australia (winter n=96; summer n=124).

In terms of reproductive status, we sampled sexually mature females, and importantly females in berry (Figure 7). Specifically, 65% of sampled females were sexually mature (across both sampling trips), of which 75% of mature females collected in winter were carrying eggs ('in berry').

n

Figure 7. Female Spiny Crayfish with attached young (in berry).

No females were sexually mature below 50 mm and all were mature above 75 mm with a robust logistic equation (r^2=0.99) estimating the size of onset of sexual maturity for 50% of the sampled population (SOM_{50}) at 61.5 ± 0.7 mm OCL (Figure 8).

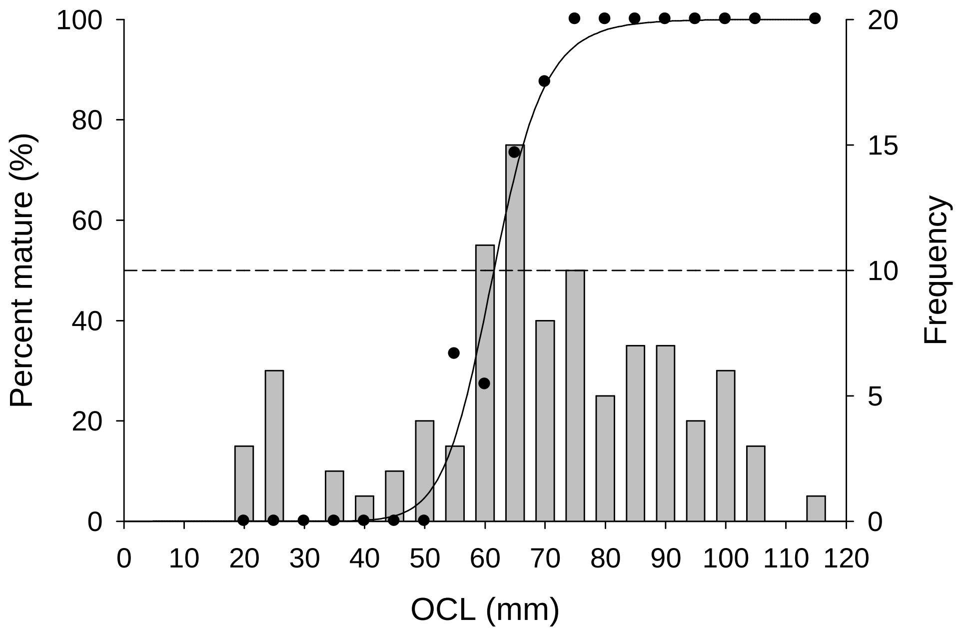

Figure 8. Size of onset of sexual maturity (SOM) for female Glenelg Spiny Crayfish in rising-spring habitats of south east of South Australia (n=101).

When demographics were examined for the fragmented Glenelg Spiny Crayfish SA sub-populations considerable variation is evident (Table 2 and Figure 9). CPUE (netting) fluctuated considerably, high amongst the Cress Creek (0.83 individuals per net night), Eight Mile Creek (0.60) and Deep Creek (0.43) sub-populations but low in Jerusalem Creek (0.09). Similarly, CPUE (efishing) was variable, but lower than 0.46 across all sub-populations. Length-frequency distributions reveal unstable population structures in all sampled sub-populations, with the possible exception of Eight Mile Creek (Figure 8). Most notably, juveniles were not recorded in half of the sub-populations (Bones Pond, Jerusalem Creek, Clarke Park) and individuals 30-60 mm are underrepresented across all sub-populations. Sex ratios were variable, ranging from heavily skewed toward females at Bones Pond (0.3:1) to moderately skewed toward males in Creek Creek (1.4:1). Finally, the percentage of aberrant males varied from zero (Bones Pond, Clarke Park, Jerusalem Creek, n=18) to 53% within Cress Creek (n=36) amongst sub-populations, but up to 75% individual of males were aberrant at individual sites (e.g. Cress Creek ds bubbling spring, n=11).

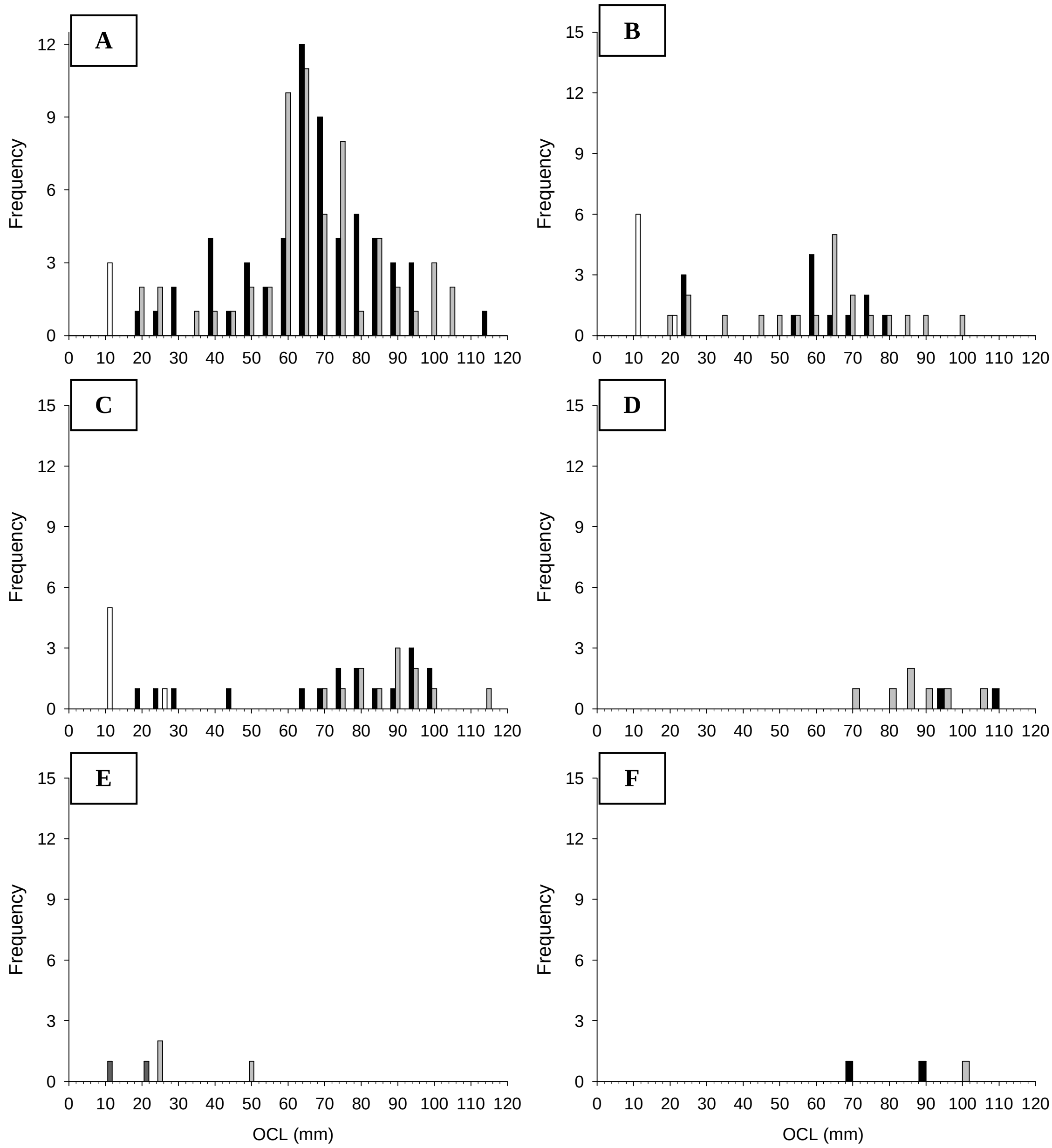

Figure 9. Length-frequency distributions of female (grey bars), male (black bars) and juvenile (white bars) Glenelg Spiny Crayfish from (a) Eight Mile Creek (n=124), (b) Cress Creek (n=36), (c) Deep Creek (n=40), (d) Bones Pond (n=9), (e) Clarke Park (n=6), and (f) Jerusalem Creek (n=3) sub-populations across the south east of South Australia.

3.3 Environmental data

The environmental conditions across sites is summarised in Table 3 and Figure 11, with comparison made to results from 2006 monitoring.

In the present study, physical (rocks, boulders) habitat was, at most sites, limited (0-50%). The amount of submerged vegetation contributing to aquatic habitat was variable, ranging from 10-90% across all sites, and was dominated by *Potamogeton* and *Myriophyllum*. However, a common feature at the majority of sites was the prevalence of filamentous algae, which often completely covered (smothered) submerged physical habitat and aquatic vegetation (Figure 10). The submerged sections of emergent plants provided low to moderate aquatic cover (0-40%), with most sites possessing suitable sections of edge or fringing habitat (e.g. *Triglochin* and *Typha*) but typically limited surrounding riparian vegetation.

Broad comparison of habitat condition revealed that submerged physical and aquatic habitat remained consistent or increased at most sites over the five year period between 2006 and 2011 (Table 3). Conversely, emergent habitat and edge vegetation was more degraded and overall vegetation cover was generally lower in 2011 compared to 2006. In an attempt to assess trends in habitat condition amongst these variable patterns, evaluation of changes at key sites is provided below (along with selected visual representation in Figure 11):

- **Clarke Park** (ds SA Water pump shed) – Water level has increased and subsequently submerged aquatic habitat now present (e.g. water cress). However, water level and surface DO (3.22 mg L^{-1}) is still low (0.3-0.4 m) and emergent habitat and surrounding vegetation has declined. TREND: **declining**.
- **EMC Road Bridge** (Cress Creek) – Submerged habitat has improved (although filamentous algae is now making a greater contribution), but emergent and edge vegetation has declined. TREND: **declining**.
- **54ft Pond** (Deep Creek) – shown some sign of improvement (due in part to fencing), although filamentous algae now more common. TREND: **stable**.
- **EMC Road Bridge** (Deep Creek) – gradual declining in habitat across this site, including reduced emergent habitat as well as edge vegetation. TREND: **declining**.
- **Stratmans Pond** (Deep Creek) – submerged aquatic habitat (once *Myriophyllum* and *Ranunculus* dominated) now dominated by filamentous algae and emergent habitat, has declined. Fencing of the pond has stablised impact to surrounding vegetation. TREND: **declining**.
- **us Wooden Bridge** (Deep Creek) – submerged aquatic habitat (once *Myriophyllum* and *Ranunculus* dominated) has declined and is now dominated by filamentous algae (Figure 11). TREND: **declining**.
- **Ewens Pond** (EMC) – Both Pond 1 and 3 remain in relatively good condition, although filamentous algae is becoming more common and emergent vegetation (e.g. *Triglochin* has declined in Pond 1. The interconnecting channels between the ponds remain is excellent condition. TREND: **stable**.
- **Other sites** (EMC) – other sites on EMC are still in moderate condition despite slight declines in submerged aquatic and emergent habitat as well has edge vegetation at some sites. Condition of habitat of some concern given the lack of crayfish observed. TREND: **stable**.
- **Spencer Pond** (EMC) – submerged aquatic habitat has declined (along with edge vegetation) and decaying filamentous algae makes a considerable contribution to remaining aquatic habitat (Figure 11). Although fenced, bank slumping is still occurring. TREND: **declining.**
- **Little Picanninnie** (Jerusalem Creek) – pool and creek are stagnant with low DO (3.5 mg L^{-1}) and filamentous algae have largely replaced water cress as dominant aquatic habitat (Figure 11). Additionally, 100% reduction in submerged physical habitat due to bank slumping and subsequent creek sedimentation. TREND: **declining.**

From these evaluations it is evident that the condition of many sites across the core area of occurrence is declining.

Table 3. Summary of environmental conditions in 2011 and percentage change from 2006 to 2011. Note: percent change represented by ±10 (grey), >10 (green), -10 to -20 (orange) and >20 (red).

Waterway (site)	Habitat condition (2011)					Percentage change (2006 to 2011)				
	Subsurface physical	Subsurface biological	Emergent	Edge vegetation	Veg cover	Subsurface physical	Subsurface biological	Emergent	Edge vegetation	Veg cover
Bones Pond	5	20	20	50	50					
Clarke Park										
Crossroads (Dingy Dell & Spring Rd)	-	-	-	-	-					
ds SA Water pump shed	20	10	65	5	5	0	0	5	-25	-5
Sea Parade	1	50	10	30	40					
Cress Creek										
Bubbling spring	10	40	40	40	40					
ds bubbling spring	20	30	20	5	10					
EMC Road Bridge	20	60	0	0	10	0	20	-20	-20	0
Dead Pond	0	20	0	5	20					
Deep Creek										
54ft Pond	20	30	30	10	30	0	10	10	0	20
EMC Road Bridge	30	35	5	5	0	0	5	-5	-15	-10
Stratmans Pond	10	20	20	10	90	0	-10	-6	0	0
us Wooden Bridge	20	45	10	20	0	0	-20	0	-20	0
Eight Mile Creek										
ds Drain 5	10	30	20	70	5	0	-20	0	20	0
Edge of Conservation Park	20	60	10	10	0	0	10	-10	0	-10
Pond 1	10	40	10	100	10	0	20	-30	0	0
Pond 2	30	40	25	100	20					
Pond 3	30	40	25	100	20	0	20	5	0	0
Spencer Pond	10	20	10	70	20	0	-40	0	-20	0
Drain 5 us EMC junction	30	15	20	20	10	10	5	10	-10	0
us EMC Road bridge	5	70	10	5	0	-15	30	0	-55	-10
Horse & Cart Sinkhole	20	10	1	50	20	0	20	5	0	0
Jerusalem Creek										
Little Piccaninnie	0	70	20	20	50	-10	20	0	-30	0
Rising spring close to LP	15	40	10	30	100					
Nene Valley	-	-	-	-	-					
Tea-tree Sinkhole	-	-	-	-	-					

Figure 10. Filamentous algae covering submerged aquatic and physical habitat.

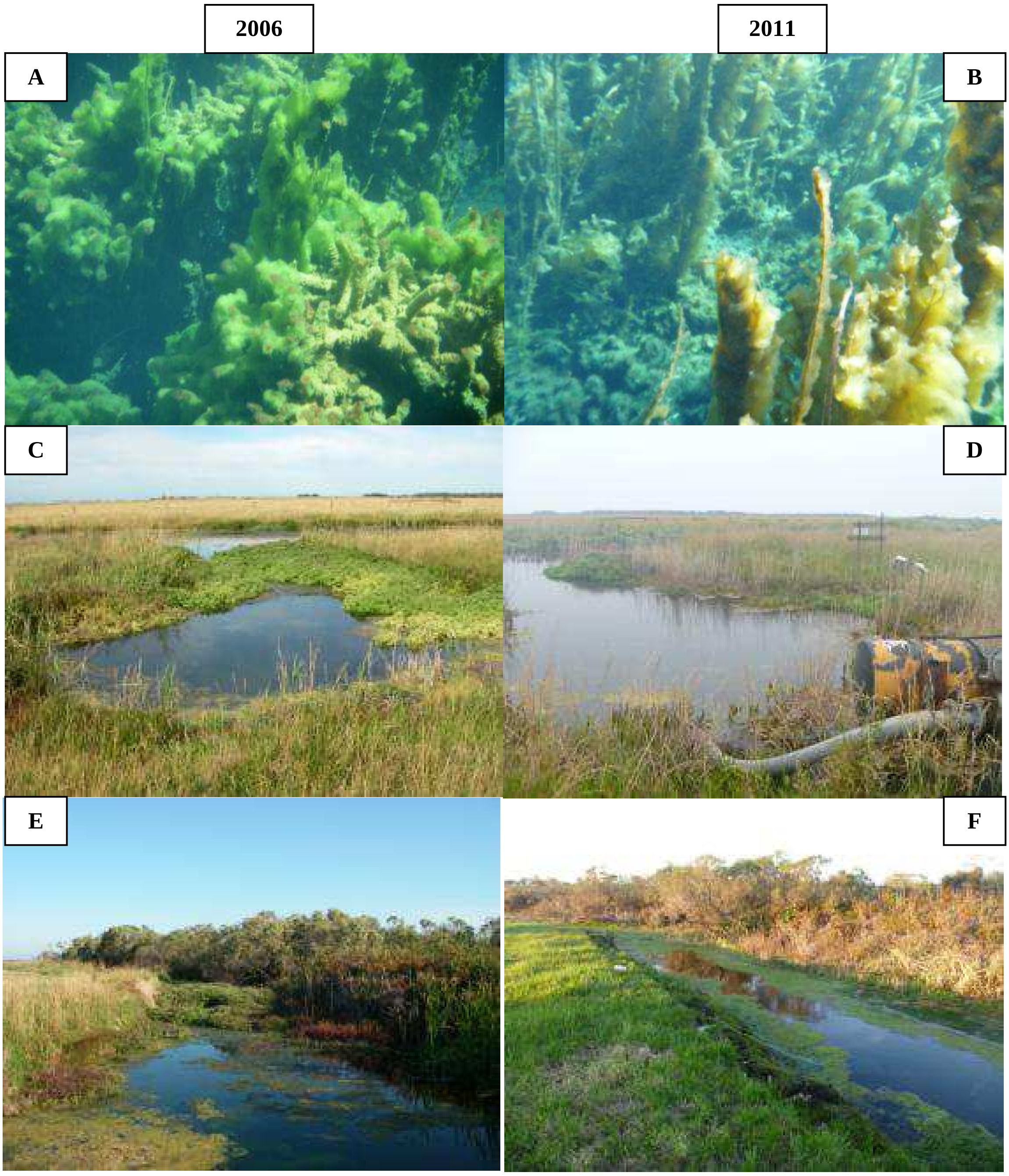

Figure 11. Comparison of habitat condition at between 2006 and 2011 for representative sites in the lower south east of South Australia: Spencer Pond (a – 2006; b - 2011), upstream Wooden Bridge, Deep Creek (c – 2006; d - 2011), Little Piccaninnie, Jersulem Creek (e - 2006; f – 2011).

3.4 Other species

Swamp Yabby (*Geocharax* sp.), Freshwater Crab (*Amarinus lacustris*), Glass Shrimp (*Paratya australiensis*), Long-neck Turtle (*Chelodina longicollis*), and previously documented fish species, including a range of threatened species, were recorded opportunistically (Hammer 2002).

4.0 Discussion

4.1 Outcomes of monitoring

Glenelg Spiny Crayfish sub-populations have previously been recorded in five rising-spring habitats across a restricted core area of occurrence in the lower south east of South Australia (Hammer and Roberts 2008). The present study confirmed the continued presence of these five sub-populations, and also identified a new sub-population (Bones Pond within the Hitchcox Drain area). The presence of Glenelg Spiny Crayfish in Bones Pond is important as the loss of this sub-population was presumed following the cessation of the spring discharge during the drought in the 2000s (Hammer and Roberts 2008). However, no juvenile crayfish were recorded from Bones Pond (in fact all individuals were >70 mm), although two berried females were caught. Conversely, the species was once relatively common in Jerusalem Creek (Zeidler 1982; Honan and Mitchell 1995a), but declining numbers were recorded during the early 2000s (Hammer and Roberts 2008) and this decline is ongoing as documented during the present study. It would appear that a combination of greatly declined spring discharges and severe habitat degradation are placing this sub-population on the verge of localised extinction (Hammer and Roberts 2008).

In the present study, no individuals were detected outside the known SA core area of occurrence. Previously identified sub-populations nearby (e.g. The Pines & Allendale Sinkhole) and further north in Mosquito Creek at the Naracoorte Caves Conservation Park were not investigated but are presumed to be translocated (Hammer 2007; Hammer and Roberts 2008). Further, following severe drying during recent drought conditions, the status of the Mosquito Creek is unclear. Importantly, an additional sub-population has recently been found in the Piccaninnie Pond wetland complex at Donovan's Drain (adjacent to Pick Swamp) to the east of the study location, which would expand the core area of occurrence in SA to ~40 km^2 (Hammer 2007; Hammer *et al.* 2011). Yet, the genetic status of these sub-populations, particularly in Donovan's Drain remains unresolved, and hence further work is needed to clarify the core area of natural occurrence and thus the conservation status of the species (Hammer 2007; Sweeney and Dickson 2011). A genetic study has been commenced which aims to explore this issue (O. Sweeney *pers. comm.*). There is an ongoing requirement to check the status of known sub-populations outside the core area of occurrence and further range map in an attempt to discover new sub-populations.

Across the majority of SA range, successful reproduction events can be inferred through both the capture of mature females and the presence of juveniles (5-30 mm OCL). Additionally, for the first time in 20 years, females in berry were observed across much of the SA range. We also provide the first empirical estimation of the size of onset of female sexual maturity (SOM_{50}) across the SA range (61.5 mm OCL), which is considerably lower than observed in Victorian populations (85 mm OCL) (Honan and Mitchell 1995a). These differences between SA and Victorian populations may be attributed to slower growth rates related to habitat (e.g. cooler, less rich rising-spring habitats, smaller waterways), environmental conditions (e.g. water quality or food resources) or genetics (Honan and Mitchell 1995c; Hammer and Roberts 2008; Sweeney and Dickson 2011). Yet, the underrepresentation of 30-60 mm OCL individuals throughout the sample sites and continuing low overall abundance as measured against the 2006 survey suggest that recruitment into the adult population is poor. This may be a consequence of either more sporadic breeding events or a very low level of recruitment of juveniles into the adult population. More research is required to determine the mechanisms behind this pattern. Further, the high incidence of gonopore aberrations (39% of males overall, up to 75% at some sites such as Cress Creek ds Bubbling Spring) may be symptomatic of population fragmentation and small population sizes leading to impacts associated with genetic isolation (e.g. inbreeding).

The SA population is currently characterised by conspicuously low numbers (as highlighted by raw catch data and CPUE). At the sub-population level, the vulnerability of the species is clearly highlighted. Firstly many sub-populations contain alarmingly low number of individuals and are at great risk of local extinction through declines in spring discharge or one-off catastrophic events. For instance, only 11 large individuals (70-110 mm OCL) were sampled from Bones Pond, of which two were recaptures. This suggests a small population size (mark-recapture methods provide a population estimate of only 14 individuals) that could conceivably all be removed in one illegal fishing event. The Jerusalem Creek sub-population appears to be even closer to local extinction. Alarmingly, the majority (55%) of the SA population is confined to one sub-population (Eight Mile Creek). Whilst this sub-population has more extensive habitat and a robust population structure, it highlights the potential consequences of a one-off catastrophic event (e.g. large chemical runoff), or even gradual habitat decline, in Eight Mile Creek to the broader SA population.

A declining trend in CPUE between 2006 and 2011 was evident across all sub-populations. These trends are not only realised at pool sites such as Spencer Pond (CPUE nets, 1.9→1.1) and Stratmans Pond (CPUE nets, 0.6→0.19) which are typically preferred by adults, but also lower creek sites such as Cress (CPUE efishing, 2.8→0.35) and Deep Creek (CPUE efishing, 0.6→0.35) within these sub-populations which were previously noted as areas holding small juvenile crayfish. The trend in CPUE, coupled with observed length-frequency distribution skewed toward larger crayfish, indicate that the structure of many sub-populations is eroding, with low number of juveniles and increasingly patchy size class distributions across larger individuals.

Rising-spring habitats in the lower south east of South Australia represent, valuable, but highly altered, aquatic environments that are actively managed as a network of drains within an intensive agricultural and irrigation landscape (Hammer 2002; Sweeney and Dickson 2011). As such, declining spring discharge and stream flow, water extraction, channel modification, drainage, water quality/algae changes, and negative impacts to physical cover, submerged aquatic vegetation and riparian buffer zones are threats to the extent and quality of crayfish habitat. Threatening processes such as these ensure that the habitat condition of these rising-spring habitats has and continues to decline (Sweeney and Dickson 2011).

Comparison of consistent measurements of habitat made in 2006 and 2011 suggest that the condition of most sites has declined over the past five years. Indeed, across much of the core area of occurrence, submerged physical habitat such as rocks and snags remains quite limited, emergent aquatic vegetation such as *Triglochin* and *Typha* has declined slightly and riparian vegetation appears to be considerably less common. Perhaps most relevant is that once *Potamogeton* and *Myriophyllum* dominated aquatic vegetation communities, but now underwater surfaces are increasingly covered by filamentous algae. It appears likely that observed declines in stream flow (spring discharge) are contributing to the declining trend in habitat, particularly the increase in filamentous algae (Carmody 2006; Sweeney and Dickson 2011). Flows in Eight Mile Creek have, for instance, have declined by approximately 25% in the last 40 years, concomitant to lowering of groundwater levels (Brown *et al.* 2006; Sweeney and Dickson 2011). Unless these threatening processes are addressed, habitat available to Glenelg Spiny Crayfish will continue to decline.

Encouragingly, some of the threatening processes impacting Glenelg Spiny Crayfish habitat have been alleviated to varying degrees. For instance, a less destructive technique (underwater mowing as opposed to mechanical dredging and long-armed excavation) is now employed to maintain high flow rates in Eight Mile Creek for drainage purposes (Sweeney and Dickson 2011). Similarly, most creeks are now fenced, although stock have been observed within drainage reserves at similar sites (O. Sweeney *pers. comm.*). Not surprisingly, bank slumping and sedimentation still continue and reparative works for stabilisation and improvement of structural integrity are required.

Clearly, there is decline in the population and habitat of Glenelg Spiny Crayfish in SA. Taken together, it is concluded that Glenelg Spiny Crayfish sub-populations are, at best, persisting across its SA range but are more probably in slow decline, likely masked to some degree by the long lived nature of the species.

4.1 Updated conservation assessment of SA population

Hammer and Roberts (2008) concluded that the SA population of Glenelg Spiny Crayfish is 'Critically Endangered' following the criteria for listing under the *National Parks and Wildlife Act 1972 Threatened Species Schedules* which incorporates IUCN red-list criteria (see DEH 2003). This conclusion was based on: a small extent of occurrence (~24 km^2) fragmented into four main systems parts due to drainage of historic habitat (CR B1a), declines in area of occurrence due to drying and loss of habitat (CR B2b(i)), and the decline in quality of habitat through loss of flow, vegetation die back and ongoing physical disturbance of streams (CR B2b(iii)).

The overriding objective of the present study was to provide an updated assessment of the conservation status of the SA population of the species. In the intervening five years between the 2006 monitoring and the present study, the species has been afforded greater protection in conservation and fisheries legislation (i.e. Endangered nationally and Vulnerable globally; closure of recreational fishery) (Furse and Coughran 2011b). However, the outcomes of the 2011 monitoring of ongoing population and habitat decline provide no justification at the current time to amend the conservation status of the species. Thus the Glenelg Spiny Crayfish should remain listed as 'Critically Endangered' in South Australia. This assessment relies on: the extent of occurrence remaining small (~40 km^2 including Piccaninnie wetland complex) and highly fragmented (CR B1a), observed decline in the quality of habitat including the observation that filamentous algae covers submerged aquatic vegetation (CR B2b(iii)), and a decline in the number of mature individuals, highlighted by the declining trend in CPUE at most sites between 2006 and 2011 monitoring (CR B2b(v)).

4.2 Management recommendations

There is renewed focus on the conservation and management of Glenelg Spiny Crayfish, with the elevated national and global listing of the species and closure of the recreational fishery. Importantly, a regional action plan has been developed for the species in SA (Sweeney and Dickson 2011). Following on, the present study has provided a robust and updated assessment of the conservation status of Glenelg Spiny Crayfish concluding that the species remains 'Critically Endangered' in South Australia and shows signs of continued decline. In light of this updated assessment, it is useful to again evaluate the management recommendations identified following the 2006 monitoring of Hammer and Roberts (2008) (Table 5).

There have been some achievements regarding these recommendations, namely the instigation of restoration works in the lower section of Eight Mile Creek, updated population monitoring (this study), the commencement of a preliminary genetic study and community engagement and education. Yet there is much more work that needs to be done particularly given the updated conservation assessment. Namely, a detailed study and ongoing monitoring is needed to document the nature of spring discharge decline, associated nutrient inputs and possible water efficiencies with the view of improved water allocation management (Sweeney and Dickson 2011). Further, additional restoration works are required, in other sections of Eight Mile Creek and additional rising-spring habitats. A long-term monitoring strategy is needed to provide the necessary information to manage the species. In general, there needs to be a concerted push to provide a holistic conservation effort across the range of the species (South Australia and Victoria).

4.4 Conclusion

The present study provides an updated assessment of the conservation status of Glenelg Spiny Crayfish within South Australia. Persisting sub-populations of the species were observed in known and new rising-spring habitats across the known restricted core area of occurrence. However, many of these sub-populations contained low numbers, had poor or no signs of recruitment, were dominated by large and presumably aging crayfish, and contained a high percentage of individuals with gonopore aberrations. Of most concern was the declining trend in both CPUE and condition of rising-spring habitat over the five years from the 2006 survey to the present monitoring. As such, it was concluded that the species remains 'Critically Endangered' in South Australia, with an extreme risk of localised, and regional, extinction. A review of management actions highlighted that some progress (i.e. revegetation, reinstalling of physical habitat) has been made, but clearly much more work is required to ensure the conservation of Glenelg Spiny Crayfish within South Australia.

Table 5. Summary evaluation of the management recommendations, identified by Hammer and Roberts (2008), on the basis on the updated assessment provided in the present study. Overlap with recommend actions identified by regional action plan for species are highlighted (**Sweeney and Dickson 2011**).

Existing recommendation	Status	New recommendation
Address reduced flow due to declining spring discharge and related habitat decline or loss through hydrological investigation and improved water allocation planning (environmental water provisions) (forms part of regional action plan for species)	Sweeney and Dickson (2011) have strongly highlighted these impacts, concluding that declining spring discharges represents the most pressing process threatening the SA population.	Detailed study is required to document the nature of spring discharge decline, associated nutrient inputs and possible water efficiencies with the view of improved water allocation management (funding required)(Sweeney and Dickson 2011)
Undertake restoration of required habitat including review and adaptive modification of drainage practices, and targeted addition of physical structure and stream bank revegetation and remediation of vegetation die back in spring habitats (forms part of regional action plan for species)	Revegetation, reinstalling of physical habitat & trialing of new aquatic mowing technique have commenced in lower Eight Mile Creek (as part of Regional Action Plan for species) (Oisín Sweeney, DENR, pers comm.)	Continue and enhance restoration efforts to include greater sections of Eight Mile Creek and additional rising-spring habitats (possibly Deep Creek or Cress Creek) (funding required)
Fishing for Glenelg Spiny Crayfish in South Australia should be prohibited, or at the least a medium-term moratorium imposed until other threatening processes are brought under control and positive population trends are firmly established. Greater compliance is required to address illegal fishing	Recreational fishery closed (February 2011); impact of illegal fishing unknown	Ongoing community awareness and education and Fisheries compliance.
Provide additional national protection for rising-spring ecosystems of the Lower South East supporting Glenelg Spiny Crayfish and a wealth of other fauna and flora (e.g. EPBC Act listing of ecological community) (forms part of regional action plan for species)	Unresolved	Continued push for the national protection of the ecosystems of Lower South East
Undertake a molecular study of stock structure across the range of the Glenelg Spiny Crayfish to identify distinctive conservation units and population characteristics (forms part of regional action plan for species)	Preliminary genetic study has commenced to explore SA population (Oisín Sweeney, DENR, pers comm.)	Expand preliminary molecular study to allow comparison between all SA sub-populations as well as Victorian population (funding required)
Develop a future monitoring program in the South East to monitor population size, population trends and recruitment, ideally including a winter snap-shot within annual or biannual adult sampling and regular assessment of juvenile abundance at key sites. Continue the mark-recapture study to better assess adult population size across different spring pools and streams (*forms part of regional action plan for species*)	Partially achieved through the present study	Development and implementation a long-term monitoring strategy is required
The introduction of predatory fishes such as Redfin and trout is to be highly discouraged.	Informal community awareness and education	Ongoing community awareness and education
Provide a holistic conservation effort for Glenelg Spiny Crayfish by developing collaborative links across conservation organisations, natural resource allocation, drainage management, fisheries, community groups and educators, including cross-jurisdictional/interstate knowledge exchange and communication.	Partially achieved through increased management focus on the species	Increased requirement for holistic conservation effort. Need to form a stakeholder committee of provide coordinated management of the species across South Australia and Victoria.

5.0 Acknowledgments

Financial support for this study was provided by Friends of Mt Gambier Area Parks (Friends of Parks Inc.). Thanks to Oisín Sweeney (DENR) for strong positive management input, including assistance with logistics and sampling (no one sets a 10 m deep Munyana net like Oisín!) and report review; Dave Mossop for assistance during sampling trips and Mahdieh Sharafi for assistance with preparation of distribution map. Additional field assistance was provided by a number of volunteers, including Maureen Christie and Ian Mitchener, Helen Bawden, Jean Haywood, Noel Stratman, Lars Kellar (and family) Toby Read, Becky McCann, Cath Dickson, Steve Clarke, and Tania Rajic and Angus Anderson. We gratefully acknowledge access to sampling sites by the Drainage Board and local landowners.

6.0 References

Allison, G. B., Harvey, P. D. (1983). *Freshwater Lakes*. In 'Natural History of the South East'. (Eds M. J. Tyler, C. R. Twidale, J.K.Ling and J. W. Holmes) pp. 61-74. (Royal Society of South Australia Inc.)

Brown, K., Harrington, G., Lawson, J. (2006). *Review of groundwater resource condition and management principles for the Tertiary Limestone Aquifer in the South East of South Australia*. Department of Water, Land and Biodiversity Conservation, Mount Gambier.

Carmody, G. (2006). *Save Ewens Ponds!* ANGFA Victoria Inc., Melbourne.

DEH (2003). *2003 review of the status of threatened species in South Australia. Proposed Schedules under the South Australian National Parks and Wildlife Act 1972: Discussion paper*. National Parks and Wildlife Council in partnership with the Department for Environment and Heritage, Adelaide.

Furse, J. M., Coughran, J. (2011a). An assessment of the distribution, biology, threatening processes and conservation status of the freshwater crayfish, genus Euastacus (Decapoda: Parastacidae) in continental Australia. I. Biological background and current status. *Crustaceana Monographs: New Frontiers in Crustacean Research*, 241-252.

Furse, J. M., Coughran, J. (2011b). An assessment of the distribution, biology, threatening processes and conservation status of the freshwater crayfish, genus Euastacus (Decapoda: Parastacidae) in continental Australia. II. Threats, conservation assessments and key findings. *Crustaceana Monographs: New Frontiers in Crustacean Research*, 253-263.

Furse, J. M., Coughran, J. (2011c). An assessment of the distribution, biology, threatening processes and conservation status of the freshwater crayfish, genus Euastacus (Decapoda: Parastacidae) in continental Australia. III. Case studies and recommendations. *Crustaceana Monographs: New Frontiers in Crustacean Research*, 265-274.

Hammer, M. (2002). *The South East fish inventory: distribution and conservation of freshwater fishes of south east South Australia*. Native Fish Australia (SA) Inc., Adelaide.

Hammer, M. (2007). *Survey of nationally threatened fish species in the Mosquito Creek Catchment, South Eastern Australia. Report to Department for Environment and Heritage, South Australian Government*. Aquasave Consultants, Adelaide.

Hammer, M., Roberts, M. (2008). *Distribution, status and conservation management of the Glenelg Spiny Crayfish (Euastacus bispinosus) in rising-spring wetland habitats of Lower South East, South Australia. Report to Department of Environment and Heritage, South Australian Government*. Aquasave Consultants, Adelaide.

Hammer, M., Whiterod, N., Tucker, M. (2011). *Monitoring plan for freshwater fishes and crayfish in the Piccaninnie coastal wetland complex, south east South Australia. Report to Department of Environment and Natural Resources, South Australian Government*. Aquasave Consultants, Adelaide.

Hobday, D. K., Ryan, T. J. (1997). Contrasting sizes at sexual maturity of southern rock lobsters (*Jasus edwardsii*) in two Victorian fishing zones: implications for total egg production and management. *Marine and Freshwater Research* **48**, 1009-1014.

Honan, J. A. (2004). *Habitats of Glenelg Spiny Crayfish (Euastacus bispinosus) in the Glenelg River drainage*. Glenelg Hopkins Catchment Management Authority.

Honan, J. A., Mitchell, B. D. (1995a). Reproductive of *Euastacus bispinosis* Clark (Decopoda: Parastacidae) and trends in the reproductive biology of freshwater crayfish. *Marine and Freshwater Research* **46**, 485-499.

Honan, J. A., Mitchell, B. D. (1995b). Growth of the large freshwater crayfish *Euastacus bispinosus*. *Freshwater Crayfish* **10**, 118-131.

Honan, J. A., Mitchell, B. D. (1995c). Catch characteristics of the large freshwater crayfish *Euastacus bispinosus*. *Freshwater Crayfish* **10**, 57-69.

Johnston, K., Robson, B. J. (2009). Habitat use by five sympatric Australian freshwater crayfish species (Parastacidae). *Freshwater Biology* **54**, 1629-1641.

Johnston, K., Robson, B. J., Austin, C. M. (2008). Population structure and life history characteristics of *Euastacus bispinosus* and *Cherax destructor* (Parastacidae) in the Grampians National Park, Australia. *Freshwater Crayfish* **16**, 165-173.

McCarthy, B. (2005). *Distribution of Murray crayfish (Euastacus armatus) in the Mallee region 2004*. Murray-Darling Freshwater Research Centre, Lower Basin Laboratory, Mildura.

Morgan, G. J. (1986). Freshwater crayfish of the genus Euastacus Clark (Decapoda, Parastacidae) from Victoria. *Memoirs of the Museum of Victoria* **47**, 1-57.

Sweeney, O., Dickson, C. (2011). *A Regional Action Plan for the Glenelg Spiny Freshwater Crayfish Euastacus bispinosus in the South East of South Australia*. Department of Environment and Natural Resources (DENR), Mt Gambier, SA.

Zeidler, W. (1982). South Australian freshwater crayfish. *South Australian Naturalist* **56**, 37-43.