Department of
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Environment

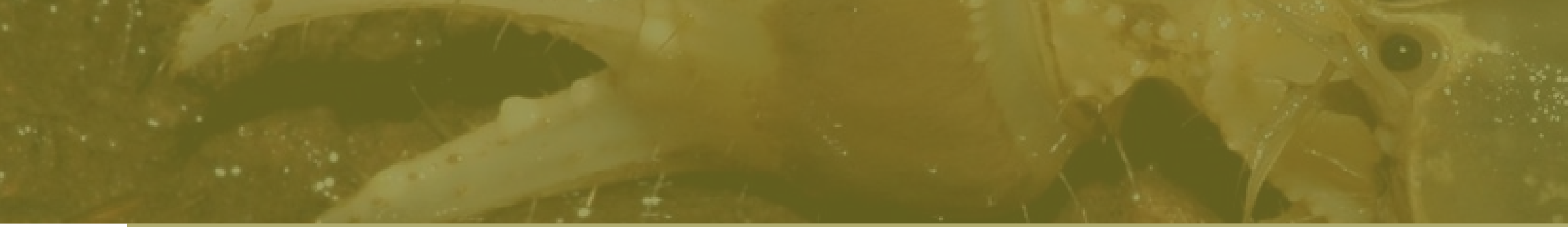
Improving survey methods and understanding the effects of fire on burrowing and spiny crayfish in the Bunyip and South Gippsland catchments

Black Saturday Victoria 2009 – Natural values fire recovery program

David Bryant, Di Crowther, Phil Papas

Parks
VICTORIA

Victoria
We will rebuild



Improving survey methods and understanding the effects of fire on burrowing and spiny crayfish in the Bunyip and South Gippsland catchments

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Front Cover photographs: Left, *Engaeus* captured within modified Norrocky trap design (Michele Kohout); right, *Euastacus neodiversus* (Gaye Davies).

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Acknowledgements

This project was funded by the Victorian and Commonwealth governments' 'Rebuilding Together' – Statewide Bushfire Recovery Plan. John McGuckin (Streamline Research), Stephen Saddlier (Department of Sustainability and Environment) and Tom Ryan (Environous) assisted with field work associated with the project. Andrew Gilham, David Bone, and their staff from Parks Victoria facilitated access to field sites within their areas. The expert panel, consisting of Beverley van Praagh (Invert-Eco), Jason Lieschke (Department of Sustainability and Environment), Dr. Pierre Horwitz (Edith Cowan University) and Dr. Tarmo Raadik (Department of Sustainability and Environment) provided taxonomic and ecological expertise and valuable comments on the report. Bill Humphries assisted with construction of crayfish traps.

Summary

Bushfires in February 2009 burnt over 400,000 hectares of land in Victoria. A state-wide bushfire recovery plan was established by the Victorian and Commonwealth governments to aid the fire recovery effort. The plan included funding for biodiversity assessments and this highlighted the lack of knowledge on the impact of fire on threatened burrowing crayfish (genus: *Engaeus*) and spiny crayfish (genus: *Euastacus*). Limited capture techniques are available for these crayfish which present a major impediment to assessing fire impacts. This knowledge gap underpinned a study undertaken in the Gippsland region which had the following objectives: develop and trial non destructive methods for burrowing crayfish, investigate detection of spiny crayfish using different sampling methods and assess the impact of the 2009 bushfires on both genera. The Gippsland region was selected for the study because its crayfish fauna is diverse and many species in this area are of statewide conservation significance. Seven threatened crayfish species occur in areas affected by the 2009 bushfires.

The effectiveness of eleven non-destructive burrowing crayfish capture methods were tested at six sites that had observed crayfish activity in the Bunyip, Latrobe and South Gippsland catchments. These included, but were not limited to, the use of carbon dioxide down burrows, electricity at burrow entrances, nets and trap door style devices. The effectiveness of electrofishing and bait traps at spiny crayfish capture was tested at nine sites in the South Gippsland catchment. Electrofishing depletion trials were conducted at seven sites in the South Gippsland catchment. These were undertaken to determine the number of passes required to achieve depletion of spiny crayfish in a 50 m reach.

Of the burrowing crayfish capture methods tested, the most activity and captures occurred with the trap door style devices. A trap similar to the previously developed Norrocky trap was the most effective in detecting crayfish. The use of this device will help improve the resolution of baseline data which is needed for an accurate assessment of impacts associated with future disturbances such as fire. The traps also minimise the need for destructive sampling. Testing of pitfall traps and additional testing of the burrowing crayfish net are warranted because they have been shown to be effective in other studies. Spiny crayfish electrofishing depletion trials demonstrated that crayfish were not completely removed from a reach with four electrofishing passes, however there was noticeable depletion. Two passes were considered sufficient to adequately represent the crayfish fauna at a site. The use of other capture techniques in conjunction with electrofishing should be considered to maximise spiny crayfish detection.

Burrowing and spiny crayfish were found at fire affected and unaffected sites. The species found and their distributions approximated those previously recorded. The age of the spiny crayfish species captured could not be confidently determined. However their size, used as a surrogate measure for age, suggests they were present during the fire. They may have taken refuge in deep water or complex instream habitats and/or recolonised from neighbouring areas which were not severely burnt. These areas may also have provided refuge for burrowing crayfish. It is also likely that burrows may have provided refuge for burrowing crayfish also during the fire. The assessment of the impact of fire was limited by both a lack of pre fire population data and the restricted number of fire affected sites that were able to be surveyed due to heavy and frequent rainfall events.

1 Introduction

Bushfires in February 2009 burnt over 400,000 hectares of land in Victoria. In response to the fires, the Victorian and Commonwealth governments established a state-wide bushfire recovery plan. The plan included funding for biodiversity assessments within the fire affected area. This provided an opportunity to improve knowledge on the distribution and effects of fire on two poorly surveyed invertebrate genera: *Engaeus* (burrowing crayfish) and *Euastacus* (spiny crayfish). The study incorporated fire-affected and adjacent unburnt areas within the Bunyip, Latrobe and South Gippsland catchments (Figure 1). Many crayfish species in these genera are of conservation significance in this region (Table1).

1.1 Crayfish fauna in the study region

South-eastern Australia has been described as a biodiversity hotspot for endemic freshwater crayfish of the family Parastacidae (Riek 1969). Morey and Hollis (1997) suggest that Labertouche Creek, a sub-catchment of the Bunyip River catchment, has Australia's most diverse crayfish assemblage. The area covered in the current study has a crayfish fauna comprised of 10 species of burrowing crayfish, four species of spiny crayfish and the yabby, *Cherax destructor* (Figures 2 and 3). Of these, eight species are of conservation significance (Table 1) and seven (excluding the yabby) are likely to occur within the areas affected by the fires in the Bunyip and South Gippsland catchments.

1.2 Burrowing crayfish

1.2.1 Ecology

Thirty five species of burrowing crayfish are recognised in south east Australia, the majority of which occur in Victoria and Tasmania (Horwitz 1994). Thirty one of these are considered short range endemics, occupying areas less than 10,000 km^2 (Horwitz 1994, Harvey 2002). The restricted ranges are likely a result of poor dispersal ability, low fecundity, slow maturation rates and habitat fragmentation (Harvey 2002, O'Brien 2007). Examples of two highly restricted species are the Narracan Burrowing Crayfish *E. phyllocercus* and Strzelecki Burrowing Crayfish *E. rostrogaleatus* which have areas of occupancy of 600 km^2 and 900 km^2 respectively (Figure 2). Because of these restricted ranges, these species are vulnerable to impacts associated with habitat disturbance (DSE 2003a, 2003b).

Whilst most crayfish are able to construct burrows to some extent (Riek 1969), the extensive burrow systems of *Engaeus* typify this genus (Shaw 1996). Horwitz and Richardson (1986) classified Australian crayfish burrows into three main types:

1. Type 1: burrows (a) located in permanent waters or (b) connected to permanent waters
2. Type 2: burrows connected to the water-table
3. Type 3: burrows independent of water-table

Engaeus typically have Type 2 or Type 3 burrows. Their burrow structure varies depending on the species and can reach considerable depths (Riek 1969). Burrows typically have excavated chambers, often at different heights above the water table, allowing crayfish to move up and down the burrow in response to rising and falling water tables (Horwitz *et al.* 1985). The excavated chambers are used for feeding, resting and brooding (Growns and Richardson 1988) and multiple generations may persist in the one burrow (Horwitz and Richardson 1986). Chimney-like structures are often observed on the soil surface and result from excavated mud pellets being deposited at burrow openings. To date, there have been no reported observations of burrowing (e.g. Suter and Richardson 1977).

Surface activity in burrowing crayfish is uncommon and may be largely nocturnal (Richardson and Swain 1980). It has been suggested that above ground activity is in response to breeding (Van Praagh and Hinkley 1999), dispersal and foraging (Shaw 1996), and is affected by rainfall and soil temperature (Shaw 1996). Van Praagh and Hinkley (1999) commented that collection of Warragul Burrowing Crayfish in Gippsland coincided with heavy spring rainfall and Kingwill (2008) demonstrated a significant correlation between rainfall and burrow activity. Burrowing crayfish diet consists of roots, decomposing leaves and small invertebrates (Lake and Newcombe 1975, Suter and Richardson 1977, Growns and Richardson 1988).

1.2.2 Survey methods

There are difficulties surveying burrowing crayfish because of their subterranean habitat. Burrow excavation is the most commonly used survey method, and while effective at capture, it is labour intensive, destructive to the burrow and is not repeatable (Welch and Eversole 2006). Non-destructive and repeatable methods are desirable, especially for surveying species of conservation significance. Such methods include pitfall traps (Shaw 1996), the Norrocky trap (Norrocky 1984), spot lighting (Loughman 2010), the burrowing crayfish net (Welch and Eversole 2006), electrofishing and dip netting (D Stoessel personal communication 2011). Spot-lighting and pitfall traps require crayfish to be active on the surface. Electrofishing and dip-netting require surface water, which is infrequently used as habitat by most burrowing crayfish species. The Norrocky trap consists of a one-way trapdoor and sits over the burrow entrance to capture any emerging crayfish. The burrowing crayfish net is placed in the burrow entrance to entangle emerging crayfish. These non destructive survey methods have not been widely adopted in Australia; there is only one documented use of burrowing crayfish nets (Kingwill 2008) and Norrocky traps (Marist Regional College 2011) for Australian surveys.

1.3 Spiny crayfish

1.3.1 Ecology

Fifty species of spiny crayfish are currently recognised in Australia (Coughran and McCormack 2011). The majority of these species are short range endemics, occurring predominately in Victoria (Harvey 2002). Spiny crayfish are characterised by the presence of spines on the carapace and abdomen and have a stout build with heavy claws held in a horizontal plane (Riek 1969). They are largely opportunistic feeders and their diet consists mainly of aquatic vegetation but may also include aquatic invertebrates, fungi and bacteria (DCE 1992). They inhabit streams and other permanent waterways that are typically structurally complex and comprised of rocks, submerged woody debris, leaf packs and/or detritus. Because of this, they are cryptic and difficult to survey.

Spiny crayfish have the capacity to burrow into stream sediments and between rocky substrate (Riek 1972) typically creating Type 1 burrows which are connected to water (Horwitz and Richardson 1986), but unlike burrowing crayfish, they are not restricted to burrows. It is not known whether burrowing is undertaken by all individuals or only reproductive females (Horwitz and Richardson 1986).

The South Gippsland Spiny Crayfish *Euastacus neodiversus* is of conservation significance in Victoria (Table 1). It is known to occur throughout the areas affected by the 2009 fires and is therefore the focal species for the spiny crayfish component of this project. The species occupies a fragmented range from Wilsons Promontory to the southern Strzelecki Ranges and there are records of an isolated population in the Mount Worth State Park (Figure 3). While some populations occur in national parks, much of their distribution occurs across the Strzelecki Ranges (Koster *et al.* 1999). Little is known about the effects of forestry practices on spiny crayfish (DSE 2003c) and there is a potential risk of disturbance from forestry activities, prevalent within the Strzelecki Ranges.

1.3.2 Survey methods

Methods commonly used to survey spiny crayfish include bait traps, dip netting (Jones and Bergey 2007, Johnston and Robson 2009), opera house and drop nets (DPI 2010), spot lighting (O'Connor 1997), visual searching for exoskeletons (T. Raadik, personal communication 2010)

Table 1. Conservation status of burrowing and spiny crayfish in the study area.

Common name	Scientific name	FFG Listed[1] (L)	DSE Advisory List[2]
Burrowing crayfish			
Warragul Burrowing Crayfish	*Engaeus sternalis*	L	Critically Endangered
Lilly Pilly Burrowing Crayfish	*Engaeus australis*	–	Critically Endangered
Curve-tail Burrowing Crayfish	*Engaeus curvisuturus*	L	Endangered
Narracan Burrowing Crayfish	*Engaeus phyllocercus*	L	Endangered
Strzelecki Burrowing Crayfish	*Engaeus rostrogaleatus*	L	Endangered
South Gippsland Burrowing Crayfish	*Engaeus karnanga*	–	Vulnerable
Tubercle Burrowing Crayfish	*Engaeus tuberculatus*	–	Vulnerable
Gippsland Burrowing Crayfish	*Engaeus hemicirratulus*	–	Not listed
Lowland Burrowing Crayfish	*Engaeus quadrimanus*	–	Not listed
Richards Burrowing Crayfish	*Engaeus laevis*	–	Not listed
Spiny crayfish			
South Gippsland Spiny Crayfish	*Euastacus neodiversus*	L	Endangered
Central Highland Spiny Crayfish	*Euastacus woiwuru*	–	Not listed
Gippsland Spiny Crayfish	*Euastacus kershawi*	–	Not listed
Yarra Spiny Crayfish	*Euastacus yarraensis*	–	Not listed

1. FFG – *Flora and Fauna Guarantee Act 1988*
2. DSE (2011a)

and electrofishing (Rabeni *et al.* 1997, Murray Darling Basin Commission 2007). Electrofishing can be effective in small streams, however in larger streams with reduced visibility and increased flows, effectiveness can be limited. There is little data available on the effectiveness of different sampling techniques for spiny crayfish capture, however Rabeni *et al.* (1997) suggests that it is dependent on habitat conditions and species behaviour.

1.4 Effects of fire on burrowing and spiny crayfish

The impacts of fire on aquatic biota are generally well documented. For example, there have been a number of studies on the effects of fire on small invertebrates in Victoria (e.g. Papas 1998, Papas *et al.* 1999, Kellar *et al.* 2004, McKay and Papas 2005, McKay *et al.* 2005, Crowther and Papas 2005, Crowther *et al.* 2008) and fish (e.g. Rieman and Clayton 1997, Bozek and Young 2004, Lyon and O'Connor 2008). Fire has been identified as a threat to some crayfish species (DSE 2003b, 2003c, Johnston and Robson 2009), however there is little information on the effects of fire on burrowing and spiny crayfish.

Burrows and underground chambers are likely to provide some shelter during fire, however crayfish may be vulnerable to post-fire impacts. Impacts may include increased predation (K. Johnston pers. comm. 2010), reduced availability of food, altered physical characteristics of soils (CALM 2008, Doerr *et al.* 2004) and degraded water quality (Lyon and O'Connor 2008, Mc Kinnon, 1995, King *et al.* 2011).

1.5 Project objectives

The project rationale is underpinned by the lack of information on both the effectiveness of survey methods and fire effects on both crayfish genera as well as their significance in the study area. The project objectives were to:

- Develop and trial non destructive methods for burrowing crayfish
- Investigate detection of spiny crayfish in the study area using different sampling methods; and,
- Assess the impact of the 2009 Victorian bushfires on burrowing and spiny crayfish in the study area.

Figure 1. Location of the study area (within the dashed line) and areas affected by the 2009 bushfires (red).

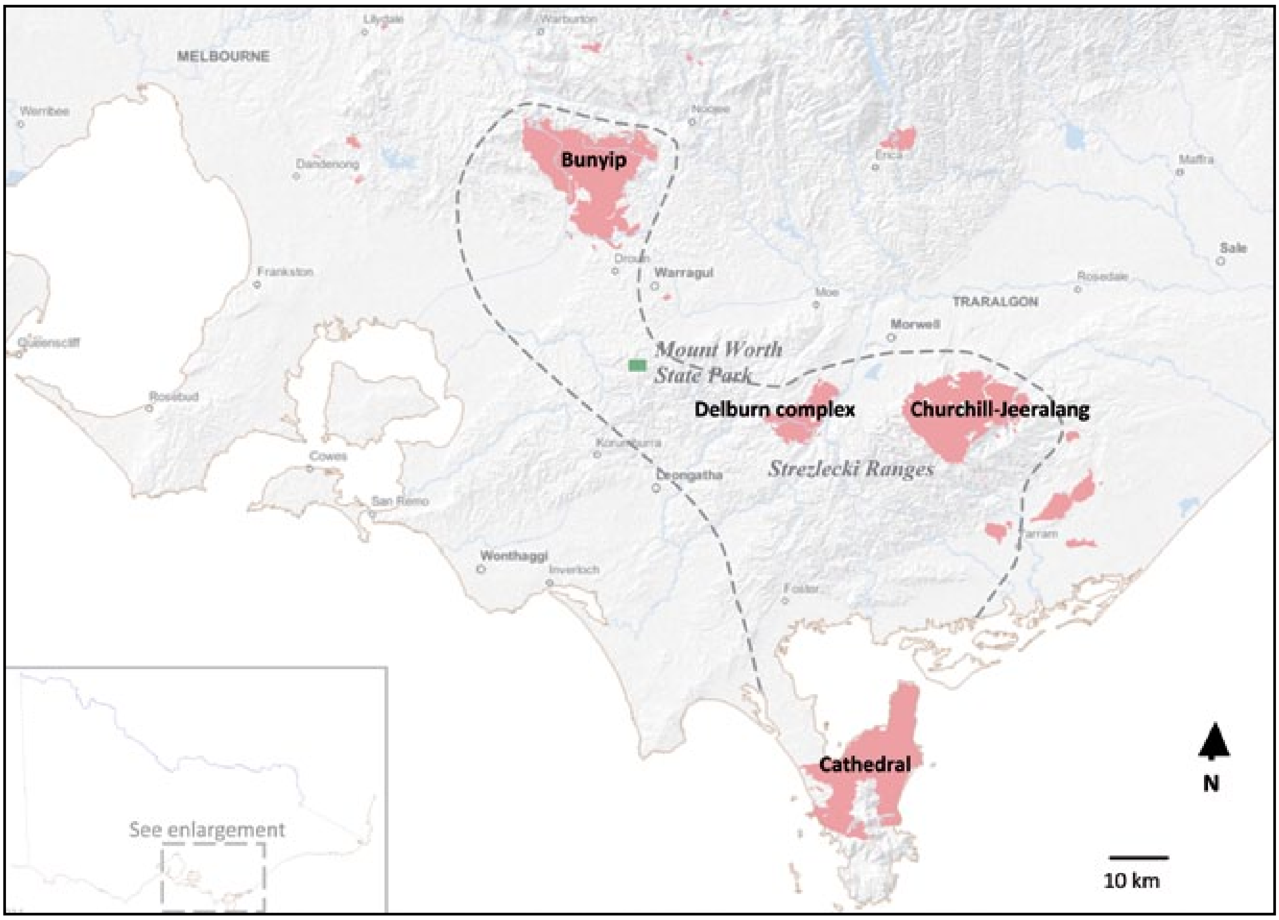
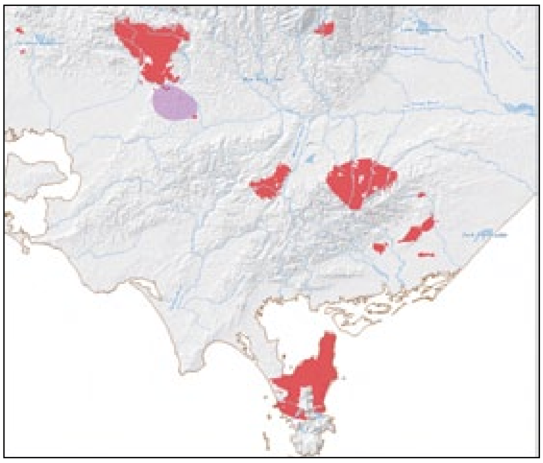
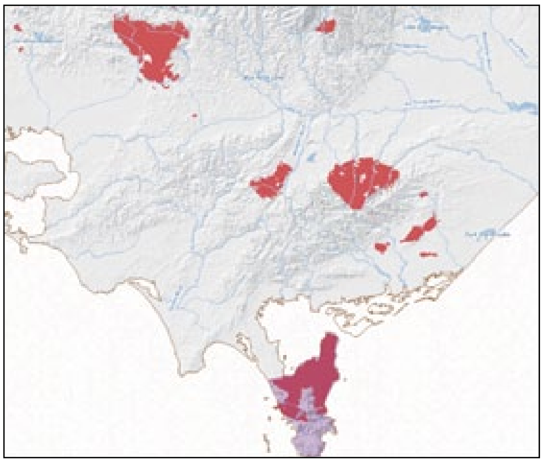


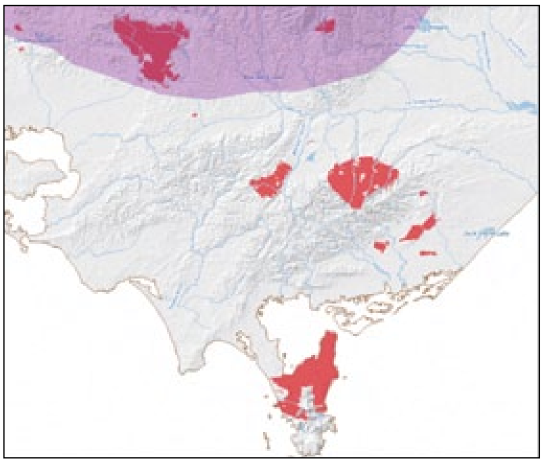
Figure 2. Approximate distribution of burrowing crayfish *Engaeus* species (purple shading) in the study area (follows Horwitz 1990) with 2009 fire areas shown in red.



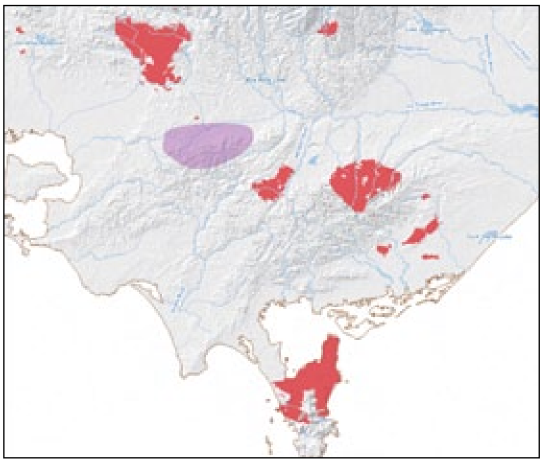
Warragul Burrowing Crayfish *Engaeus sternalis*



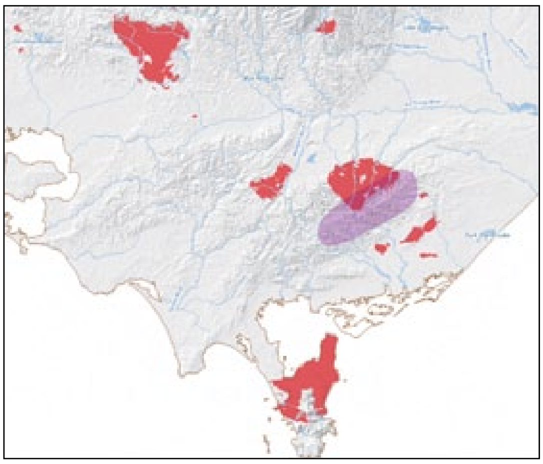
Lilly Pilly Burrowing Crayfish *E. australis*



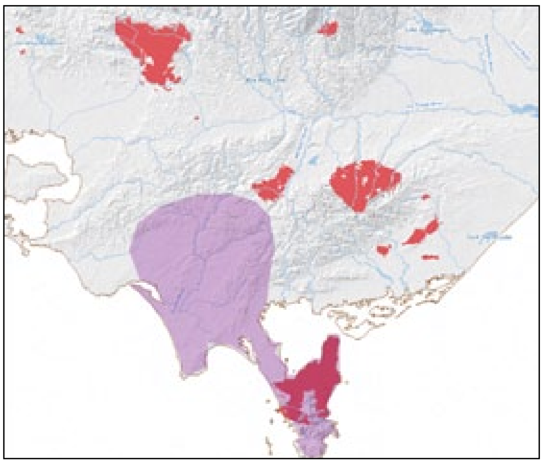
Curve-tail Burrowing Crayfish *E. curvisuturus*



Narracan Burrowing Crayfish *E. phyllocercus*



Strzelecki Burrowing Crayfish *E. rostrogaleatus*



South Gippsland Burrowing Crayfish *E. karnanga*

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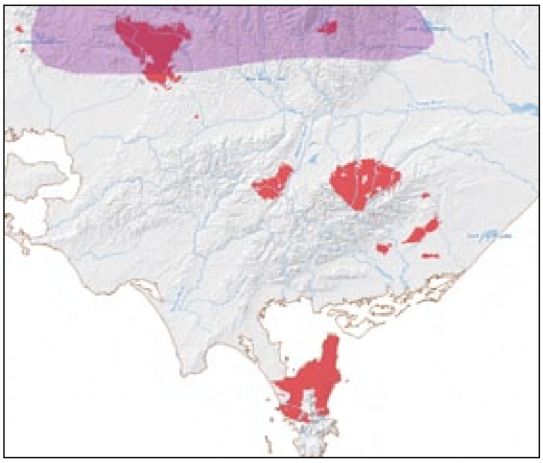
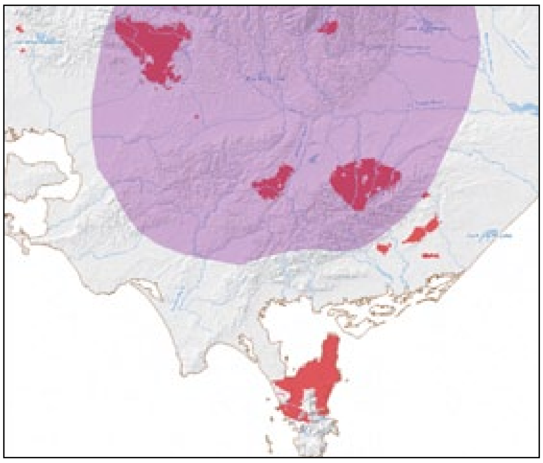
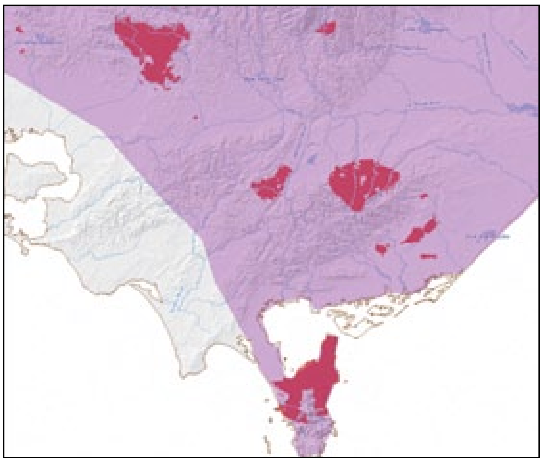
Figure 2 continued



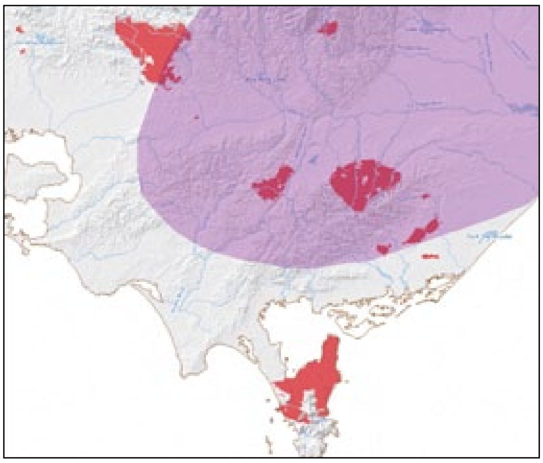
Tubercle Burrowing Crayfish *E. tuberculatus*



Gippsland Burrowing Crayfish *E. hemicirratulus*

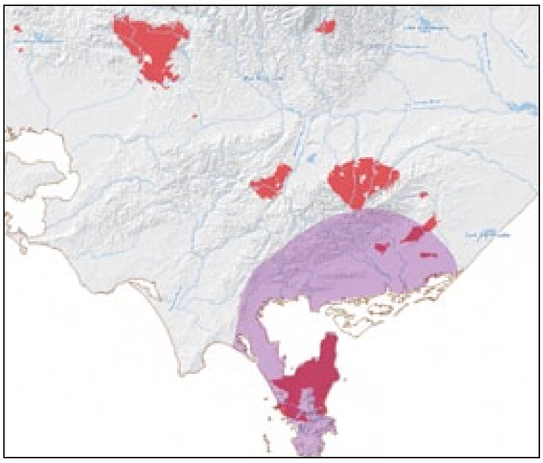


Lowland Burrowing Crayfish *E. quadrimanus*

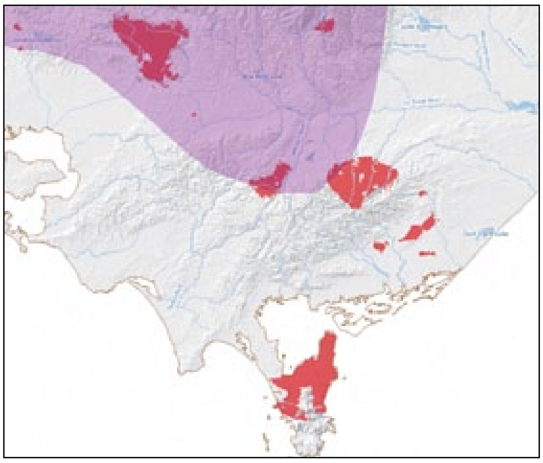


Richards Burrowing Crayfish *E. laevis*

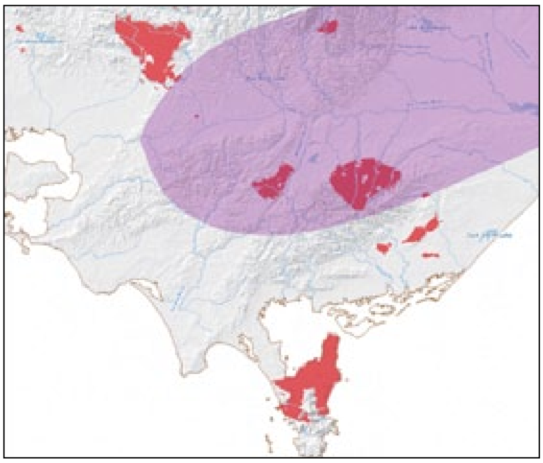
Figure 3. Approximate distribution of spiny crayfish *Euastacus* species (purple shading) in the study area (follows Morgan 1986) with 2009 fire areas shown in red.



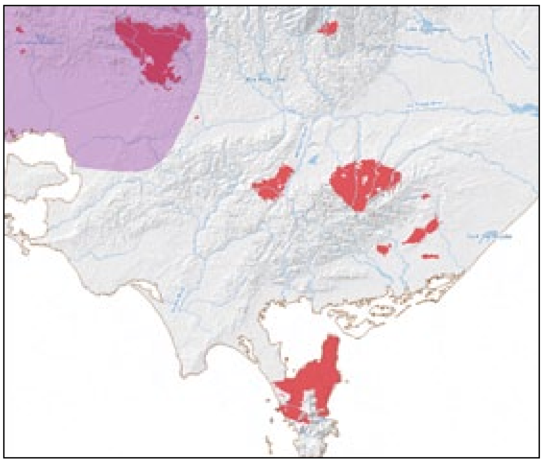
South Gippsland Spiny Crayfish *Euastacus neodiversus*



Central Highland Spiny Crayfish *E. woiwuru*



Gippsland Spiny Crayfish *E. kershawi*



Yarra Spiny Crayfish *E. yarraensis*

2 Burrowing crayfish methods and results

2.1 Methods

A desktop assessment of burrowing crayfish capture methods was undertaken to identify those most suitable for further investigation. The assessment included a literature search of methods, expert liaison with crayfish taxonomists and ecologists and an expert panel and project team workshop. Eleven non-destructive methods were identified for field testing, in addition to burrow excavation, which is currently the most commonly used capture method (Table 2). Initial trials of these methods were undertaken to determine those most suitable for more rigorous testing. Testing of suitable methods was conducted in both burnt and unburnt areas to provide data that would also allow for an assessment of the impacts of fire (Figure 4).

All burrowing crayfish specimens retained for taxonomic identification were confirmed by T. Raadik (Department of Sustainability and Environment) using Horwitz (1990). Representatives of all species captured were retained as voucher specimens.

2.1.1 Method testing

Field testing was performed in the Mount Worth State Park and Mirboo North areas. These areas were chosen because they met all of the following criteria: (i) were located within the known distribution of several species *E. phyllocercus, E. rostrogaleatus* and *E. hemicirratulus*, (ii) contained evidence of recent crayfish activity, (iii) contained more than one habitat which could be utilised by crayfish (e.g. flat wetted area adjacent to stream, lower riparian slope and mid riparian slope), (iv) were relatively protected from human disturbance, and (v) were accessible by vehicle and foot (within a 30 minute walk from the vehicle).

Twelve methods (Table 2) were initially tested in spring 2010. Methods which did not result in crayfish capture or where there was no evidence of crayfish activity were discounted for more rigorous testing.

Two trap-door style devices showed the most potential for crayfish capture: the Norrocky trap (Norrocky 1984) and a prototype design incorporating a trap door in the bottom of a container. A number of trap door devices were subsequently developed and tested (Figures 5 and 6). This concluded with a modified design of the Norrocky trap that incorporated aspects of the earlier designs. This is subsequently referred to as the 'modified Norrocky trap' (Figures 6 and 7). The key differences between the two traps were the incorporation of corrugated tubing and square trapdoor housing in the modified Norrocky trap, compared to the rigid smooth tubing and circular housing of the original Norrocky trap design.

Subsequent tests compared the effectiveness of the Norrocky trap to the modified Norrocky trap in burrowing crayfish capture (see 2.1.2).

Figure 4. Location and design of the burrowing crayfish method trials. Numbers of sites are indicated in parentheses.

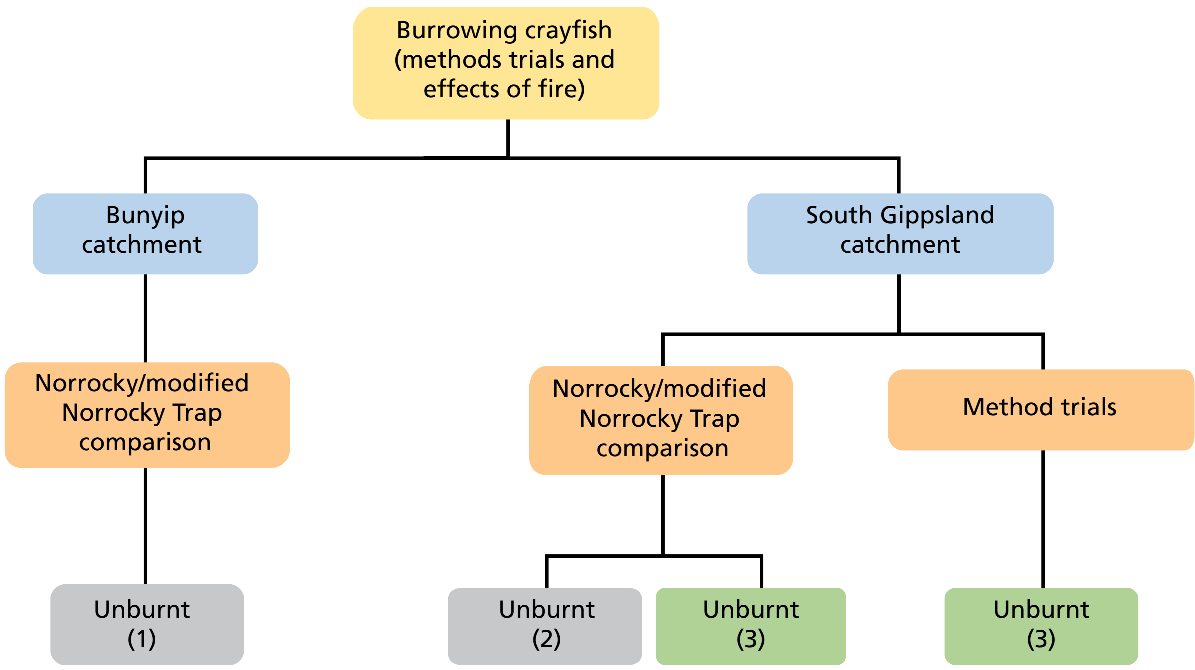


Table 2. Methods considered for burrowing crayfish testing.

Method/ device	Description of method	Testing approach
1. Bait pump	• Fishing bait pump (60 mm diameter stainless steel tube • Suction applied to extract crayfish from burrows • Method used in conjunction with excavation by B. Van Praagh with some success	• Bait pump used at burrows at each location with use dependent on soil moisture and water table • Trialled extensively at inundated sites where suction could be achieved • Used in conjunction with flooding of burrows in drier areas
2. Electricity	• Electricity passed through damp soil at burrow entrance • Has been used for harvesting earth worms for bait (http://www.oldphoneman.com/FSMagnetos.htm • Appears to be home-made design and requires strong current	• Electrodes (brass welding rods) connected to 12 V car battery via wire leads • Electrodes inserted in the ground each side of burrow openings and leads connected to the battery to form electrical circuit • Multi meter used to check current • Trialled at a number of locations with different soil moistures
3. Excavation	• Commonly used technique (Suter and Richardson 1977, Richardson and Swain 1978, Ridge *et al.* 2008, Loughman 2010) • Burrow systems are excavated using spade or similar until crayfish are captured • May be able to combine with other methods, e.g. plunging	• Several burrows excavated at various locations with different soil types, moisture levels and habitats
4. Ground vibration	• Stomping ground to cause vibrations	• Stomping by feet at burrow entrances • Reaction of crayfish visible down burrows observed
5. Alka Seltzer	• Alka Seltzer tablet dropped down crayfish burrow • Web-based forums suggest it may cause crayfish to leave burrow (http://wiki.answers.com/Q/How_do_you_get_rid_of_crayfish_that_have_burrowed_in_your_lawn) • Response may relate to CO2 or Aspirin. Alka Seltzer = Aspirin + NaCO2 + Acid	• Targeted dry burrows and those with visible water • Trialled also in conjunction with flooding of burrows with water and/or soda water
6. Soda water	• Soda water poured down burrow openings • Liquid administration of CO2	• A number of burrows flooded at different locations • Burrow observed for response
7. Spotlighting	• Active nocturnal search using spotlights (Loughman 2010)	• Several hours of spotlighting performed over four nights • Spotlight used to scan ground surface, streams and inside burrow openings

Table continued next page

Table 2 continued

Method/ device	Description of method	Testing approach
8. Baited string	• Common practice for capturing yabbies *Cherax destructor* • Bait (meat) tied on string and lowered down burrow	• Small piece of bait (meat) tied on end of string and lowered down burrow openings and left • Periodically checked over a period of three hours
9. Burrowing crayfish net	• Established by Welch and Eversole (2006) and later used by Kingwill (2008) and Ridge *et al.* (2008) • Fine mist net tied in clump and inserted into burrow entrance	• Relies on crayfish becoming entangled as they try to move through the net • Trial 1, mist net tied in clump and inserted into 10+ burrows over three evenings • Trial 2, mist net clumped and pegged over burrow entrances to avoid net being pushed out
10. Trap door	• Based on trap door concept from the Norrocky trap	• Trap door placed over burrow openings. • Numerous modifications made to the initial design to reduce trap failures (see Figure 5).
11. Norrocky trap	• Developed by Norrocky (1984) and later used by Welch and Eversole (2006) and Ridge *et al.* (2008) • Published method involving one way flap within a length of PVC pipe (Figures 6 and 7) • Trap is set by placing the tubing over a burrow entrance	• Placed over burrow openings
12. Electrofishing	• Back Pack electrofishing • Electrical current used to stun aquatic organisms	• Performed in streams at Mount Worth State Park

Figure 5. Initial trap door design (left) and refined version with addition of tube (right).

2.1.2 Capture effectiveness of the Norrocky trap designs

The final method trials involved a detailed comparison between the effectiveness of the Norrocky and modified Norrocky traps at burrowing crayfish capture. The trial took place in the Bunyip State Park, Mirboo North Regional Park, Darlimurla forestry block and Mount Worth State Park in February and April 2011, with sites located within and outside of the 2009 bushfire boundaries (Table 3, Figure 8).

As most surface activity is likely to be nocturnal (Richardson and Swain 1980), traps were set in the mid to late afternoon, left overnight and collected the following morning. Traps were placed over burrow entrances which appeared to show signs of recent activity (e.g. recently deposited mud pellets). It was sometimes difficult to differentiate burrow entrances which showed signs of recent activity from those that did not. Consequently, some of the burrows targeted may not have been recently active. Traps were placed in pairs (one Norrocky trap and one modified Norrocky trap) at each of the study sites (Table 3, Figure 9) which were located in habitats ranging from immediately adjacent to the stream to riparian slopes up to 2 m above the height of the stream.

Figure 6. Norrocky trap (left) and modified Norrocky trap (right) deployed in the field.

Table 3. Method details of Norrocky and modified Norrocky trap comparison testing.

Site	Burnt in 2009 fires	Date	Number of Norrocky traps	Number of Modified Norrocky traps
Bunyip State Park	Yes	February 2011	10	30
Mirboo North 1	Yes	April 2011	30	30
Mirboo North 2	Yes	April 2011	30	30
Darlimurla Forestry Block	No	April 2011	30	30
Mount Worth State Park 1	No	April 2011	30	30
Mount Worth State Park 2	No	April 2011	30	10

Both trap captures and failures were recorded with a failure defined as observed evidence of crayfish activity in the trap (e.g. mud pellets) but no capture. All burrowing crayfish captured were identified and subsequently confirmed by T. Raadik (Department of Sustainability and Environment) using Horwitz (1990).

A paired T-test was performed to test for differences in capture and failure rates between the Norrocky trap and modified Norrocky trap.

2.1.3 Effects of fire

The outcomes of the survey method testing (Section 2.1.1) informed the survey protocol for the assessment of fire on burrowing crayfish in the study area. Severe rainfall events and culvert/road reconstruction restricted access to a number of locations in the study area during spring and summer. This resulted in a delay in completion of methods testing and limited the time available to identify and survey suitable sites for the fire component of the study. Three locations affected by the 2009 fires were identified as suitable burrowing crayfish habitat. Norrocky and modified Norrocky traps were deployed overnight at these locations in addition to three locations unaffected by the 2009 fires (see Table 3 in Section 2.1.2). The abundance and species richness of crayfish captured at sites affected by fire were compared to those at unaffected sites. Time constraints did not allow a rigorous assessment of burrowing crayfish in burnt and unburnt areas within the project time frame.

2.2 Results

2.2.1 Method testing

The effectiveness of burrowing crayfish capture was variable among the methods tested (Table 4). Five of the twelve methods tested: bait pump, excavation, alka seltzer, spotlighting and trap door designs resulted in captures. Ten burrowing crayfish were captured across all methods during the trial period (Table 4).

2.2.2 Capture effectiveness of the Norrocky trap designs

From the six study sites, significantly more burrowing crayfish were captured in the modified Norrocky trap (14) than from the Norrocky trap (1) , P =0.024 (Table 5, Figure 11).

Trap failure (i.e. evidence of crayfish activity within the trap but no capture) was higher in the modified Norrocky trap than the Norrocky trap but this was not significant (P = 0.065) (Figure 10). Failures in the modified Norrocky trap were caused by either condensation or jamming of the hinge resulting in the door staying open. A modified hinge mechanism used in a later design, resolved both of these issues. Failures of the Norrocky trap were caused by deposited mud pellets wedging the trap door open.

Collectively, four species were captured among the two trap types (Table 5, Figure 11).

2.2.3 Effects of fire

Burrowing crayfish were captured at sites both affected by and unaffected by fire (Table 6). Ten crayfish from three species (*E. hemicirratulus*, *E. phyllocercus* and *E. quadrimanus*) were captured from 100 traps at four burnt sites. Four crayfish from one species (*E. laevis*) were captured from 60 traps at two unburnt sites. No exoskeletons were found at any sites. Two dead crayfish (*E. quadrimanus*) were found on inundated ground at the Bunyip State Park site. There had been very heavy rainfall in the catchment and localised flooding in the area.

Figure 7. Norrocky trap (left) and modified Norrocky trap design (right).

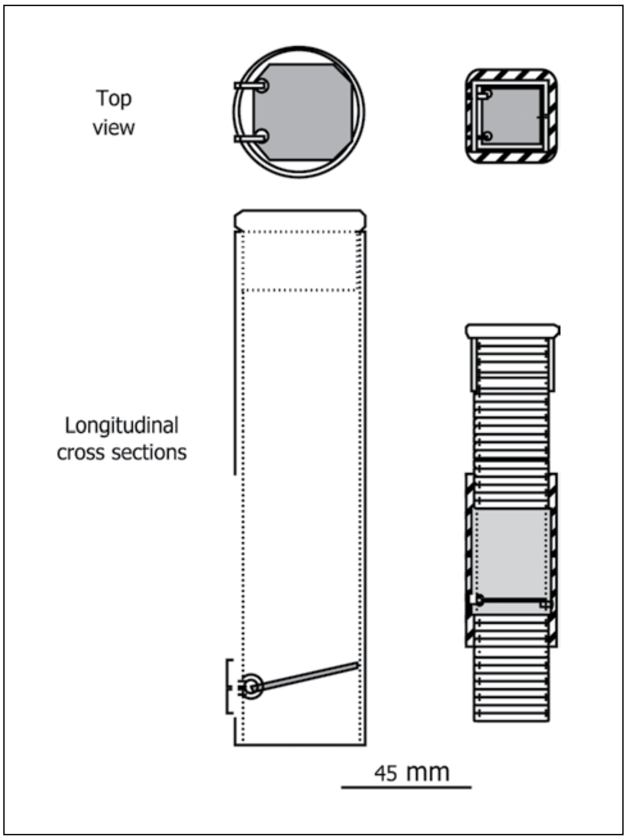


Table 4. Burrowing crayfish preliminary method trial observations, captures and assessment of effectiveness.

Method (see Table 2)	Observations (numbers captured)	Assessment
Bait pump	*Engaeus laevis* (1)	• Easy to use and commercially available • Used in conjunction with excavation allows extraction of crayfish from flooded underground chambers • Less destructive than excavation • Use restricted to boggy areas with saturated soil
Electricity	No crayfish response	• Higher voltage may be required to evoke a response increasing complexity of method • Ineffective at low voltages
Excavation	*Engaeus hemicirratulus* (3)	• Effective at capture however very destructive to burrows
Ground vibration	Crayfish retreated down burrows	• Ineffective
Alka Seltzer	*E. hemicirratulus* (1)	• Large amounts of water required to flood burrows • Limited effectiveness
Soda water	Crayfish retreated down burrow	• Large amounts of soda water required to flood burrows • Ineffective
Spotlighting	Many crayfish observed in burrows *E. laevis* (1) observed and captured from stream	• Potential as search method • Use restricted to night
Baited string	No crayfish response	• Ineffective
Burrowing crayfish net	Net was either pushed from or dragged into burrows without capture	• Ineffective
Trap door designs	*Engaeus phyllocercus* (1) *E. hemicirratulus* (3)	• Minimal effort to deploy and collect large numbers of traps • Not destructive to burrows • Effective, however trap-door failure rate high
Norrocky	No captures, however significant crayfish activity observed	• Minimal effectiveness
Electrofishing	No captures	• Ineffective

Figure 8. Method testing locations for burrowing crayfish (blue squares).

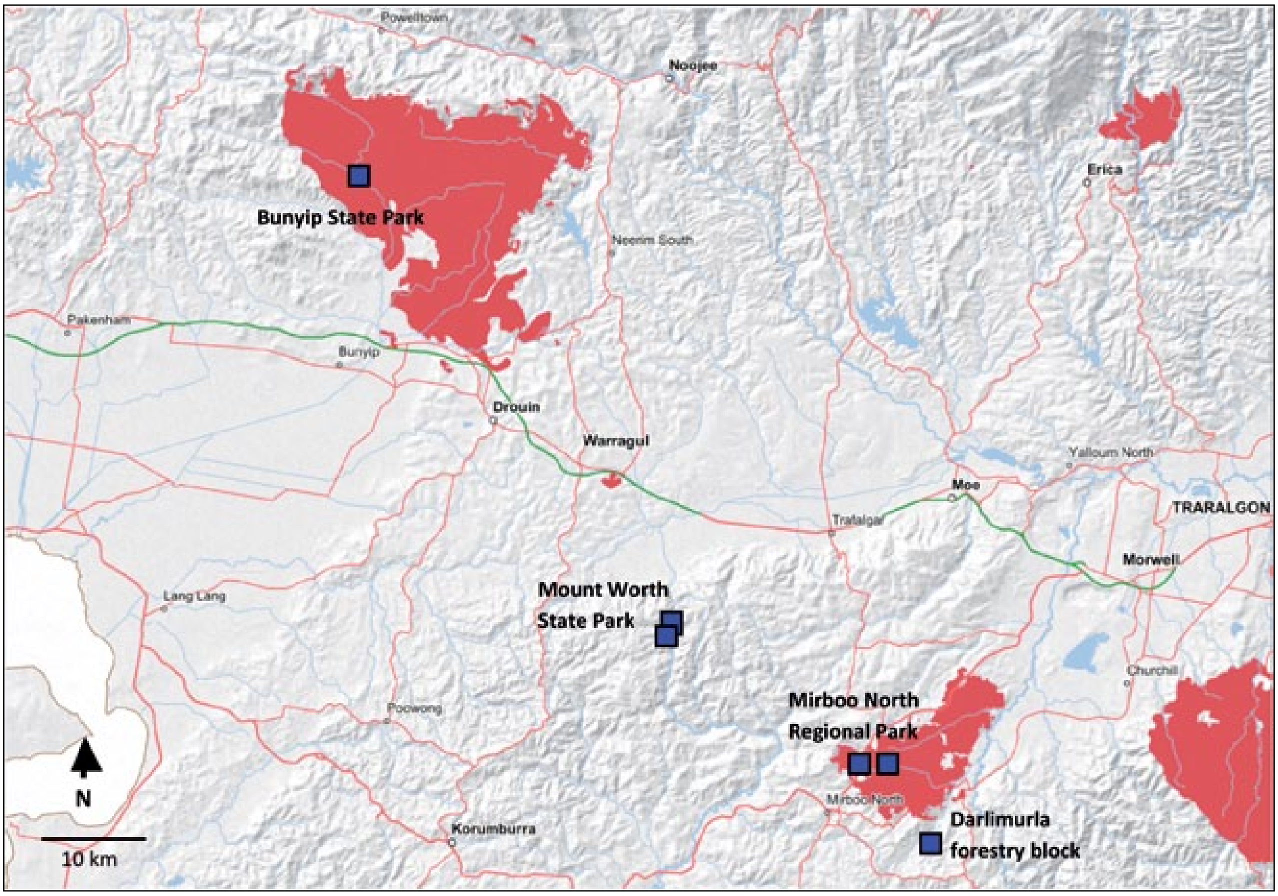


Table 5. Comparisons of burrowing crayfish results from the Norrocky trap and modified Norrocky trap testing sites.

Site	Number of traps	Norrocky trap		Modified Norrocky trap	
		Captures	Failures	Captures	Failures
Darlimurla Forestry Block	30	0	2	0	4
Mount Worth State Park 1	30	0	3	2 (*E. phyllocercus*)	4
Mount Worth State Park 2	30	0	10	2 (*E. phyllocercus*) 4 (*E. hemicirratulus*)	9
Bunyip State Park	10	0	0	2 (*E. quadrimanus*)	0
Mirboo North 1	30	0	2	2 (*E. laevis*)	3
Mirboo North 2	30	1 (*E. laevis*)	1	2 (*E. laevis*)	6
Total	160	1	18	14	26

Figure 9. Modified Norrocky trap (foreground) and Norrocky trap (background), deployed as a pair for testing the effectiveness at burrowing crayfish capture.

Figure 10. Comparison of burrowing crayfish trap capture rate (top) and trap failure rate (bottom) between the Norrocky and modified Norrocky traps. Trap failure was recorded as evidence of burrowing crayfish activity within the trap but no capture.

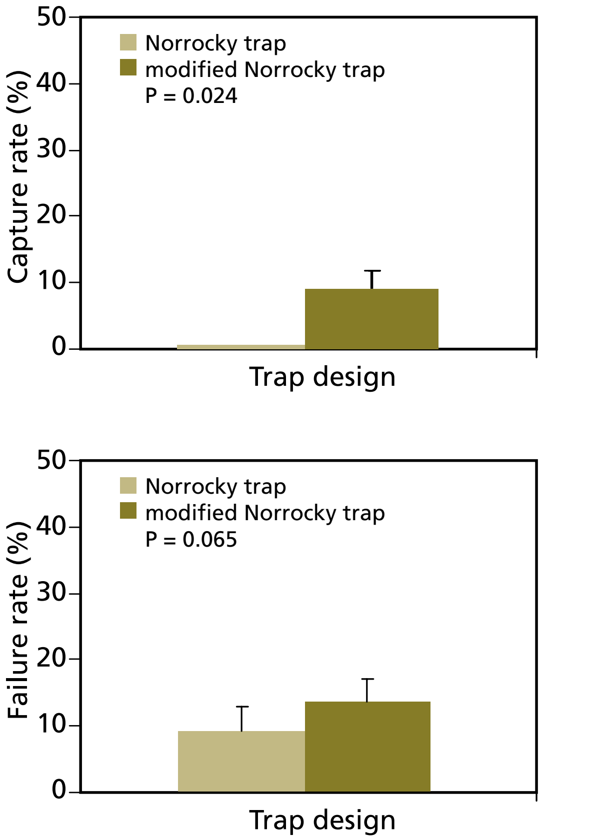


Table 6. Burrowing crayfish captures using the modified Norrocky trap at fire affected and unaffected sites.

Sites affected by fire	Number of traps	Captures	Sites unaffected by fire	Number of traps	Captures
Darlimurla Forestry Block	30	0	Mirboo North 1	30	2 (*E. laevis*)
Mount Worth State Park 1	30	2 (*E. phyllocercus*)	Mirboo North 1	30	2 (*E. laevis*)
Mount Worth State Park 2	30	2 (*E. phyllocercus*) 4 (*E. hemicirratulus*)			
Bunyip State Park	10	2 (*E. quadrimanus*)*			
Totals	**100**	**10**	**Totals**	**60**	**4**

* two dead *E. quadrimanus* individuals were also found at this site

Figure 11. Burrowing crayfish *Engaeus* species captured using the modified Norrocky trap design
a) *E. phyllocercus* (Photo: T.A. Raadik) and b) chimney; c) *E. hemicirratulus* (Photo: T.A. Raadik) and d) chimney;
e) *E. laevis* and f) chimney; g) *E. quadrimanus* and h) location where *E. quadrimanus* was captured.

a)

b)

c)

d)

e)

f)

g)

h)

3 Spiny crayfish methods and results

3.1 Methods

The methods considered for spiny crayfish field testing and surveys (Table 7) were determined by a literature review, examination of state policy and consultation with the expert panel. Following this, electrofishing and bait traps were identified as the most suitable methods for testing in the field due to their effectiveness. Both methods are well established and commonly used in fish and crayfish surveys.

There were three components to the field testing: (i) a comparison of the effectiveness of bait traps and electrofishing at spiny crayfish capture, (ii) investigation of electrofishing sampling efficiency and effort using depletion trials and (iii) surveys investigating the effects of fire on spiny crayfish species across the study area using electrofishing (Figure 12).

Depletion trials and surveys were undertaken in burnt and unburnt areas to assess impacts of fire and identify distributions and possible range extensions for species. Three sites in the Strzelecki Ranges within the Latrobe River catchment were surveyed to determine possible range extension of the South Gippsland Spiny Crayfish.

All spiny crayfish specimens retained for taxonomic identification were confirmed by T. Raadik (Department of Sustainability and Environment) using Morgan (1986).

3.1.1 Method comparison

Trials comparing the effectiveness of crayfish capture between bait traps and electrofishing were undertaken at nine sites in the Mount Worth State Park (3 sites), Tarra Bulga National Park (2 sites) and Wilsons Promontory National Park (4 sites) in October 2010 (Figure 13). The number of sites was limited by high stream flows caused by heavy rainfall over the trial period. The species of spiny crayfish captured at Mount Worth State Park could not confidently be determined and therefore comparisons were only undertaken at the genus level for this location.

Comparisons of bait traps and electrofishing were undertaken in 100 m stream reaches. Each reach was divided into two 50 m sections and the bait trap or electrofishing method was randomly assigned to each section (Figure 14). The methods were trialled in a random order. Where two reaches were located on the same stream, a minimum distance of 100 m was maintained between reaches and the most downstream site was sampled first to minimise disturbance effects.

Between six and 16 bait traps were set at each site. Traps were baited with cat mince, contained light sticks or were unbaited in equal proportions. The number of traps set was influenced by the amount of low flow habitat available. Electrofishing was undertaken using a NIWA 600 Volt Back Pack Electro-fishing unit. Two passes were made and each pass was timed to allow catch per unit effort to be determined. A 30 minute interval between electrofishing passes was observed to allow for recovery of uncaptured individuals still in the stream and for turbidity to return to background levels. Species, sex, weight and occipital carapace length (OCL) were recorded for all but very small (immature) individuals. It is not possible to identify species and determine the sex of immature crayfish.

Site characteristics and water quality variables were recorded at all sites (Appendix 1).

3.1.2 Depletion trials

Depletion trials of electrofishing passes were conducted between October 2010 and February 2011 at three locations (Figure 15). Up to four passes were undertaken in a 50 m reach. Trials took place at ten sites in the Tarra Bulga National Park (3 sites), Wilsons Promontory National Park (4 sites) and Mount Worth State Park (3 sites). The data collected from the Mount Worth state park sites could not be used in the analysis due to being unable to determine the species of spiny crayfish captured. Data from the other seven sites was used to determine the capture rate for each electrofishing pass.

3.1.3 Effects of fire

Surveys of spiny crayfish, including searches for exoskeletons along the riparian zones, were conducted at twenty four sites between October 2011 and February 2011 (Figure 16). The twenty four sites incorporated method comparison and depletion trial sites with additional sites surveyed to investigate the effects of fire. Sites were located in fire affected and unaffected areas. Due to a number of severe rainfall events and culvert/road reconstruction in some areas in spring and summer, access to many locations during this time was restricted. Consequently only three sites affected by fire, two in the Wilsons Promontory National Park and one in the Bunyip State Park, could be surveyed.

At each site, streams were surveyed by electrofishing using a NIWA 600 Volt Back Pack Electro-fishing unit. Two passes were made and each pass was timed to allow catch per unit effort to be determined. A 30 minute interval between electrofishing passes was observed to allow recovery of uncaptured specimens still in the stream and for turbidity to return to background levels. Species, sex, weight and occipital carapace length (OCL) were recorded for all but very small individuals i.e. immature individuals. Identification of species and sex is not possible in immature specimens.

Abundance and size classes of spiny crayfish from the twenty four sites from fire affected and unaffected areas were compared to detect differences which could be attributed to the fires.

Figure 12. Location and design of the spiny crayfish method comparison, depletion trials and fire effect surveys. Numbers of sites are indicated in parentheses.

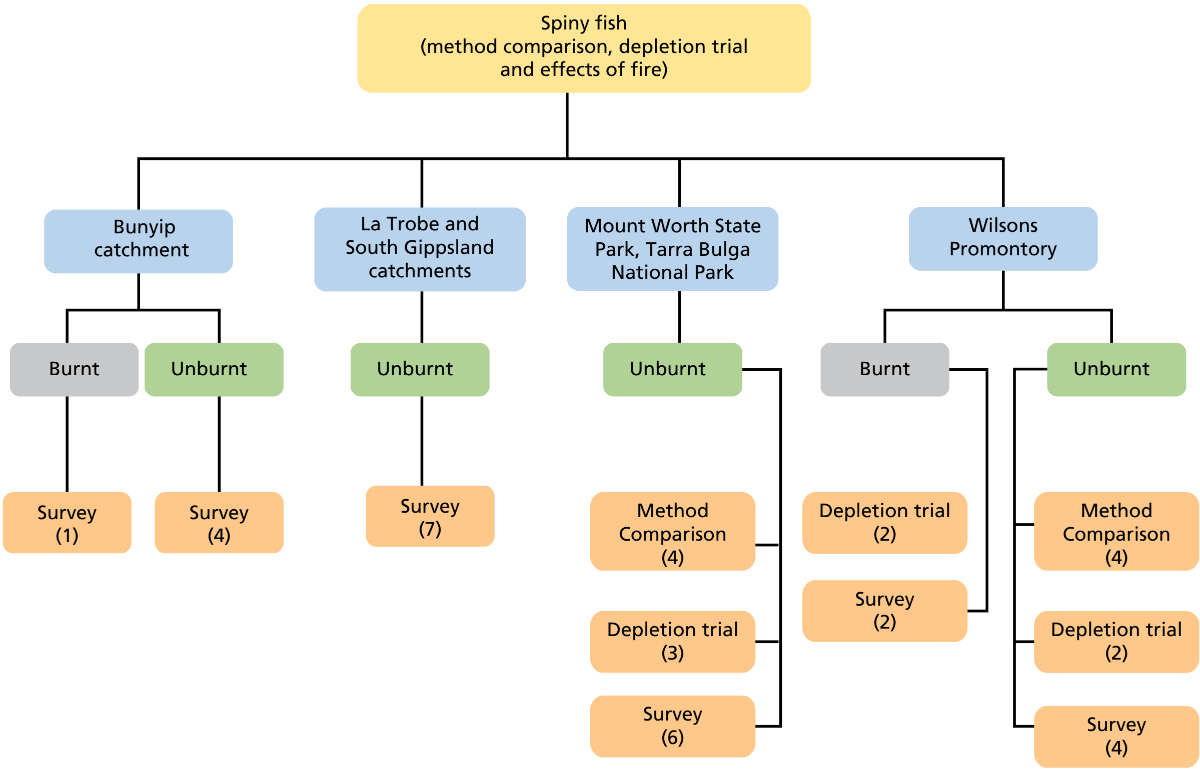


Table 7. Methods considered for spiny crayfish testing and surveys.

Method / device	Rationale for inclusion/exclusion in trials
1. Back Pack Electrofishing (licence required)	• Demonstrated as an effective method • Widely used in general fish surveys incorporating crayfish • Effectiveness can be determined by multiple pass electrofishing depletion trials
2. Bait traps (commercially available)	• Demonstrated as an effective method • Widely available and easy to set • Small mesh aperture allows capture of most size classes
3. Opera House nets (commercially available but illegal for use in public waters)	• Can capture non-target species e.g. platypus, water rats and turtles • Wide mesh aperture not suitable for capture of small individuals of spiny crayfish • Illegal for use in public waters
4. Hoop nets (commercially available)	• Require sampler to be present over long period, limiting the number of sites that can be sampled • Wide mesh aperture not suitable for capture of small individuals of spiny crayfish

3.2 Results

3.2.1 Method comparison

Of the three bait trap treatments, 80% of captures were in bait traps with cat mince and 20% with light sticks. No captures were made in unbaited traps. Ten times as many spiny crayfish individuals were captured by electrofishing than in the bait traps (Table 8). Captures from two electrofishing passes occurred at 100% of the method comparison sites compared to captures from only 40% of sites for bait traps (Table 8). Multiple size classes were captured by electrofishing at all sites (Table 9). At the Tarra Bulga National Park sites, the OCL was significantly higher (t-test, $P<0.001$) for bait trap captures (mean = 36.7, sd = 3.3) than electrofishing captures (mean = 22.8, sd = 6.9). Analysis was not undertaken at Mount Worth and Wilsons Promontory sites due to insufficient capture data.

3.2.2 Depletion trials

There was no complete depletion of spiny crayfish among the five depletion trial sites after four electrofishing passes (Figure 17). There was, however, some evidence of depletion at the fourth pass, with approximately 50% fewer individuals captured than in the first three passes (Figure 17). From the five depletion trials, the majority of individuals (60%) were captured by two passes (Figure 18).

Of the five sites, the mean duration of each electrofishing pass was approximately 30 minutes. Therefore, the mean time taken to perform four passes was three and a half hours (n=5) which included a 30 minute interval between electrofishing passes.

3.2.3 Effects of fire

Spiny crayfish were recorded from all sites affected and unaffected by fire (Table 9). Crayfish abundance at sites affected by fire (mean = 8.5) was similar to that at sites unaffected by fire (mean = 10.1). Multiple size classes (small to large individuals) of all species were present at fire affected sites and most sites unaffected by fire (Table 9). Streams sampled were generally small to moderate in size, with average widths up to 4 m. Most sites were dominated by rocky substrate (gravel to boulders) e.g. Turtons Creek with only five sites dominated by clay/silt substrate e.g. Moonlight Creek. Percentage of pool and riffle/run habitats was variable across all sites. There were no notable differences in recorded water quality across sites (Appendix 1).

Three species of spiny crayfish were captured across the study area: the South Gippsland Spiny Crayfish *E. neodiversus* from the South Gippsland catchment; the Central Highlands Spiny Crayfish *E. woiwuru* from the Bunyip and South Gippsland catchments, and the Gippsland Spiny Crayfish *E. kershawi* from the Latrobe, Bunyip and South Gippsland catchments (Figures 19 and 20). Observed distributions approximated those outlined in Morgan (1986).

Table 8. Number of spiny crayfish captured using bait traps and two electrofishing passes.

Location (target species)	Site	Number of bait trap captures (number of bait traps)	Number of electrofishing captures – 2 passes
Tarra Bulga National Park (South Gippsland Spiny Crayfish)	Tarra River upstream of falls site 1	0 (6)	7
	Tarra River upstream of falls site 2	6 (16)	15
Mount Worth State Park (Spiny Crayfish spp.)	Larkin Creek	2 (12)	26
	Clark Creek	0 (12)	17
	Moonlight Creek	1 (12)	17
Wilsons Promontory National Park (South Gippsland Spiny Crayfish)	Growler Creek	0 (12)	1
	Macalister Creek	0 (12)	10
	Roaring Meg Creek at Telegraph Track	1 (12)	5
	Roaring Meg Creek at Campground	0 (12)	2
Total		**10 (118)**	**100**

Figure 13. Location of method comparison trials for spiny crayfish (green squares).

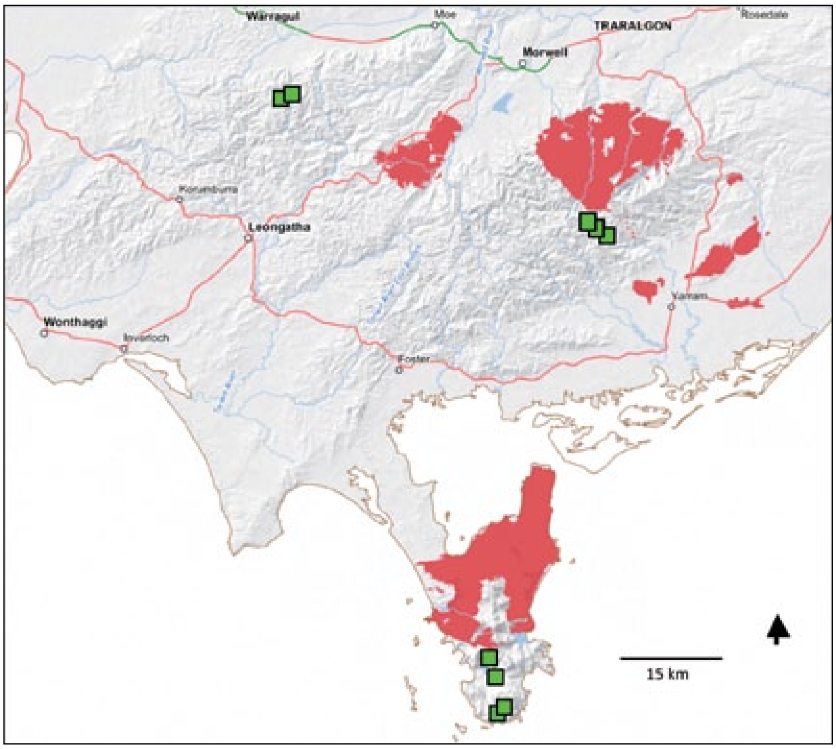


Figure 14. Design of the method comparison component for spiny crayfish.

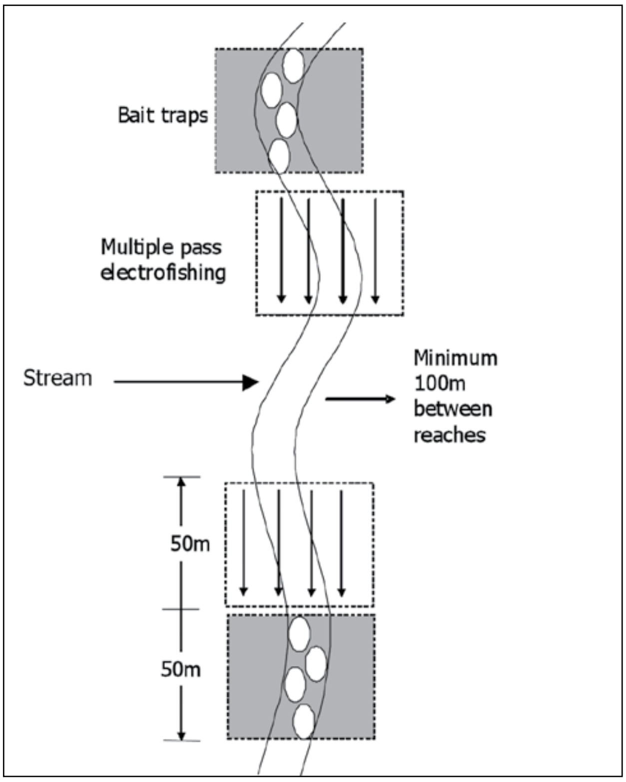


Figure 15. Location of depletion trials for spiny crayfish (green squares).

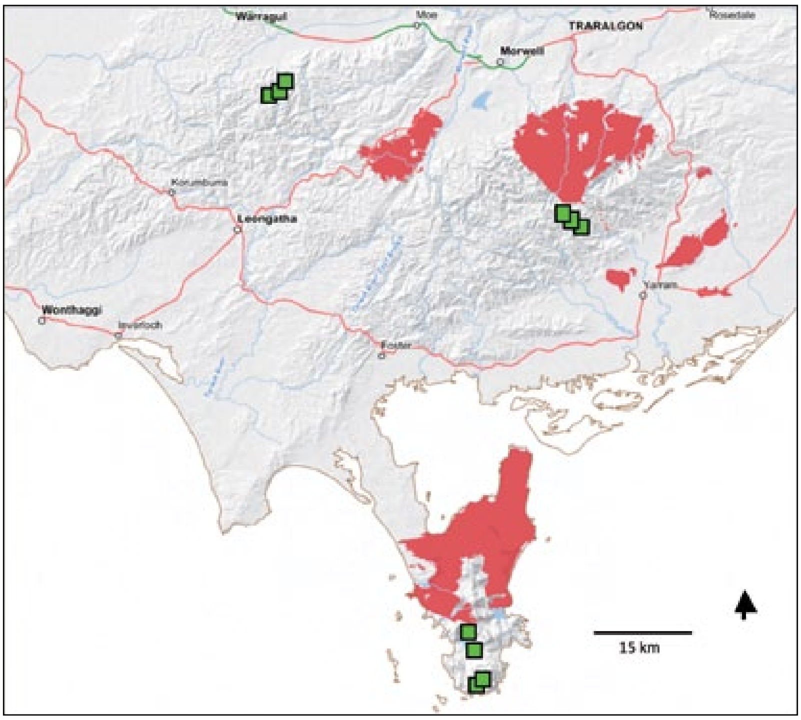


Figure 16. Location of survey sites used for the assessment of the effects of fire on spiny crayfish (green squares).

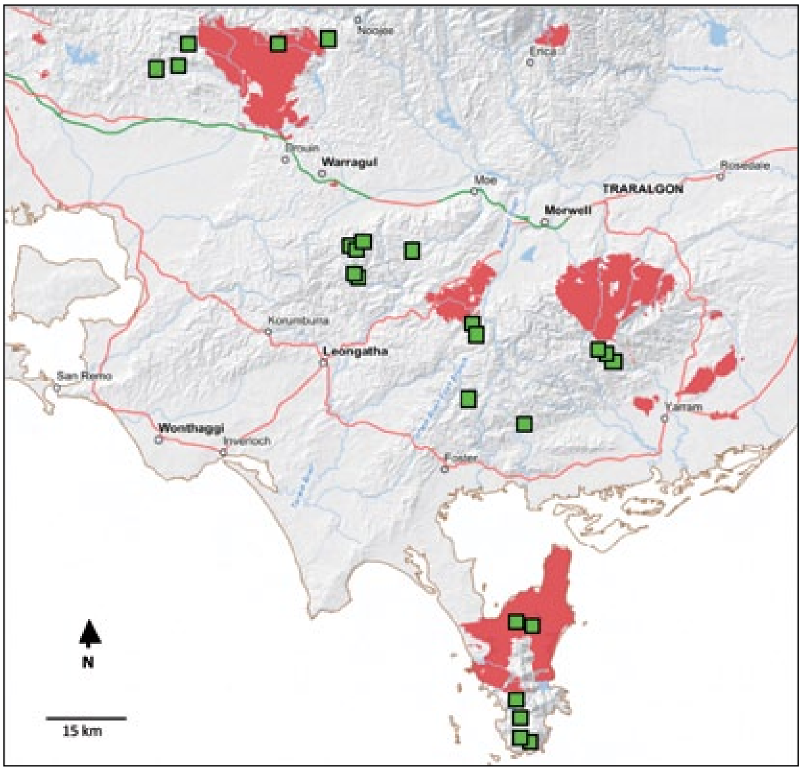


Figure 17. Mean number (with standard error) of the South Gippsland Spiny Crayfish *E. neodiversus* collected in four consecutive electrofishing passes undertaken at five sites.

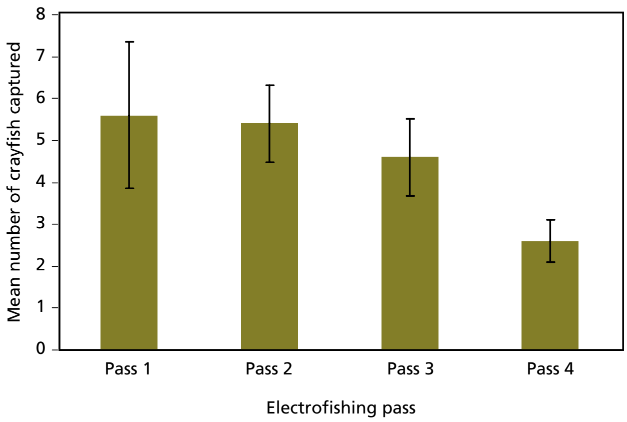


Figure 18. Mean cumulative percentage of total catch for spiny crayfish depletion trials undertaken at five sites.

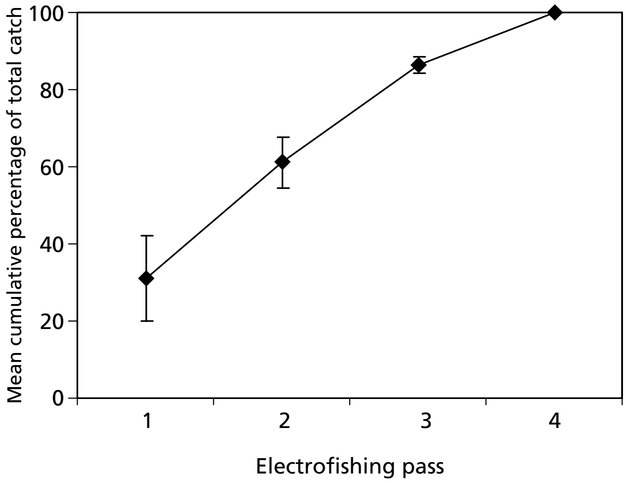


Figure 19. The three species of spiny crayfish captured in the study area: Gippsland Spiny Crayfish (top left), Central Highlands Spiny Crayfish (bottom left) and South Gippsland Spiny Crayfish (right).

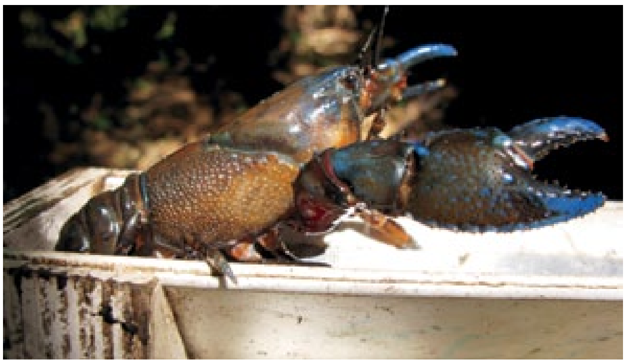
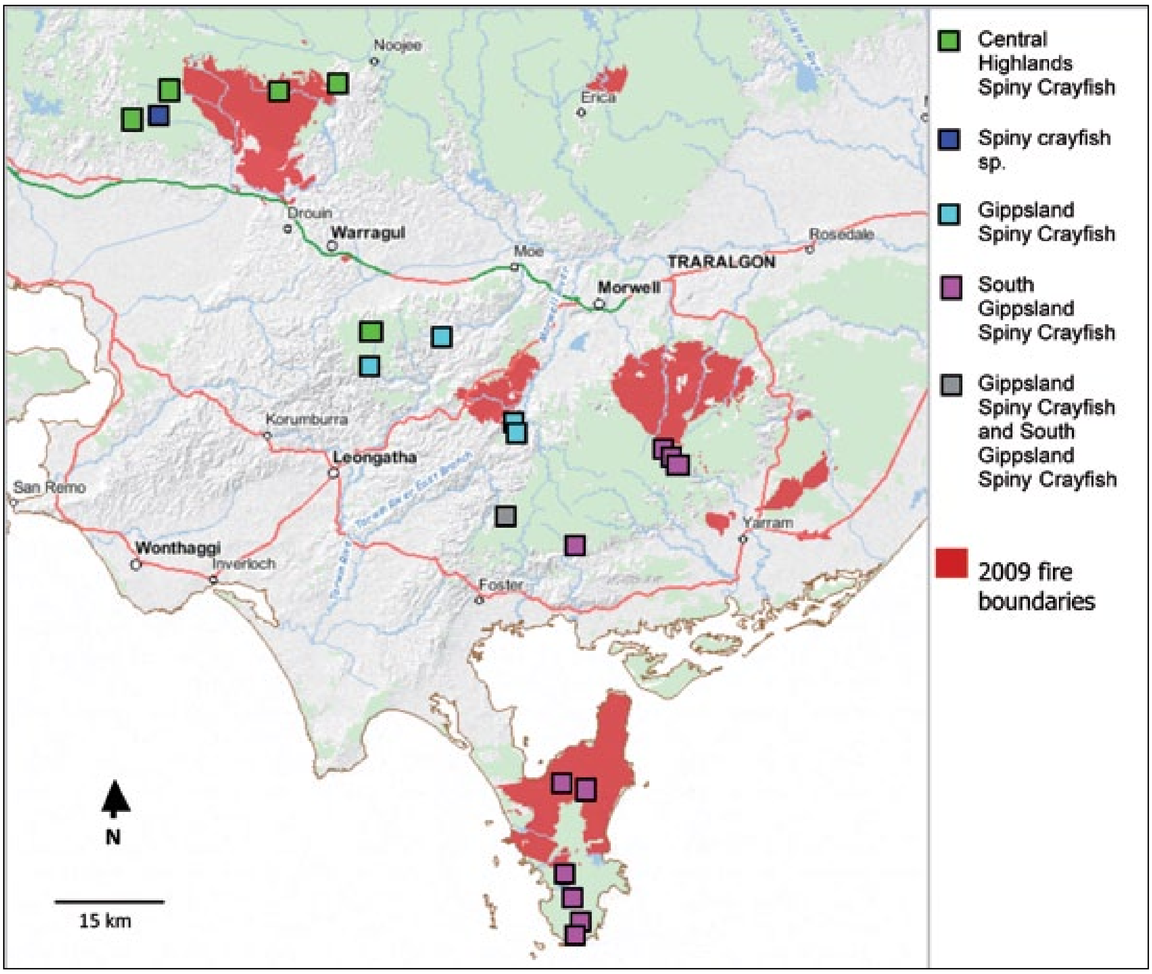


Table 9. Numbers of spiny crayfish caught at fire affected and unaffected sites using electrofishing. Fire affected sites are shaded in grey.

Catchment	Site	Species (*E = Euastacus*)	Captures (two electrofishing passes)	OCL range (rounded to nearest mm)
South Gippsland	Tarra River upstream of falls site 1	*E. neodiversus*	6	14–36
	Tarra River upstream of falls site 2	*E. neodiversus*	13	10–36
	Tarra River downstream Tarra Valley picnic area	*E. neodiversus*	4	12–26
	Growler Creek	*E. neodiversus*	1	
	Roaring Meg Creek at Telegraph Track	*E. neodiversus*	4	24–44
	Roaring Meg Creek at campground	*E. neodiversus*	2	*
	Mcalister Creek	*E. neodiversus*	9	12–28
	Clark Creek	*E. neodiversus*	17	11–29
	Moonlight Creek	*E. neodiversus*	17	12–26
	Agnes River	*E. neodiversus*	8	13–32
	Barry Creek	*E. neodiversus*	12	6–27
	Chinamans Creek	*E. neodiversus*	10	8–25
	Larkin Creek	*E. woiwuru*	1	*
	Tarwin River West	*E. kershawi*	1	*
	Turtons Creek	*E. kershawi*	1	*
		E. neodiversus	4	16–24
	Bowdens Creek	*E. kershawi*	4	20–24
Latrobe	Narracan Creek	*E. kershawi*	39	13–115
	O'Grady Creek	*E. kershawi*	3	21–26
	Walkley Creek	*E. kershawi*	11	14–108
Bunyip	Tarago River East	*E. woiwuru*	26	10–57
	Black Snake Creek	*E. woiwuru*	3	16–17
	Upper Diamond Creek	*E. woiwuru*	12	18–29
	Tarago River West	*E. woiwuru*	5	16–25

* OCL not recorded

Figure 20. Location of spiny crayfish captured during the study.



4 Discussion

4.1 Effectiveness of methods

4.1.1 Burrowing crayfish

Twelve of the sixteen reviewed published and unpublished burrowing crayfish capture methods were tested in the field for their capture effectiveness. Burrowing crayfish were captured by five of these: bait pump, excavation, Alka Seltzer down burrows, spotlighting and trap door devices over burrow entrances. Information specific to these methods and those used in other studies is provided below.

Excavation

This is the most common method employed in surveys (e.g. Suter and Richardson 1977, Richardson and Swain 1980, Van Praagh and Hinkley 1999) and resulted in captures in the current study. The technique however destroys the crayfish burrow, which has the potential to cause immediate impacts on the resident crayfish and longer term impacts on the crayfish population. This is especially so if brood chambers containing young crayfish are destroyed. These impacts have not been investigated. Repeated sampling is not possible with this method and therefore it cannot be used for population monitoring.

In the current study, some excavated specimens were maintained in a laboratory in aquaria with moist soil for identification and observation of their burrowing behaviour. Burrowing within 12 hours was observed, which suggests that when displaced (by excavation) they may be able to construct new burrows if the soil is moist. Further investigation into the burrowing behaviour of multiple species in different soil types and moisture levels is required. This will help inform the rehabilitation of populations that may be unearthed by road works, building construction or other large scale excavations.

Spotlighting

One individual was captured from an inundated area adjacent to a small stream by spotlighting and crayfish at drier sites were observed within burrows but never above ground. This method has proved successful for at least one species of *Engaewa* in Western Australia, a burrowing crayfish genus with very similar ecology to *Engaeus*. It is reported that *Engaewa* were hand picked by spotlight from peaty areas with shallow surface pools (Department of Environment and Conservation 2008). Surface moisture is thought to be an important cue for above ground activity by burrowing crayfish and spotlighting in wet habitats or during wet periods may result in greater detection rates.

Norrocky trap

This study recorded a capture rate of 0.6% using the Norrocky trap. Studies in the United States report higher capture rates of 13%, (Norrocky 1984), 5.2% (Ridge *et al.* 2008) and 5% (Welch and Eversole 2006). Differences in capture rates are likely to reflect the duration of trap setting and the ecology and behaviour of the target species. In the overseas studies traps were deployed for a considerably longer duration than those in the current study (minimum of 48 hours *c.f.* 18 hours respectively). Capture effectiveness may also be a reflection of environmental conditions, such as soil moisture and temperature, at the time of trapping.

Modified Norrocky trap

The trap door devices were improved and refined for *Engaeus* capture by simple design enhancements to reduce failure and thereby increase capture rates. The modified Norrocky trap produced an average capture rate of 8.75% across all habitats. Capture rates ranged from 0 to 20% within habitat types. This result was significantly higher than the capture rate achieved with the Norrocky trap and additionally demonstrated the success of the modified Norrocky trap in a range of habitat types.

The differences in capture rates between the Norrocky and modified Norrocky traps are likely a result of three design elements incorporated into the modified Norrocky trap: (i) the texture of the trap tube, (ii) the size of the trap tube and (iii) the design of the trap door unit. The Norrocky trap tube is a smooth PVC pipe which, in this study, was identified as a potential obstacle to *Engaeus* climbing the pipe. In contrast, the corrugated hose used in the modified Norrocky trap is likely to provide a more practical surface for crayfish to climb. The diameter of the Norrocky was larger than most burrow entrances observed in the study area. This allowed crayfish to deposit excavated mud without having to move past the one way door within the trap. A similar observation was reported in the study by Marist Regional College (2011). The smaller diameter of the modified Norrocky trap approximated burrow diameters encountered in the study and also allowed easy insertion into burrows. This is likely to have assisted movement of crayfish past the trap door (to deposit excavated mud), resulting in more successful captures than the Norrocky trap.

The failure rate for the modified Norrocky trap (16%) was slightly higher than the Norrocky trap (10%). Small improvements to the modified Norrocky trap hinge design were made following the current study and failure rate was reduced to 0.4% in a later Dandenong Ranges survey (Lumsden *et al.* 2011).

Further work is needed to test the effect of the number of traps per number of burrow entrances on detection and capture rates.

Alka Seltzer

Placing Alka Seltzer tablets into crayfish burrows resulted in the capture of one crayfish from an inundated burrow. Carbon dioxide is produced when Alka Seltzer comes in contact with water and oxygen is depleted. This can be rapid, as demonstrated in the laboratory where upon placing two tablets in 1 l of water, the oxygen concentration dropped to 7% within five minutes. It is not known whether the capture was caused by oxygen depletion or CO_2 or both. The method is limited to inundated burrows. Artificially inundating burrows is likely to be impractical in many situations because of the large volume of water required.

Bait pump

The bait pump was effective at crayfish capture only when the soil was sufficiently saturated to create a strong vacuum. A vacuum was not generated in burrows which were artificially inundated and this limits its application as a survey method. If used intensively in an area, the pump can cause significant damage to the burrow system.

Burrowing crayfish net

The trial of Burrowing Crayfish Nets in this study yielded no captures. On a number of occasions nets were observed to be pushed out of their burrows indicating crayfish activity. These results are in contrast to a Gippsland study by Kingwill (2008) which reported captures on 19 out of 50 trapping days for a total of 30 crayfish. The capture rate in the latter study may be explained by the amount of time the nets were left in place. Kingwill (2008) left nets in place for five days in contrast to the current study where nets were only in place overnight. Welch and Eversole (2006) and Ridge *et al.* (2008) also reported captures using the net in several studies in the United States. Whilst the method is not destructive to crayfish burrows it can be lethal to crayfish, with Kingwill (2008) observing fatalities resulting from trying to extract entangled individuals from burrows.

Pitfall traps

Pitfall traps were not tested in this study. Shaw (1996) found pitfall traps to be effective in certain conditions, which related to rainfall and soil temperature levels. These factors have been suggested as drivers of surface activity. Van Praagh and Hinkley (1999) suggested a long period of monitoring would be required for pitfall traps to be effective as capture rates would likely be low.

General observations

Collectively, the number of crayfish captured by all methods was low. This is likely a normal result due in part due to their limited surface activity. Van Praagh and Hinkley (1999) suggest crayfish movement to the surface may be greater in mating season (from late spring to early summer) and immediately following periods of high rainfall. A significant correlation between rainfall and burrow activity has been demonstrated by Kingwill (2008). In the current study, some of the burrowing crayfish method testing was performed in late summer. Capture rates may have been higher if all testing was performed during spring to early summer. Further work is required to better understand burrowing crayfish surface activity patterns.

Selecting crayfish burrows to sample was at times problematic because it was difficult to determine whether a burrow was likely to be occupied. Crayfish were sometimes observed down burrows that showed no signs of recent activity (e.g. absence of fresh mud pellet deposits on the chimney or absence of burrow excavations). As a result, it is likely that in some instances unoccupied burrows were surveyed and occupied burrows were not. In addition, burrows may have multiple entrances which can often be difficult to locate, especially in densely vegetated areas, making it very difficult to confidently survey all entrances.

4.1.2 Spiny crayfish

Method comparison

Among the sites assessed, electrofishing was far more effective than all bait trap treatments at detecting crayfish presence. In two electrofishing passes, ten times as many crayfish were captured than in 100 bait traps. Baited traps resulted in captures at only 40% of sites compared to 100% of sites with electrofishing. These differences can be attributed to (i) the mechanism of capture of these methods and (ii) the area and habitats they sampled. Electrofishing actively targets crayfish and is not reliant on their movement, whereas bait traps rely on crayfish movement (i.e. a passive capture technique). Electrofishing was effective at capture over a large area at a range of depths and flow velocities. This was in contrast to bait traps, which sampled a more limited range of habitats and flow velocities.

Electrofishing captured a range of size classes at all sites. Only one bait trap site had a sufficient number of captures to enable a size class assessment. At this location there was a bias toward larger individuals. Brown Trout were recorded at the Tarra Bulga National Park sites and are known predators of crayfish, especially small individuals (Faragher 1983, Englund and Krupa 2000). Predation pressure from Brown Trout may be limiting the movement of small crayfish and thereby reducing the chance of capture in the bait traps.

While there are a number of advantages of electrofishing over bait traps, two limitations have been reported: compromised detectability and physical impacts on crayfish. Detectability is compromised in highly turbid waters as stunned individuals are difficult to see and collect (Cowx and Lamarque 1990). A physical impact, the loss of claw(s) from crayfish, can occur in response to the current (Alonso 2001), though this does not happen to all individuals, or every time (Raadik, T.A. pers. comm. 2011).

In shallow riffles, Gladman *et al.* (2010) assessed the effectiveness of individual and combined methods in detecting crayfish including electrofishing, kick sampling, and stone turning. Maximum detection was achieved with (a minimum of) two electrofishing passes in conjunction with a three minute kick sample. This demonstrates other capture techniques in conjunction with electrofishing should be considered to maximise detectability.

Electrofishing depletion trials

Depletion trials were conducted at typically shallow streams in mid to upper catchments where the South Gippsland Spiny Cray *E. neodiversus* was the most abundant crayfish taxon. As the number of electrofishing passes that could be achieved was limited by time, the number required to achieve 100% depletion was not determined. However, noticeable depletion was observed at four passes. It could be expected that several more passes would be required to fully deplete populations in reaches similar to those surveyed in this study. Two electrofishing passes was sufficient to confidently detect the presence of crayfish. Of the five depletion trials using four passes, crayfish capture was highest in the first and second pass. Further work is required to test electrofishing depletion in different habitat types (e.g. deeper water) and among different species.

One pass was insufficient to adequately detect crayfish which was consistent with findings of studies in North America (Gladman *et al.* 2010) and Spain (Alonso 2010). It is has been proposed that crayfish hidden in complex habitat may become more active after the initial electrical exposure, drawing them out of their retreats and making them easier to catch in subsequent passes (Gladman *et al.* 2010).

4.2 Effects of fire

There is a lack of pre-fire burrowing and spiny crayfish population data in the fire affected areas. This is partly due to limited survey methods. The lack of pre-fire data prevented a comparison of crayfish abundance and diversity before and after the fires. An assessment of the effect of fire on crayfish was limited to a comparison between fire affected and unaffected areas two years following the fires. The number of fire affected sites surveyed was limited by several significant rainfall events. These caused access difficulties and delayed completion of the methods testing component which was critical to informing the survey methods for the fire component of the study.

At the fire-affected sites which were surveyed, both spiny and burrowing crayfish were found. There were two size classes of the South Gippsland Spiny Crayfish *E. neodiversus* at fire affected sites and also at most sites unaffected by fire. Size can be used as a surrogate measure for determining the age of crayfish. The growth rate of *E. neodiversus* has not been documented and consequently the age of specimens could not be determined. The size of individuals in fire affected and unaffected sites was similar. It appears likely that the larger individuals (OCL ~25 mm) were greater than two years old and therefore were present during the fire. These individuals could have taken refuge in deep water or complex instream habitats and/or recolonised from neighbouring areas which were not severely burnt. Fire severity classes (low to high severity) were present within the 2009 fire boundary areas (Department of Sustainability and Environment 2011b). These areas may also have provided refuge for burrowing crayfish. It is also expected that burrows may have provided refuge for burrowing crayfish during the fire, especially in severely burnt areas. The two dead crayfish *E. quadrimanus* were found at the fire affected Bunyip State Park site after very heavy rainfall. Localised flooding was evident in the area at the time of sampling and the mortalities appear to be flood related rather than fire related.

Degraded water quality, such as high temperatures and reduced dissolved oxygen concentrations, can occur during fire and has the potential to have an adverse impact on spiny crayfish. McKinnon (1995) and King *et al.* (2011) associated spiny crayfish mortality with low dissolved oxygen concentrations. Water quality impacts associated with ash and sediment in runoff caused by intense rainfall shortly after fires can also adversely affect spiny crayfish. This was observed following two fires in 2006, one in the Grampians National Park (K. Johnston pers. comm.) and another in north east Victoria (Lyon and O'Connor 2008). There were no such rainfall events in the study areas shortly after the fires and consequently the likelihood of these water quality impacts on spiny crayfish was low.

5 Key findings and suggested further work

The key findings from the study and suggestions for further work are as follows:

Burrowing crayfish

- Of the devices tested for detecting and capturing burrowing crayfish, the modified Norrocky trap was the most successful. It was able to capture a number of species in several habitats.
- Deployment of the modified Norrocky trap for a longer duration (e.g. two days) is warranted to test the influence of trap setting time on crayfish capture and detectability.
- Deployment of more traps per site is warranted to test the influence of trap density on crayfish capture and detectability.
- The burrowing crayfish net did not capture any crayfish in this study but has been used successfully in other studies. The method warrants further investigation, including consideration of overcoming crayfish fatalities.
- Pitfall traps were not tested for effectiveness at capture of burrowing crayfish but have been effective in at least one study. Their use warrants further investigation.
- Further work is required to test methods in other areas with different species.
- Further work is required to identify periods of peak crayfish movement which may be related to their breeding season and weather conditions (e.g. spring-summer and following wet conditions).
- Further investigation into the burrowing behaviour of multiple species in different soil types and moisture levels is required. This will help inform the rehabilitation of populations that may be unearthed by road works, building construction or other large scale excavations.

Spiny crayfish

- Electrofishing was more effective than bait traps at capturing the South Gippsland Spiny Crayfish *E. neodiversus*.
- Only bait traps containing bait or light sticks resulted in spiny crayfish captures.
- Two electrofishing passes was sufficient to confidently detect the presence of spiny crayfish.
- The number of passes required to achieve 100% depletion of spiny crayfish was not determined, however noticeable depletion was observed at four passes.
- The time required to undertake more than two electrofishing passes is prohibitive for rapid surveys.
- The use of other capture techniques in conjunction with electrofishing should be considered to maximise detection.

Effects of fire

- Burrowing and spiny crayfish genera were recorded at sites affected by the fires.
- The assessment of the affect of fire on crayfish was impaired by the lack of pre-fire population data for both genera from fire affected areas, the time interval between the fires and the surveys and the extreme rainfall events, which limited the number of fire affected sites that were able to be surveyed.
- Burrows are likely to have provided some protection from fire for burrowing crayfish.
- Multiple size classes of spiny crayfish were evident at sites affected by the fires. Larger individuals were likely to be more than two years old and present during the fire.
- The large spiny crayfish individuals at fire affected sites either took refuge in deep water and complex instream habitat or recolonised from neighbouring areas which were not severely burnt.

6 Notes on taxon identification

Identification of *Engaeus* and juvenile *Euastacus* typically requires considerable expertise and magnification of key features with a microscope. Identification of species and sex in the field is not possible for some species or size classes in these genera. Surveys should therefore include the capacity to safely transport crayfish to a laboratory where they can be accurately identified.

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Appendix 1

Table A1. Physico-chemical water measurements and instream habitat attributes at sites where the spiny crayfish method comparison, depletion trials and surveys were undertaken. Sites shaded in grey were affected by the fires.

Catchment	Site	Altitude (m)	Riffles (%)	Pools (%)	Mean stream width (m)	Mean stream depth (cm)	Stream shading at midday (%)	Water temperature (°C)	Conductivity (mS/cm)	Dissolved oxygen concentration (%)	pH	Turbidity (NTU)
South Gippsland	Tarra River upstream of falls site 1	345	90	10	1.6	20	>75	11.4	109	NA	6.4	8.5
	Tarra River upstream of falls site 2	362	80	20	2.4	20	>75	11.2	109	NA	6.5	11.0
	Tarra River downstream of Tarra Valley picnic area	382	65	35	2.5	20	>75	10.4	106	NA	6.9	24.0
	Growler Creek at Telegraph Track	28	95	5	0.9	40	51–75	9.5	385	87	6.5	3.8
	Roaring Meg Creek at Telegraph Track	191	90	10	2.2	25	51–75	9.9	321	92.5	6.4	3.0
	Roaring Meg Creek at campground	180	95	5	2.2	30	51–75	9.9	321	92.5	6.4	3.0
	McAlister Creek at Telegraph Track	36	75	25	1.4	45	51–75	10.1	382	93	6.5	2.4
	Clark Creek at Mt Worth State Park	340	90	10	1	25	51–75	10	135	83	6.6	47.0
	Larkin Creek at Mt Worth State Park	338	100	0	1.05	25	51–75	9.5	139	87	6.5	37.4
	Moonlight Ceek at Mt Worth State Park	314	85	15	2	45	26–50	9.2	147	83	6.7	35.6
	Tarwin River West upstream of Allambee Bridge	140	10	90	7	70	51–75	15.2	155	90.0	6.2	22.6
	Bowdens Creek downstream of Allambee Estate Road bridge	140	90	10	4	40	26–50	19.1	189	95.0	6.4	24.2
	Turtons Creek at Turtons Creek Road	150	20	80	8.3	50	26–50	16.4	193	91.8	6.5	25.1
	Agnes River upstream of Dingo Creek Road crossing	220	90	10	8	30	26–50	17.1	138	61.0	6.5	10.3
	Barry Creek upstream and downstream of Five Mile Road	65	20	80	3	30	51–75	17.5	397	72.0	5.6	3.7
	Chinamans Creek upstream of crossing on Five Mile Road	65	15	85	3	15	51–75	18.4	493	74.8	7.5	2.3

Catchment	Site	Altitude (m)	Riffles (%)	Pools (%)	Mean stream width (m)	Mean stream depth (cm)	Stream shading at midday (%)	Water temperature (°C)	Conductivity (mS/cm)	Dissolved oxygen concentration (%)	pH	Turbidity (NTU)
Latrobe	Narracan Creek at Sunny Creek Road	280	70	30	2.7	20	>75	17.8	100	69.0	6.4	36.8
	O'Grady Creek upstream of Limonite Road bridge	115	15	85	3.2	30	26–50	17.1	316	67.0	6.6	32.4
	Walkey Creek upstream of Fishers Road	150	85	15	3.4	20	>75	20.7	93	83.7	6.1	99.5
Bunyip	Tarago River East at Nayook Glen Reserve	340	70	30	2.4	25	>75	17.1	77	77.4	6.4	21.0
	Black Snake Creek upstream and downstream of Ash Landing Road	132	65	35	2.7	40	51–75	14.6	122	85.3	5.9	9.9
	Diamond Creek downstream of Gembrook-Tonimbuk Road crossing	121	75	25	4.2	45	51–75	15.2	124	83.0	5.9	17.1
	Upper Diamond Creek downstream of Creighton Road crossing	155	60	40	2	30	51–75	16.0	136	82.9	5.6	10.7
	Tarago River West adjacent to Tarago Road	303	80	20	7	40	26–50	14.2	72	91.4	5.8	5.2

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