Burrowing Crayfish (*Engaeus*) Group Recovery Plan

2001-2005

Prepared by
Niall Doran
Threatened Species Unit
Parks and Wildlife Service
Department of Primary Industry, Water and the Environment

November 1999

Citation: Doran, N.E. (1999). Burrowing Crayfish (*Engaeus*) Group Recovery Plan 2001-2005. Threatened Species Unit, Parks and Wildlife Service, Hobart.

Foreword

Acknowledgements

Thanks are due to Dr Pierre Horwitz and Associate Professor Alastair Richardson for their input and comments on this plan, as well as the continued interest of field naturalist groups (including the Central North Field Naturalists), volunteers and the Forest Practices Board in collecting data and information on these species.

Abbreviations

CONTENTS

SUMMARY

Current Species Status
Four Tasmanian *Engaeus* species are of conservation significance. The Mount Arthur, Scottsdale and Burnie burrowing crayfish (*E. orramakunna, E. spinicaudatus* and *E. yabbimunna*, respectively) are currently all listed as Vulnerable under the Tasmanian *Threatened Species Protection Act* 1995, and have all been identified as Priority Species requiring recovery action under the *Tasmanian Regional Forest Agreement* 1997. The Furneaux burrowing crayfish, *E. martigener*, has previously been recognised as rare and has been nominated for listing under the Tasmanian Act. *Engaeus spinicaudatus* has been nominated for upgrading to Endangered under the Tasmanian Act, and all four species qualify and have been nominated for listing at a Commonwealth level.

Habitat Requirements & Threatening Factors
All four species are endemic to Tasmania and have highly restricted distributions. Habitat requirements are governed by water quality and availability, and the presence and quality of soil and native riparian vegetation. Threatening processes include urban and industrial pollution, agricultural activity and forestry, long term fire effects, clearance and removal of native vegetation, sedimentation, and waterway disturbance or alteration of drainages. Each of the four species has been subjected to differing degrees of each of these processes.

Recovery Plan Objectives

Overall Objective: To stabilise and improve the conservation status of these species so that they may be considered for downlisting according to population sizes and trends, area and occupancy and security of habitat within or beyond the timespan of this plan.

Specific Objectives:
1. Improve habitat protection for each species.
2. Increase public awareness and involvement in threatened species protection.
3. Ensure each species persists in the long-term throughout its area of occupancy.

Recovery Criteria:
1. Improved security for each species through reservation, improved land use techniques and management agreements with landholders and forestry, agricultural and urban or public stakeholders.
2. Increased public awareness of these species and involvement in or willingness to be involved in conservation related programs.
3. Each species measured at selected monitoring sites indicates overall stability or long-term increase in populations or range.

Recovery Actions Needed:
1. Assessment of habitat (particularly for *E. martigener*).
2. Improvement of reservation status for all species.
3 . Habitat management with agricultural areas, forestry & urban).
4. Habitat management within forestry and commercial harvesting areas.
5. Habitat management within urban and other areas.
6. Community involvement and education.
7. Population and habitat monitoring, combined with the results of actions 1-6 (as above).

Estimated Cost of Recovery: 2000 prices in $000s/year.
Scientific Officer salary & on costs are divided between individual actions.

Action	1.1	1.2	2	3	4	5	6	7	8	Total
2001	45.3	14.4	67.6	11.7	11.8	16.1	13.3	20.4	42.0	**242.6**
2002	--	--	79.9	41.6	23.4	40.6	13.3	23.4	34.4	**256.6**
2003	--	--	79.9	41.6	23.4	40.6	13.3	23.4	34.4	**256.6**
2004	--	--	--	--	--	--	6.35	23.4	8.4	**38.15**
2005	--	--	--	--	--	--	6.35	23.4	8.4	**38.15**
Total	**45.3**	**14.4**	**227.4**	**94.9**	**58.6**	**97.3**	**52.6**	**114.0**	**127.6**	**832.1**

Costings do not incorporate community and volunteer time

Biodiversity Benefits: Protection and management of the four *Engaeus* species will have direct conservation benefits for other stream-dwelling and stream-associated species (including Nationally listed species) within these areas. It will also have directly beneficial consequences for water quality and waterway health affecting the Burnie and Dorset communities. On Flinders Island, the Strzelecki National Park has been identified as containing significant areas of habitat that have been lost from elsewhere on the Bass Strait Islands (Walsh 1999). In addition to the crayfish, the park contains valuable and high levels of biodiversity, and is noted as being of high scientific interest "due to the high number of endemic species, rare flora and fauna and significant vegetation communities" it contains.

INTRODUCTION

Description

Species of *Engaeus* are small freshwater crayfish, with a general body length of under ten centimetres. They vary in colour from orange to reddish brown, grey-blue and purple. During the breeding season (late spring to summer), females carry large orange eggs and recently hatched young under their tail. They are believed to eat rotting wood, detritus, root material and the occasional animal material.

Most species of *Engaeus* are characterised by their ability to burrow, often to considerable depths, and specimens are only rarely seen above ground or in standing water (Horwitz 1990a). Burrows often have chimneys of pelleted soil where they meet the surface, and in sheltered areas these may be quite high (up to 40 cm). Burrows can be simple and shallow or complex, deep and extensive, and a burrow system may often be the product of several generations of crayfish activity. Burrows may be directly connected to streams or lakes (type 1), may connect to the water table (type 2), or may simply rely on run-off to stay wet (type 3). Those relying solely on run-off are only found in Australia and are specific to *Engaeus* species, making them the most terrestrial of the world's freshwater crayfish (Horwitz & Richardson 1986). Consequently, their dispersal through waterways may be limited, leading to restricted ranges and a high degree of local speciation.

Taxonomic Status

Engaeus is one of four freshwater crayfish genera native to Tasmania, the other three being *Parastacoides*, *Geocharax*, and *Astacopsis*. The genera can be distinguished on the basis of chelae (claw) orientation and shape, carapace grooves, and the location and number of spines on the body (Horwitz 1988a). There are 35 species of *Engaeus* found in south-east Australia, 20 of which are endemic to mainland Australia, 13 are endemic to Tasmania, and two are found in both. The taxonomic status of the genus has recently been reviewed by Horwitz (1990a, 1994), in which he described the four species covered here.

Distribution

Tasmanian *Engaeus* species are mostly found in the north and west of the state, with both the north-east and north-west characterised by their own distinct subgroups. The distribution of some of these has been extensively studied (Horwitz 1986, 1988b, 1990a & 1996; Doran & Richards 1996; Doran 1998).

The genus displays remarkable diversity given the relatively small geographic area over which it occurs, and is characterised by a jig-saw pattern of distinct and interlocking ranges for individual species. Overlap between species does occur, but is not the norm. Some species have very wide geographic ranges, while others are very restricted. Four Tasmanian *Engaeus* species are of conservation concern due to their small ranges: *E. orramakunna* (the Mt Arthur

burrowing crayfish), *E. spinicaudatus* (the Scottsdale burrowing crayfish),*E. yabbimunna* (the Burnie burrowing crayfish) and *E. martigener* (the Furneaux burrowing crayfish). All four of these species are endemic to Tasmania (Figure 1: map of general distributions).

Habitat

All burrowing crayfish species favour wet, muddy areas and seepages, where their burrows exhibit characteristic chimneys of pelleted soil. Particular species vary in the level of water availability and other environmental conditions that they tolerate and/or prefer. Such differences are reflected in the longitudinal ('source to mouth') and transverse ('across gully', or distance from stream/water) distribution of species along a water course (Suter & Richardson 1977, Horwitz *et al*. 1985, Horwitz 1986, Richardson & Horwitz 1987).

Abundance

Burrowing crayfish can be locally abundant in any area of suitable habitat within their range. Given the unpredictable nature of habitat types within wider geographic regions and the often small seepages in which these species occur, the most reliable population estimates have been made for *E. spinicaudatus* (the species for which available habitat has been most closely documented). Over a total 3.881 x 10^6 m^2 identified as suitable habitat, Horwitz (1991) estimated the overall population of *E. spinicaudatus* as 1.36 - 2.67 x 10^6 adults, according to burrow densities and occupancies in both disturbed and undisturbed land. Richards (1997) increased the estimated available habitat for this species by 0.022 km^2, with the discovery of the species in a small strip of lesser quality habitat within its range. This increase was estimated to represent approximately 1000 individuals, and so does not significantly alter Horwitz's original estimate.

Estimates for *E. orramakunna*, *E. yabbimunna*, and *E. martigener* are more difficult, as these species cover larger areas which have not been surveyed at as fine a scale over their whole range. Rough population estimates can be made for these species by coupling the general density/occupancy estimates determined for *E. spinicaudatus* (Horwitz 1991) coupled with known locations and ranges, GIS-projections of available habitat, and degree of potential disturbance of that habitat as relating to tenure within each range. *Engaeus orramakunna* may vary from 1.38 - 4.04 x 10^6 adults, *E. yabbimunna* from 2.29 x 10^5 to 1.65 x 10^6 adults, and *E. martigener* from only 2.20 x 10^4 to 1.42 x 10^5 adults. Given good habitat, the potential size of these *Engaeus* species colonies may therefore be quite large, despite being geographically restricted.

Life History

Relatively little is known about the life history of *Engaeus* species in general and of these four species in particular. Of the four, the most detailed information is available for *E. spinicaudatus* (as below: Horwitz 1991). The life histories of the three other species (*E. orramakunna*, *E. yabbimunna*, and *E. martigener*) are likely to follow similar patterns with minor variations between species. All may be found with varying size classes of young within their burrows, and individuals may show some degree of variation in morphological features and sexual characteristics between and within sites (Horwitz 1990a, Doran & Richards 1996, Doran 1998, unpubl. data).

Threatening processes

The four species are of conservation concern due to their acutely restricted ranges and areas of occupancy, and the presence of actively threatening processes within these (Horwitz 1990b, 1991 & 1994, Gaffney & Horwitz 1992, Doran & Richards 1996, Doran 1998). Threatening processes particularly include those that affect water quality/quantity, and soil and food (wood/plant) availability.

These include:

- agricultural processes including stock grazing (which churns and compacts soil), dam construction, clearance of riparian vegetation and ploughing;
- forestry activities (eg clearing, burning, conversion to plantation) which impose significant mechanical disturbance on stream headwaters and seepage channels (to which crayfish may display varying degrees of tolerance);
- both agriculture and forestry may both have significant effects via alteration of drainage and siltation characteristics, the application and timing of fertilizers and pesticides, and hazard reduction burning;
- high intensity fires and the consequent effects on vegetation and habitat quality;
- urban impacts, via waste management policies, waterway pollution and habitat removal;
- general roading and drainage activities (urban and non-urban) impacting on seepage/wetland/stream bank habitat quality, and any activities (eg alluvial mining) that degrade river bank integrity and enhance erosion.

While all of these impacts have the potential to affect burrowing crayfish habitat quality over the long term, crayfish are at most risk from these activities at periods when they are moulting, visiting the surface, mating or nurturing young (Horwitz 1991).

THE SPECIES IN DETAIL

Engaeus orramakunna

Distribution

The Mt Arthur Burrowing Crayfish (Mt ABC), is known from a range (extent of occurrence) of approximately 300 km^2 centred on Mt Arthur in north-east Tasmania. Occupancy within this area is not known, but suitable habitat is common. The species extends to near Lilydale, Nabowla and South Springfield, and across this range borders on the distributions of *E. tayatea* , *E. nulloporius*, *E. mairener* and *E. leptorhynchus* (Doran & Richards 1996, Doran 1999, unpublished data). It is also found in the vicinity of Launceston, although the southern boundary to its distribution remains undefined. At its north-east extreme, *E. orramakunna* extends into an area of significant biological diversity and evolutionary importance for both burrowing crayfish and the Tasmanian fauna as a whole (Horwitz 1996).

Habitat

Engaeus orramakunna prefers moist seeps and flat swampy or marshy land feeding into or next to streams and rivers, but can also be found in stream banks, wet pasture, culverts, and roadside drains (Doran & Richards 1996). The species may construct burrows in both type 2 and 3 habitats (Horwitz 1990a).

Life history

Breeding for *E. orramakunna* may begin in late winter. Female *E. orramakunna* have been found carrying undifferentiated eggs in mid-June, early August, late October and early November (Horwitz 1990a, Doran & Richards 1996). On some of these occasions males have been found occupying the same burrow (Horwitz 1990a).

Threatening processes

A major proportion (41%, Table 1) of the distribution of *E. orramakunna* is in State Forest, and so is subject to extensive forestry activity (the effects of which may be minimised for *E. orramakunna* within the provisions of the Forest Practices Code). In the remainder of its range the species is also subject to heavy pressure from agricultural activity on private land (approx 52%), for which no code or guidelines are in place.

Conservation status

Engaeus orramakunna is currently listed as Vulnerable under the Tasmanian *Threatened Species Protection Act* (1995) according to guidelines from the Scientific Advisory Committee (SAC). The species has also been nominated for listing as Vulnerable under the Commonwealth *Endangered Species Protection Act* (1992) based on IUCN (1994) criteria. According to EFN-modified criteria for sessile species (as per Keith 1998), *E. orramakunna* satisfies the guidelines for Vulnerable under both State and Commonwealth Acts as:

- its linear range is less than 50km (Rule B);
- its extent of occurrence is less than 2000km^2 (Rule B);
- 90% of mature individuals occur in 10 or less populations (Criteria B1);

and
- there is a continuing decline or potential decline due to the operation of threatening processes throughout its range (Criteria B2).

Although *E. orramakunna* is likely to be the most secure of the four species covered by this recovery plan, there are insufficient data on the long term effects of the above threatening processes on the species. The species was identified as a Category 2 fauna species (requiring a combination of reservation and management prescription, with protection required in areas of high quality habitat) under the Tasmanian comprehensive regional assessment process (Tasmanian Public Land Use Commission 1997). It has ultimately been identified as a Priority Species "...requiring recovery action" under the *Tasmanian Regional Forest Agreement*

(Attachment 2, Part A.1) signed between the Commonwealth of Australia and the State of Tasmania in November 1997.

Engaeus spinicaudatus

Distribution

The Scottsdale Burrowing Crayfish (SBC), is found north of Scottsdale within an area of approximately 23 km^2, containing only 3.9 km^2 of suitable habitat (Horwitz 1991, Gaffney & Horwitz 1992, Richards 1997). The extent of this distribution has previously been well defined (Horwitz 1991), and is unlikely to be extended further. *Engaeus spinicaudatus* is closely bounded by the distributions of *E. mairener*, *E. tayatea*, and *E. leptorhynchus*. Recent discoveries also indicate that *E. orramakunna* may be found close to the southern extent of this species (Doran, unpublished data). Given the extremely restricted distribution of *E. spinicaudatus*, all of the natural habitat in which it occurs should be considered critical habitat for the future of the species (Doran & Richards 1996).

Habitat

Engaeus spinicaudatus is primarily found in wet buttongrass and heathy plains (particularly with peaty and saturated soils), but also occurs in surface seepages, the floodplains of creeks (often with scrubby or taller tea-tree vegetation), wet areas converted to pasture from any of the preceding habitat types, and some creekbanks in open dry eucalypt forest (Horwitz 1991, Richards 1997). Burrows for this species tend to be type 2 (Horwitz 1990a).

Life history

Female *E. spinicaudatus* become reproductively mature once they reach an occipital carapace length (OCL) of 16.4mm, and may undergo a pre-copulatory moult (which possibly releases mating pheromones and reduces her aggressive ability). Mating occurs between mid November and late December, and may represent the only time that male crayfish will be found openly wandering on the surface (in search of female burrows). Females carry eggs and larvae through December and January, with light orange undifferentiated eggs developing early limbs and eyespots, followed by clear development of the limbs, abdomen, telson and carapace. Female *E. spinicaudatus* have been found with free young in their burrow in March (Horwitz 1990a). While a strong linear relationship exists between body size and fecundity in *E. spinicaudatus*, no information exists regarding the rate of growth, survivorship and recruitment, age, or number and frequency of breeding events (e.g. biennial or singular) for this species.

Threatening processes

Forestry and agricultural activities also provide the main threats to *E. spinicaudatus*, alongside downstream effects of road construction, quarrying and the impacts of inappropriate fire management. Hot fires pose a direct threat to the peaty soils in which *E. spinicaudatus* is found, while the absence of fire may promote successional change and eventual drying of the buttongrass communities upon them. The acute range restriction of this species makes the identification and amelioration of such impacts a priority, particularly as none of the available habitat for the species falls within reserved areas (Table 2).

Conservation status

Engaeus spinicaudatus is currently listed as Vulnerable under the Tasmanian *Threatened Species Protection Act* (1995) according to the guidelines from the SAC. However, given the restricted distribution of the species, its negligible reservation status and continued threatening processes throughout its distribution, the species also now satisifies the criteria for Endangered based on EFN-modified criteria for sessile species (as per Keith 1998) under both State and Commonwealth (IUCN) Acts:

- its linear range is less than 20km (Rule B);
- its extent of occurrence is less than 500km^2 (Rule B);
- 90% of mature individuals occur in 5 or less populations (Criteria B1);
- there is a continuing decline or potential decline due to the operation of threatening processes throughout its range (Criteria B2);

and
- of the 90% of mature individuals in 5 or less populations, no populations are free of Class I threats (Criteria F1).

For this reason, the species has been nominated for the upgraded listing of **Endangered** under both the Tasmanian *Threatened Species Protection Act* (1995) and the Commonwealth *Endangered Species Protection Act* (1992).

Due to the acute restriction of its range and large number of directly threatening processes, *E. spinicaudatus* was identified as a Category 1 fauna species (requiring protection of *all* populations and habitat within its known range) under the Tasmanian comprehensive regional assessment process (Tasmanian Public Land Use Commission 1997). It has ultimately been identified as a Priority Species "...requiring recovery action" under the *Tasmanian Regional Forest Agreement* (Attachment 2, Part A.1) signed between the Commonwealth of Australia and the State of Tasmania in November 1997.

Engaeus yabbimunna

Distribution

The Burnie Burrowing Crayfish (BBC) is known from an overall area of approximately 130 km^2 covering Burnie and the area immediately to the west. The

species has only been known since 1992, when it was discovered by Mr Bill Walker of the Burnie City Council within Burnie Park. Originally only known from fragmented populations on Shorewell Creek, Romaine Creek and the eastern arm of Cooee Creek within urban Burnie (Horwitz 1994, Doran & Richards 1996), the recorded distribution of the species was extended when it was found in Seabrook Creek by Mr Jim Nelson in 1998. Subsequent survey work located *E. yabbimunna* along Camp Creek, Distillery Creek, two small intervening catchments and one small tributary of the Cam River (Doran 1998). Further searching has located other *Engaeus* species in surrounding areas, but no new sites for the BBC. A large gap (at least 18 km^2) separates the smaller eastern (urban) and larger western (newly discovered) populations of *E. yabbimunna*, including the lower reaches of Distillery Creek, the Cam River, Messengers Creek and Cooee Creek (including the whole of the western arm). Other *Engaeus* species bordering on or within the range of *E. yabbimunna* include *E. fossor*, *E. cisternarius*, *E. cunicularius*, and *E. disjuncticus. E. fossor* appears to dominate along the coast in these streams, and may coexist with *E. yabbimunna* where the ranges of the two species overlap (Horwitz 1994, Doran 1998).

Habitat

Engaeus yabbimunna prefers well-covered, slowly draining strips of fern-dominated native riparian vegetation. The species is known from stream banks and seepages retaining remnant riparian vegetation within Burnie (Horwitz 1994, Doran & Richards 1996), and, outside the city, in open and grassy sheep pasture, farm dams, roadside seeps and culverts, sedgey marsh, and some moderately disturbed stream sides (Doran 1998). Burrows are often of type 2.

Life history

A large male and female *E. yabbimunna* were found together in early September (Doran 1998), at a proximity almost certainly representing courtship and mating (A. Richardson, pers. comm.). Large numbers of berried female *E. yabbimunna* have been found in early December, all carrying eggs in early developmental stages (Horwitz 1994). Well developed/hatching larvae have been found under the tail of *E. fossor* (in the same region as *E. yabbimunna*) in January (Doran, unpubl. data).

Threatening processes

The greatest threats to *E. yabbimunna* are water pollution, water diversion and habitat removal within the urban environment. There is some evidence that a marked reduction in population size and distribution has occurred in response to decreasing water quality and increasing urban and industrial pollution at the centre of the species' distribution. (The abundance of other burrowing crayfish species also appears markedly reduced in the more polluted streams falling between the two distributions of the BBC). As with *E. spinicaudatus*, the reservation

status of *E. yabbimunna* is poor (Tables 1 & 2). Given the restricted amount of good quality habitat available to this species and the limited information available on its responses to disturbance, areas where agricultural and forestry activities are in progress are also of concern.

Conservation status

Engaeus yabbimunna is currently listed as Vulnerable under the Tasmanian *Threatened Species Protection Act* (1995) according to the guidelines from the SAC. The species has also been nominated for listing as Vulnerable under the Commonwealth *Endangered Species Protection Act* (1992), based on IUCN (1994) criteria. According to EFN-modified criteria for sessile species (as per Keith 1998), *E. yabbimunna* satisfies the guidelines for Vulnerable under both State and Commonwealth Acts as:

- its linear range is less than 50km (Rule B);
- its extent of occurrence is less than 2000km^2 (Rule B);
- its area of occupancy is less than 50 ha (Rule B);
- 90% of mature individuals occur in 10 or less populations (Criteria B1);
- there is a continuing decline or potential decline due to the operation of threatening processes throughout its range (Criteria B2);

and

- of the 90% of mature individuals in 10 or less populations, no populations are free of Class I threats and none are free of Class II threats (Criteria F1 & F2)

Due to its restricted range and the large number of directly threatening processes operating within that range, the species was identified as a Category 1 fauna species (requiring protection of *all* populations and habitat within its known range) under the Tasmanian comprehensive regional assessment process (Tasmanian Public Land Use Commission 1997). It has ultimately been identified as a Priority Species "... requiring recovery action" under the *Tasmanian Regional Forest Agreement* (Attachment 2, Part A.1) signed between the Commonwealth of Australia and the State of Tasmania in November 1997.

Engaeus martigener

Distribution

The Furneaux Burrowing Crayfish (FBC), has previously only been known from isolated locations at high altitude on Mt Strzelecki on Flinders Island and Mt Munro on Cape Barren Island (Horwitz 1990a & pers. comm.). Recent survey work has located the species elsewhere in the Strzelecki National Park, as well as in the Darling Range on Flinders Island (Doran, unpublished data). There is a transition from *E. martigener* to *E. cunicularius* at lower altitudes. *Engaeus martigener* is clearly of very restricted distribution, although little is known of its available habitat and numbers within these three regions.

Habitat

Engaeus martigener has previously only been known from boggy areas and small clearwater creeks in high altitude wet ferny gullies (Horwitz 1990a, Doran & Richards 1996). These areas again appear to be the stronghold of the species, although recent survey work has also located populations at lower altitudes, and in poorly drained mossy tea-tree bog and a small grassy spring/soak in open dry eucalypt forest (Doran, unpubl. data). The species occupies a type 2 burrow habitat (Horwitz 1990a).

Life history

Reproductively active, and egg or juvenile-bearing, *E. martigener* females have been found in November and December (Horwitz 1990a). Very small juveniles have been found individually within larger burrow systems in November (Horwitz 1990a), while both similar juveniles and older, free-swimming ones (dispersing in surface waters) have also been found in March (Doran unpubl. data).

Threatening processes

Although the reservation status of the species is relatively high (Tables 1 & 2), potentially catastrophic processes still threaten its status. One of the greatest potential dangers to the status of *E. martigener* is the risk of wildfire. The accumulation of high levels of fuel throughout the Strzelecki National Park, and the lack of access for fire control means that high intensity burns may pose a danger to the species in the future. Although in some areas the crayfish appear able to burrow deep enough to avoid the direct effects of disturbances such as fire, long term consequences of intense or repeated burns may be catastrophic. Problems include the exposure and loss of erosion-prone granitic soils in the region, and the loss of water retention within the remaining soils of the gullies. The flora in the upper reaches of Fotheringate Creek (type locality of *E. martigener* and containing exceptional habitat for the species) has been identified as the most

fire-sensitive, and persists as rainforest remnants largely due to the protection of the surrounding topography (Walsh 1999).

The efficacy of such protection, however, may be lost or reduced in periods of drought (e.g. Collett 1998). Similar ferny wet gullies have already been completely lost due the combination of fire and drought on Deal Island (Doran, unpubl. data), and these are unlikely to regenerate for centuries (S. Harris, pers comm.). Some level of fern die-off has already been observed under current drought conditions on Flinders Island (PWS staff, Flinders Island, pers. comm.). In contrast, frequent burning of gullies on Cape Barren Island may produce a similar effect.

Forestry and agricultural issues are currently of little relevance to *E. martigener*, although this may change depending upon future decisions regarding such activities on the island, any future extensions to the known range of the species, and changes to the status of unallocated Crown land. Feral pigs have previously been identified as a potential risk to the species; while burrow depth would again appear to protect crayfish from the direct effects of such disturbance, this is also an issue that needs to be addressed.

Conservation status

Engaeus martigener has previously been reported as Rare by the Tasmanian Invertebrate Advisory Committee (1994), and has been nominated for listing as Vulnerable under both the Tasmanian *Threatened Species Protection Act* (1995) and the Commonwealth *Endangered Species Protection Act* (1992). The species satisfies this classification based on EFN-modified criteria for sessile species (as per Keith 1998) under both Acts as:

- its linear range is less than 50km (Rule B);
- its extent of occurrence is less than 2000km^2 (Rule B);
- its area of occupancy is less than 50 ha (Rule B);
- 90% of mature individuals occur in 10 or less populations (Criteria B1);
- there is a potential continuing decline due to the operation of threatening processes within its range (Criteria B2);

and
- it occurs in 5 or less populations (Criteria D2);

Given the poor distributional data available for this species, it currently also satisfies the criteria for **Endangered** under both Acts. Further distributional work needs to be conducted to confirm that an Endangered classification is not required and that Vulnerable is more appropriate.

The species has not previously received any management attention, but due to the acute restriction of its range and the presence of potentially threatening processes (also operating within newly discovered parts of its range), it is now recognised as a species requiring recovery action. Such action can be effectively combined with the management required by the other *Engaeus* species covered in this plan.

TABLE 1:
Approximate tenure breakdown of the total distributional area (extent of occurrence) of the relevant species. Cons Res = Conservation Reserves; NC Res = Non-Conservation Reserves (including Unallocated Crown Land); Public = Other Public Land; State For = State Forest; Private = Private land.

Species	Cons Res.	NC Res.	Public	State For.	Private	Total (ha)
Mt ABC	1.29%	0.17%	5.31%	41.46%	51.77%	29, 910
SBC	0.04%	0.77%	21.78%	51.60%	25.80%	2, 286
BBC	0.01%	4.64%	0.09%	3.57%	91.69%	8, 218
FBC	unknown	unknown	unknown	unknown	unknown	unknown

TABLE 2:
Approximate tenure breakdown of estimated available habitat (potential area of occupancy) of the relevant species. Abbreviations as per Table 1.

Species	Cons Res.	NC Res.	Public	State For.	Private	Total (ha)
Mt ABC	0.98%	0.50%	6.34%	26.43%	65.75%	797
SBC	0%	0%	22.04%	39.22%	38.74%	390
BBC	0%	3.92%	0.21%	4.36%	91.51%	258
FBC	unknown	unknown	unknown	unknown	unknown	unknown

Existing Conservation Measures - all species

The conservation status and potential threatening processes for these four species were identified by Horwitz (1990b, 1994). *Engaeus spinicaudatus* has subsequently received specific attention in two studies (Horwitz 1991, Gaffney & Horwitz 1992), while background information and draft management prescriptions were compiled for all four species during the Tasmanian RFA process (Doran & Richards 1996). Follow up work has added further information on the distribution and status of *E. spinicaudatus* (Richards 1997), *E. yabbimunna* (Doran 1998), *E. orramakunna* (Doran 1999), and *E. martigener* (Doran, unpubl. data).

While *E. orramakunna* is known to occur within some large formal reserves (Doran & Richards 1996),*E. spinicaudatus* and *E. yabbimunna* are not. Similarly, although *E. martigener* is found within an existing National Park, the percentage of its distribution in formal reserves is completely unknown.

All species except *E. martigener* are currently incorporated in a notification and conservation prescription system established by the Forest Practices Board (FPB) and the Threatened Species Unit (TSU) to advise forestry operations within sensitive areas. Forestry operations in areas affecting these crayfish species have been successfully modified in consultation with landholders, forestry operators, the FPB and the TSU. Long term monitoring programs have begun on these species to provide feedback information on the effectiveness of conservation measures currently in place.

While no specific regulations govern agricultural, industrial, civic or other processes threatening these species, initiatives have been undertaken to increase awareness of them and their conservation requirements. Land owners have been contacted to make them aware of the species and to ascertain their plans and attitudes towards the land in question, and work has been undertaken towards establishing management agreements and covenants on relevant private land.

Contact has been made with representatives of relevant Councils (Burnie, Dorset) regarding specific developments and their interests and concerns in the protection of these species. Issues relating to *Engaeus martigener* have been included within the draft management plan for the Strzelecki National Park (Walsh 1999), and the presence of the species has been noted as a potential issue for the future development of unallocated Crown land on Flinders Island (Artemis Publishing Consultants 1999).

Public awareness of these species has also been raised through school and community talks and a series of magazine, press and newsletter articles at local, state and national levels. School projects conducted under permit on *Engaeus yabbimunna* have won one Burnie school a place in the University of Sydney Eureka Schools Prize for Biological Sciences, and have led to one student from this college being selected as the first ever Australian representative in the Stockholm Junior Water Prize. This student has travelled to Sweden to present a talk on this species, its habitat and threats, thereby raising awareness of *E. yabbimunna* at an international level.

Strategy for Recovery

The Recovery Plan covers a five year period. The overall aim of the plan is to manage habitat in the ranges of the relevant species, in order to:

- maintain or improve water availability (especially in seepages);
- maintain or improve water quality (against pollutants, pesticides);
- maintain or improve habitat (native riparian vegetation and soil integrity);
- exclude disruptive processes from sensitive areas (seepages/marshes/streamside areas)
- increase the reservation/protection of these species on Crown and private land
- increase public awareness and appreciation of, and involvement in, threatened species protection.

Seven primary strategies underlie the actions described in the plan. They are:

1) ASSESSMENT OF HABITAT

Before recovery actions can be effectively implemented on these species, proper assessment of their distribution and the quality of available habitat needs to be undertaken. The distribution of the relevant species needs to be determined in order to identify the quantity, quality and long term security of their available habitat. Such information will allow modelling of these species, and predictions of the level of habitat loss that can be sustained for each one according to habitat type and tenure.

Distribution mapping is nearly complete for *E. orramakunna*, *E. spinicaudatus* and *E. yabbimunna*, but has not been undertaken for *E. martigener.* Given the significant degree of high-intensity fire risk posed for this species and its habitat, it is therefore a priority that detailed survey work of the Strzelecki Park, Darling Range, the Mt Munro and Mt Kerford regions (and other likely areas) is undertaken *prior* to any significant fire event passing through these areas (Abbott 1984). Subsequent survey and census work should also be conducted in the aftermath of serious burns within these areas. Ideally, such data should be collected over a number of years pre and post-fire to ensure that valid assessments can be made (Campbell & Tanton 1981, Majer 1985, Friend 1995).

A draft management plan for the Strzelecki National Park has recently identified the protection of *E. martigener* and its habitat as a priority for the park, and identifies the collection of distributional information and addressing other data gaps as key actions of future management (Walsh 1999). It should be noted that adequate care and precautions should be taken during such work, given the access required to isolated areas, the potential to transport muddy material between these areas, and the current problems regarding cinnamon fungus disease

(*Phytophthora cinnamomi*) within and surrounding both the Strzelecki Park (Walsh 1999) and the Darling Ranges (Artemis Publishing Consultants 1999).

2) IMPROVEMENT OF RESERVATION STATUS

Engaeus spinicaudatus and *E. yabbimunna* in particular are of poor reservation status. None of the listed *Engaeus* species are recognised as receiving adequate protection by management prescription, reservation, or "existing mechanisms" (*Tasmanian Regional Forest Agreement* 1997; Attachment 2, Parts A.2 & A.3). Inter-agency discussions need to be held through this plan and other mechanisms to identify potential areas for the reservation of these species. This issue is critical for *E. spinicaudatus* and *E. yabbimunna*. Several previous recommendations have been listed increased reservation for *E. spinicaudatus* as a priority (Horwitz 1991, Gaffney & Horwitz 1992, Doran & Richards 1996), but this has not been implemented. The species now qualifies for upgrading to Endangered under both State and Commonwealth Acts in the absence of such action.

3) HABITAT MANAGEMENT -- AGRICULTURE

In consultation with landholders, it is planned to develop both general and specific voluntary guidelines for the protection of these species on agricultural land. These guidelines would be based on the prescriptions successfully developed and implemented in conjunction with the forestry industry, but would be tailored to the farm environment (as per Doran 1999). The guidelines would aim to alleviate agricultural impacts on crayfish species (through cattle trampling, dam construction, riparian clearing, and other activities) without imposing on normal farm productivity and operation. This will achieved by recruiting landholders who are interested in working with the Threatened Species Unit to develop both a general voluntary agricultural code (which could also have larger scale and more general benefits for riparian habitats as a whole) as well as specific prescriptions and rehabilitation techniques for particular situations and farms. Where possible, such guidelines will be fitted within larger scale strategies that are being devloped to manage agricultural activities, and will in turn make reference to such major developments as the Summer Rains program.

Depending upon the management and operational needs of specific farms, guidelines and rehabilitation could include the retention or re-establishment of riparian strips or habitat clumps, the relocation of sensitive species prior to the undertaking of significant works, incorporation of 'species friendly' aspects to the design of significant works, reduction of siltation characteristics and enhancement of seepages, the introduction of fencing and other limitations of cattle/livestock access to sections of creek and dam banks, and minimisation of chemical and

pesticide drift into creeks, dams and surrounding areas. As with the developing forestry prescriptions outlined above, many of these modifications to existing farm practices could, ultimately, be incorporated into such works in future with minimal inconvenience to the landholder. Other modification/rehabilitation work may have to be conducted separately or subsequent to such works. As these would potentially involve significant additional cost, they could be supported through the recovery program by targeting key catchments and properties, and by interacting with receptive landholders prepared to volunteer their land.

4) HABITAT MANAGEMENT -- FORESTRY & COMMERCIAL HARVESTING

The generic and specific guidelines developed for commercial and non-commercial forestry activities in areas containing these species need to be evaluated and refined. Depending on individual situations, these guidelines have included combinations of the following: enhanced buffer strip sizes beyond those standard for the Forest Practices Code and increased protection of native riparian vegetation; buffer sizes individually tailored to specific situations where required; re-establishment of native riparian and understorey vegetation in areas where it has previously been lost; exclusion of machinery, site preparation, plantings & pesticide/fertiliser application from identified and important pre-class 4 drainage lines; spot and subsurface pesticide/fertiliser application near sensitive seepage areas; the type of pesticide/fertiliser chosen to minimise potential harm to crayfish species, with the timing of application avoiding periods of crayfish activity and increased runoff; operations conducted with particular care regarding maintenance of water quality and availability in waterways; all landings and crossings constructed with maximum care regarding stream bank and bed damage; and disturbance avoided in any areas where burrows were visible.

Such co-operative development has so far been successful, with initial indications that *E. orramakunna* is well protected by the general provisions of the Forest Practices Code (Doran & Richards 1996). Given the large percentage of the range of this species that is subject to forestry activity, however, long term monitoring of populations in plantation and native forest areas should be established and continued pre- and post-harvest. The impacts of forestry activities on *E. spinicaudatus* and *E. yabbimunna* are less well known and also require attention. The different habitat and burrow types occupied by *E. spinicaudatus* may leave the species more prone to the effects of forestry activities (Horwitz 1991), while the restricted range of *E. yabbimunna* combined with limited availability of good quality forested habitat and the lack of records of the species in harvested areas demands that it be treated with caution until more information is available. Successful development and implementation of conservation prescriptions additional to the Forest Practices Code (as recently devised in consultation

between the Threatened Species Unit, the Forest Practices Board and private forestry concerns) also need to be encouraged and evaluated.

5) HABITAT MANAGEMENT -- URBAN & OTHER LAND MANAGERS

Urban impacts mainly affect *E. yabbimunna*, although some Council-related issues (e.g. road and drain construction, stream and river rehabilitation) also affect the other species. In addition, relevant land management issues may affect councils and regulating bodies in control of reserves and non-urban areas.

The Recovery Plan aims to both increase awareness of these species within the relevant Councils and to work with these Councils to develop appropriate management guidelines for their respective regions. These actions would specifically target the rehabilitation of streams within urban Burnie, by developing a program with the Burnie City Council to address water quality/pollution issues and promote native streamside revegetation. The value of these crayfish to the Burnie community will also be promoted: they provide a reliable indicator of water quality, with corresponding biodiversity and community benefits; they are cheaper and provide a longer-term measure of such conditions than corresponding single-point chemical tests; and they have already brought national and international recognition to the city through the award of student prizes.

6. COMMUNITY INVOLVEMENT AND EDUCATION

The interest and involvement of the community is seen as a vital component in the ongoing protection of these species. The Recovery Plan will aim to continue the increasing level of public exposure and community participation for these species. Landholders, industry, schools and community groups will all be provided with information on these species, their habitat and their relevance to environmental health. This information will highlight what can be done to improve habitat and waterway quality and will provide recognition for the successes that are achieved in conjunction with forestry, agricultural, and civic management strategies and industry (as outlined above). The benefits of protecting these species and their environment will again be promoted, while these species also present a good profile for threatened species in general: their requirements are relatively easily met, the benefits of their protection are good, and the presence of the species has no deleterious effect on production crops or other agricultural, industrial or civic considerations.

7) POPULATION AND HABITAT MONITORING

Long term monitoring will need to be conducted on these species in order to determine the efficacy of the recovery actions that are implemented. Additional and concurrent investigations into the ecology of these species will also provide further information on population structures, including survival, recruitment and dispersal rates, which can be further used to refine the recovery strategy.

The effects of fire on both *E. martigener* and *E. spinicaudatus* need to be determined, and provision for these species may need to be incorporated into fire management strategies developed by the relevant authorities (in the case of *E. martigener*, these should cover both the 'imminently-expected' high intensity natural burn and any subsequent burns).

RECOVERY TEAM

A burrowing crayfish recovery team will be established, including representatives of the Endangered Species Program of the Australian Nature Conservation Agency; the Wildlife Branch, Parks and Wildlife Service, Tasmania; the School of Zoology, University of Tasmania; the Tasmanian Conservation Trust, Forest Practices Board, and other stakeholder and community representatives as appropriate. Distributional work similar to that compiled during the Tasmanian RFA process (Doran & Richards 1996) has recently been conducted for threatened *Engaeus* species in Victoria (Van Praagh & Hinkley 1999). It would be valuable to include representatives of any subsequent Victorian recovery effort within the team, so that information and ideas on the management of these species can be readily exchanged and reworked between states.

The recovery team will guide the implementation of the recovery plan, evaluate and review progress, and will have the ability to modify actions if necessary. The team will review the effectiveness of the recovery actions on completion of this plan. It will also make recommendations as to the necessity of a new plan, and the actions to be included if one is required.

RECOVERY OBJECTIVES AND CRITERIA

The long term objective is to reduce the impact of threatening processes upon the four species, to improve their reservation status and to increase our understanding of them in order to avoid the need to upgrade their status to more critical IUCN (IUCN 1994) conservation categories.

The objectives of this recovery plan and the criteria for successfully achieving them are:

SPECIFIC OBJECTIVES	CRITERIA FOR SUCCESS	ACTIONS
Improve habitat protection for each species.	Improved security for each species through land acquisition or reservation, improved land use techniques and management agreements with landholders and forestry, agricultural and urban or public stakeholders.	1. Assessment of habitat. 2. Improvement of reservation status. 3 - 5. Habitat management with relevant groups.
Increase public awareness and involvement in threatened species protection.	Increased public awareness of these species and involvement in or willingness to be involved in conservation related programs.	6. Community involvement and education.
Ensure each species persists long-term throughout its area of occupancy.	Each species measured at selected monitoring sites indicates overall stability or long-term increase in populations or range.	7. Population and habitat monitoring, combined with the results of actions 1-6 (as above).

RECOVERY ACTIONS

The actions in this recovery plan are based on the current knowledge of the biology and ecology of these burrowing crayfish species. Management requirements have been based on the recommendations of Doran & Richards (1996), augmented with subsequent work in support of the current plan. Actions will need to be reassessed as knowledge improves.

1) ASSESSMENT OF HABITAT

1.1 Assessment of habitat for *E. martigener*

PRIORITY 1 **Proposed timeframe: year 1**

Recovery and management actions for *E. martigener* can only be effectively established once the range and abundance of the species, and the quality and quantity of habitat in which it is found, are determined.

Survey costings need to include:

A • salary component for the Scientific Officer, incl. on costs *etc*., for 2.5 months to undertake field surveys and mapping on Flinders Island and Cape Barren Island;

B • salary for a Technical Assistant for 2.5 months, particularly for Occupational Health & Safety (OHS) reasons in remote areas;

C • additional field assistance (volunteers and District support);

D • air travel to and from both Flinders Island and the Mt Munro region of Cape Barren Island (allowing for 50 days field work broken into three periods);

E • sea transport to and from the Mt Kerford region of Cape Barren Island, as well as other likely locations in the region;

F • base accommodation and food allowance for two people for periods spent on Flinders Island (35 days);

G • camp allowance for two people for periods spent on Cape Barren Island (15 days);

H • car hire costs & mileage for periods spent on Flinders Island;

I • wash-down kits and related equipment to avoid the transportation of phytophthora into uncontaminated areas;

J • miscellaneous equipment and supplies;

Cost estimates: ($000s/yr)

	Year 1
A	12.5
B	6.5
C	8.2
D	2.5
E	2.8
F	8.4
G	0.9
H	2.0
I	0.5

J	1.0
TOTAL	**45.3**

1.2 Assessment of habitat for *E. orramakunna*, *E. spinicaudatus* and *E. yabbimunna*

PRIORITY 2 **Proposed timeframe: year 1**

A short period of survey work is required to finalise a management overview of the distribution and habitat types occupied by the remaining three species, and to determine the degree of management or protection required for these habitat components. In particular, this work will focus on the north-east corner and southern extremes of *E. orramakunna* (where the species is exposed to increasing agricultural, forestry and potentially urban development), and the distribution of *E. yabbimunna* around the Cam River catchment (a major catchment subjected to heavy industrial and urban development in its lower waters, and increasing forestry activity in its upper waters).

Survey costings need to include:

A • salary component for the Scientific Officer, incl. on costs, *etc.* for 1 month to undertake field work and mapping;

B • salary for a Technical Assistant for 1 month for OHS reasons;

C • vehicle hire & mileage (4WD);

D • accommodation and food allowances for two people;

E • miscellaneous field equipment/consumables.

Cost estimates: ($000s/yr)

	Year 1
A	5.0
B	2.6
C	1.4
D	4.8
E	0.6
TOTAL	**14.4**

2) IMPROVEMENT OF RESERVATION STATUS

PRIORITY 1 **Proposed timeframe: years 1-3**

It will be important to prioritize specific Crown, public and private land and general areas within the relevant catchments for both formal and informal reservation. These actions are particularly important for *E. spinicaudatus* and *E. yabbimunna*, for which reservation status is poor.

Costings need to include:

A • salary component for the Scientific Officer, incl. on costs, *etc.* for one month in year 1 and for 0.5 months in years 2 and 3, in order to assess and negotiate over priority areas of Crown land;
B • vehicle hire & mileage;
C • accommodation and food allowances;
D • miscellaneous field equipment/consumables;
E • funds covering purchase, inducement, covenant, consideration or compensation for the land involved (including in-kind support);
F • funds covering negotiations and contracts for the above;
G • funds for the fencing and signposting of land (including sections of private land under informal management agreement);
H • funds for ongoing management of procured land or its transfer to other agencies.

Cost estimates: ($000s/yr)

	Year 1	Year 2	Year 3	TOTAL
A	5.0	2.5	2.5	**10.0**
B	1.0	0.5	0.5	**2.0**
C	1.3	0.7	0.7	**2.7**
D	0.3	0.2	0.2	**0.7**
E	40.0	60.0	60.0	**160.0**
F	10.0	5.0	5.0	**20.0**
G	10.0	5.0	5.0	**20.0**
H	0	6.0	6.0	**12.0**
TOTAL	**67.6**	**79.9**	**79.9**	**227.4**

3) HABITAT MANAGEMENT -- AGRICULTURE

PRIORITY 1 **Proposed timeframe: years 1-3**

An impact assessment of existing agricultural activities will be conducted throughout the range of each species. Based upon this, a voluntary or more formal code of conduct will be developed in consultation with affected land holders and interest groups for the long term management of these species. Where possible, this will be integrated within agreed broader-scale strategies, including the management of farm dam proposals and the Summer Rains program. Part of this action will involve trialling modified agricultural practices (eg partial rehabilitation of selected stream and dam sides) to determine how effectively they will continue to meet farm operational requirements while improving habitat quality for the crayfish and related fauna. This will include ongoing monitoring and assessment of such sites.

Costings need to include:

A • salary component for the Scientific Officer, incl. on costs, *etc.* for 1.5 months in year 1 and three months each in years 2 and 3, in order to discuss, develop and implement appropriate conservation strategies with affected agricultural stakeholders;

B • vehicle hire & mileage;

C • periodic accommodation and food allowances;

D • miscellaneous field equipment/consumables;

E • other supplies;

F • inducements for landholders (eg fencing, as per (2));

G • funding for rehabilitation works and trials.

Cost estimates: ($000s/yr)

Note: these costings do not incorporate volunteer/community time.

	Year 1	**Year 2**	**Year 3**	**TOTAL**
A	7.5	15.0	15.0	**37.5**
B	1.5	3.0	3.0	**7.5**
C	2.0	4.0	4.0	**10.0**
D	0.5	0.9	0.9	**2.3**
E	0.2	0.4	0.4	**1.0**
F	0	3.3	3.3	**6.6**
G	0	15.0	15.0	**30.0**
TOTAL	**11.7**	**41.6**	**41.6**	**94.9**

4) HABITAT MANAGEMENT -- FORESTRY & COMMERCIAL HARVESTING

PRIORITY 1 **Proposed timeframe: years 1-3**

Impact assessment of existing commercial and non-commercial forestry works will be conducted throughout the range of each species. Based upon this, a management agreement will be developed with Forestry Tasmania and private landholders for the long term management of these species. Where possible, this will be integrated within agreed broader scale operational management strategies, including ongoing monitoring of long term survey sites.

Costings need to include:

A • salary component for the Scientific Officer, incl. on costs, *etc.* for 1.5 months in year 1 and three months each in years 2 and 3, in order to discuss, develop and implement appropriate conservation strategies with affected forestry stakeholders;

B • vehicle hire & mileage;

C • periodic accommodation and food allowances;

D • miscellaneous field equipment/consumables;

E • other supplies.

Cost estimates: ($000s/yr)

Most cost in long term monitoring (Action 7); habitat management costs should be negligible as these can be implemented through existing FPB/TSU mechanisms and through the education and monitoring protocols below

	Year 1	**Year 2**	**Year 3**	**TOTAL**
A	7.5	15.0	15.0	**37.5**
B	1.5	3.0	3.0	**7.5**
C	2.0	4.0	4.0	**10.0**
D	0.5	0.9	0.9	**2.3**
E	0.3	0.5	0.5	**1.3**
TOTAL	**11.8**	**23.4**	**23.4**	**58.6**

5) HABITAT MANAGEMENT -- URBAN & OTHER LAND MANAGERS

PRIORITY 1 **Proposed timeframe: years 1-3**

An impact assessment of habitat change due to urban zoning and development will be conducted, specifically focussing on *E. yabbimunna*. Methods will then be suggested for alleviating these changes and associated pressures, ranging from small scale alterations to stream bank characteristics to larger scale programs addressing streamside revegetation and water quality. Part of this work will involve community involvement and education, as below (6). Actions will also target other landmanagers (e.g. councils that manage reserves, Croiwn land and other areas).

Costings need to include:

A • salary component for the Scientific Officer, incl. on costs, *etc.* for 1.5 months in year 1 and three months each in years 2 and 3, in order to discuss, develop and implement appropriate conservation strategies with affected urban stakeholders and other relevant landmanagers;

B • vehicle hire & mileage;

C • accommodation and food allowances;

D • miscellaneous field equipment/consumables;

E • other supplies;

F • funding for revegetation and rehabilitation works and trials;

G • funds for community group support (see 6).

Cost estimates: ($000s/yr)

Note: these costings do not incorporate volunteer/community time.

	Year 1	Year 2	Year 3	TOTAL
A	7.5	15.0	15.0	**37.5**
B	1.5	3.0	3.0	**7.5**
C	2.0	4.0	4.0	**10.0**
D	0.4	0.9	0.9	**2.2**
E	0.3	0.5	0.5	**1.3**
F	2.2	15.0	15.0	**32.2**
G	2.2	2.2	2.2	**6.6**
TOTAL	**16.1**	**40.6**	**40.6**	**97.3**

6) COMMUNITY INVOLVEMENT AND EDUCATION
PRIORITY 1 **Proposed timeframe: years 1-5**

Community involvement in the recovery process will be promoted by making information on these species and their habitat requirements as accessible as possible, and by actively promoting the participation of community groups and individuals in the protection of these species and waterways in general. This action will aim to make use of existing information pathways and infrastructures where possible, as well developing new outlets and contacts where required. Improved interpretation has been highlighted as a priority for the Strzelecki National Park (Walsh 1999). (Community involvement will also be incorporated under Actions 3 and 5).

Costings need to include:

A • salary component for the Scientific Officer, incl. on costs, *etc.* for one month per year for the first three years and half a month per year for years 4 and 5;
B • vehicle hire & mileage;
C • periodic accommodation and food allowances;
D • miscellaneous equipment/consumables;
E • other supplies;
F • funding for rehabilitation works and trials (see 5);
G • funds for volunteer and community group support;
H • funding for leaflet production and distribution;
I • funding for slides, overheads, posters and other educational aids;
J • funding for interpretation boards and costs;
K • preparation of a media strategy.

Cost estimates: ($000s/yr)

Note: these costings do not incorporate volunteer/community time.

	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
A	5.0	5.0	5.0	2.5	2.5	**20.0**
B	1.0	1.0	1.0	0.5	0.5	**4.0**
C	2.7	2.7	2.7	1.35	1.35	**10.8**
D	0.1	0.1	0.1	0.05	0.05	**0.4**
E	0.2	0.2	0.2	0.1	0.1	**0.8**
F	1.1	1.1	1.1	0.55	0.55	**4.4**
G	1.1	1.1	1.1	0.55	0.55	**4.4**
H	0.6	0.6	0.6	0.6	0.6	**3.0**
I	0.3	0.3	0.3	0.15	0.15	**1.2**
J	0.6	0.6	0.6	0	0	**1.8**
K	0.6	0.6	0.6	0	0	**1.8**

TOTAL	**13.3**	**13.3**	**13.3**	**6.35**	**6.35**	**52.6**

7) POPULATION AND HABITAT MONITORING
PRIORITY 1 **Proposed timeframe: years 1-5**

In support of the actions outlined in (3), (4) and (5), established long term monitoring sites for *E. orramakunna, E. spinicaudatus*, and *E. yabbimunna* will continue to be sampled to provide base line information on the responses of the species to threatening processes and varying levels of protection or remedial action over time. Continued monitoring of these sites will require relatively little input in terms of resources or time.

The identification of long term monitoring sites for *E. martigener* needs to wait until the range of the species is determined and types of available sites is known (as per 1.1 above). Given the cost of reaching field sites on Flinders Island, it is possible that any monitoring may be undertaken by field staff on the island, or that monitoring can be incorporated within future faunal considerations highlighted in the draft management plan for the park (Walsh 1999). One of the objectives of the Strzelecki National Park plan is to "*protect, maintain and monitor threatened fauna species, in particular the swift parrot, burrowing crayfish, and New Holland mouse... to protect maintain and monitor the diversity of indigenous fauna and habitat...[and] to minimise harmful impacts on indigenous fauna and habitats*". Other relevant aspects of the Strzelecki National Park management plan include policies for the control of wildfire and feral pigs.

Costings need to include:

A • salary component for the Scientific Officer, incl. on costs *etc.*, for one month per year for the five year duration of the recovery plan;

B • field assistance (volunteers, District and Forest Practices Board support);

C • vehicle hire & mileage;

D • accommodation and food allowances for two people;

E • miscellaneous equipment/consumables;

F • ongoing monitoring within the Strzelecki National Park and/or provision for post-fire survey(s) of sites identified as key areas for the survival of *E. martigener* and fire (and other) management meetings between the relevant authorities. $300 per day in-kind district support.

Cost estimates: ($000s/yr)

	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
A	5.0	5.0	5.0	5.0	5.0	**25.0**
B	8.8	8.8	8.8	8.8	8.8	**44.0**
C	1.0	1.0	1.0	1.0	1.0	**5.0**
D	5.3	5.3	5.3	5.3	5.3	**26.5**
E	0.3	0.3	0.3	0.3	0.3	**1.5**
F	0	3.0	3.0	3.0	3.0	**12.0**
TOTAL	**20.4**	**23.4**	**23.4**	**23.4**	**23.4**	**114.0**

8) ORGANISATIONAL SUPPORT

PRIORITY 1 **Proposed timeframe: years 1-5**

8.1 Burrowing Crayfish Recovery Officer

A Scientific Officer will be appointed to coordinate implementation of the Recovery Plan. The Scientific Officer will be required to liaise with government agencies, farming organisations, the forest industry, community groups, study organisations and academic institutions. The Scientific Officer will carry out some of the actions in the plan, coordinate the implementation of all actions and report to the recovery team. The salary component and on-costs of the Scientific Officer have been incorporated into the above actions on a pro-rata basis. For this action, Scientific Officer costs relate to time budgeted for meeting with and producing reports for the Recovery Team.

Costings need to include:

A • Scientific Officer salary, including on-costs, *etc.* to cover (in conjunction with action 8.2) one month in the first year and 0.5 months for the ensuing years;
B • Report production costs;
C • Office accomodation
D • Office support
E • Admin assistance
F • Information technology support
G • GIS services
H • Recruitment costs

Cost estimates: ($000s/yr)

Cost to be determined following discussion - see rough estimates

	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
A	5.0	2.5	2.5	2.5	2.5	**15.0**
B	0.8	0.8	0.8	0.8	0.8	**4.0**
C	2.7	2.7	2.7	0.5	0.5	**9.1**
D	13.7	13.7	13.7	2.3	2.3	**45.7**
E	6.3	6.3	6.3	1.1	1.1	**21.1**
F	5.0	5.0	5.0	0.8	0.8	**16.6**
G	6.0	3.0	3.0	-	-	**12.0**
H	2.1	-	-	-	-	**2.1**
TOTAL	**41.6**	**34.0**	**34.0**	**8.0**	**8.0**	**125.6**

8.2 Recovery team

Government agencies will meet any costs associated with attendance of their representatives at recovery team meetings. In cases where NGO representatives are required to attend a meeting, their travel expenses and other valid costs will be reimbursed from the Recovery Plan budget.

Costings need to include:
A • Funds for the attendance of NGO representatives at recovery meetings.

	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
A	0.4	0.4	0.4	0.4	0.4	2.0

IMPLEMENTATION SCHEDULE

It is recommended that a Scientific Officer is employed for 3 years full-time to implement the key actions of this recovery plan. The Scientific Officer will conduct the required surveys, liaise with interest groups and establish both the described programs and the means of their ecological evaluation according to priorities determined by the recovery team.

For the subsequent two years of the recovery period outlined in this plan, it is envisaged that a Scientific Officer would only be contracted on a sporadic basis to check on the status quo of the species and these programs, and to evaluate their effectiveness. The Scientific Officer would ensure that recovery actions are proceeding as planned, that management agreements are being maintained, that community groups are receiving adequate support and that long term monitoring is continued.

Table 3: Approximate breakdown of time (months/year) allocated for each action, as incorporated in the above costings.

Action	2001	2002	2003	2004	2005
1.1	2.5	--	--	--	--
1.2	1	--	--	--	--
2	1	0.5	0.5	--	--
3	1.5	3	3	--	--
4	1.5	3	3	--	--
5	1.5	3	3	--	--
6	1	1	1	0.5	0.5
7	1	1	1	1	1
8.1+8.2	1	0.5	0.5	0.5	0.5
TOTAL	**12**	**12**	**12**	**2**	**2**

Table 4: Breakdown of costs associated with above schedule.

Action	Priority	Feasibil.		Cost	Est.	$000		
			year 1	year 2	year 3	year 4	year 5	Total
1.1	1	100%	45.3	--	--	--	--	**45.3**
1.2	2	100%	14.4	--	--	--	--	**14.4**
2	1	100%	67.6	79.9	79.9	--	--	**227.4**
3	1	100%	11.7	41.6	41.6	--	--	**94.9**
4	1	100%	11.8	23.4	23.4	--	--	**58.6**
5	1	100%	16.1	40.6	40.6	--	--	**97.3**
6	1	100%	13.3	13.3	13.3	6.35	6.35	**52.6**
7	1	100%	20.4	23.4	23.4	23.4	23.4	**114.0**
8.1	1	100%	41.6	34.0	34.0	8.0	8.0	**125.6**
8.2	1	100%	0.4	0.4	0.4	0.4	0.4	**2.0**
		Total	**242.6**	**256.6**	**256.6**	**38.15**	**38.15**	**832.10**

REFERENCES

Abbott, I. 1984. Changes in the abundance and activity of certain soil and litter fauna in the Jarrah Forest of Western Australia after a moderate intensity fire. *Aust. J. Soil. Res.* **22**: 463-469.

Artemis Publishing Consultants. 1999. *Inquiry into unallocated Crown land on Flinders Island, Tasmania.* Background Report to the Resource Planning & Development Commission, Tasmania.

Campbell, A.J. & Tanton, M.T. 1981. Effects of fire on the invertebrate fauna of soil and litter of a eucalypt forest. In: Gill, A.M., Gloves, R.H. & Noble, I.R. (Eds). *Fire and the Australian Biota* . Australian Academy of Science, Canberra. Pp 215-241.

Collett, N.G. 1998. Effects of two short rotation prescribed fires in autumn on surface-active arthropods in dry sclerophyll eucalypt forest of west-central Victoria. *Forest Ecology and Management* **107**: 253-273.

Doran, N.E. 1998. The Burnie Burrowing Crayfish, *Engaeus yabbimunna*: assessment of the Seabrook Creek catchment for the CAR Private Reserve System. Report to the RFA Private Land Reserve Program, Department of Primary Industry, Water & the Environment.

Doran, N.E. 1999. Survey of the burrowing crayfish at a proposed dam site for Forester River Farms Pty Ltd, with recommendations for managing the development. Report on behalf of the Threatened Species Unit, Parks & Widlife Service.

Doran, N.E. & Richards, K. 1996. Management requirements for rare and threatened burrowing crayfish in Tasmania. Report to the Tasmanian RFA Environment and Heritage Technical Committee.

Friend, G.R. 1995. Fire and invertebrates - a review of research methodology and the predictability of post-fire response patterns. *CALM Science Supplement* **4**: 165-174.

Gaffney, R.F. and Horwitz, P. (1992). The Scottsdale Burrowing Crayfish Recovery Plan: Management Phase. Endangered Species Program, Project Number 240, Tasmanian Parks and Wildlife Service.

Horwitz, P. 1986. The systematics and zoogeography of the freshwater crayfish genus *Engaeus* Erichson (Decapoda: Parastacidae). Unpublished Ph.D. thesis, Zoology Department, University of Tasmania, Hobart.

Horwitz, P. 1988a. A key to genera of Tasmanian freshwater crayfish. *The Tasmanian Naturalist* **94**: 1-3.

Horwitz, P. 1988b. Sea-level fluctuations and the distributions of some freshwater crayfishes of the genus *Engaeus* (Decapoda; Parastacidae) in the Bass Strait Area. *Australian Journal of Marine and Freshwater Research* **39**: 497-502.

Horwitz, P. 1990a. A taxonomic revision of species in the freshwater crayfish genus *Engaeus* Erichson (Decapoda: Parastacidae). *Invertebrate Taxonomy* **4**: 427-614.

Horwitz, P. 1990b. *The Conservation Status of Australian Freshwater Crustacea (with a provisional list of threatened species, habitats and potentially threatening processes)*. Report Series No. 14, Australian National Parks and Wildlife Service, Canberra.

Horwitz, P. 1991. The conservation biology of *Engaeus spinicaudatus*, a threatened crayfish from north-eastern Tasmania. Report to the Australian National Parks and Wildlife Service, Canberra.

Horwitz, P. 1994. A new species of the freshwater crayfish genus *Engaeus* Erichson (Decapoda: Parastacidae) from north-western Tasmania. *Memoirs of the Museum of Victoria* **54**: 439-445.

Horwitz, P. 1996. Biogeographical affinities of macrocrustacean groups in northeast Tasmania. *Records of the Queen Victoria Museum* **103**: 171-177.

Horwitz, P. & Richardson, A. M. M. 1986. An ecological classification of the burrows of Australian freshwater crayfish. *Australian Journal of Marine and Freshwater Research* **37**: 237-42.

Horwitz, P., Richardson, A.M.M. & Boulton, A. 1985. The burrow habitat of two sympatric species of land crayfish, Engaeus urostrictus and E. tuberculatus (Decapoda: Parastacidae). *Victorian Naturalist* **102**: 188-197.

Invertebrate Advisory Committee. 1994. Interim List of Native Invertebrates which are Rare or Threatened in Tasmania. *Species at Risk, Tasmania - Invertebrates.* Parks and Wildlife Service, Tasmania.

IUCN Species Survival Commission. 1994. *IUCN Red List Categories.* World Conservation Union, IUCN Species Survival Commission, Kew, United Kingdom.

Keith, D.A. 1998. An evaluation and modification of World Conservation Union Red List Criteria for classification of extinction risk in vascular plants. *Conservation Biology* **12**: 1076-1090.

Majer, J.D. 1985. Fire effects on invertebrate fauna of forest and woodland. In: Ford, J.R. (Ed.). *Symposium on Fire Ecology and Management in Western Australian Ecosystems*.

Richards, K. 1997. The distribution of *Engaeus spinicaudatus* along Ruby Creek and China Creek, Scottsdale. Report to the Threatened Species Unit, Parks and Wildlife Service and the Forest Practices Unit, Hobart.

Richardson, A.M.M. and Horwitz, P.H.J. 1987. Habitat partitioning by Australian burrowing crayfish. In *Freshwater Crayfish Volume VII. Papers from the Seventh International Symposium of Astacology* (International Association of Astacology). pp. 91-97.

Suter, P. J. and Richardson, A. M. M. 1977. The biology of two species of Engaeus (Decapoda: Parastacidae) in Tasmania III: habitat, food, associated fauna and distribution. *Australian Journal of Marine and Freshwater Research* **28**: 95-103.

Tasmanian Public Land Use Commission. 1997. *Tasmania-Commonwealth Regional Forest Agreement: Supplement to Environment & Heritage Report Vol VI. Processes and guidelines for determining the conservation requirements for priority flora and fauna species in the Tasmanian comprehensive regional assessment.*

Van Praagh, B. & Hinkley, S. 1999. Distribution of four species of burrowing crayfish, the Warragul Burrowing Crayfish, *Engaeus sternalis* Clark; the Narracan Burrowing Crayfish, *E. phyllocercus* Smith & Schuster; the Strzelecki Burrowing Crayfish, *E. rostrogaleatus* Horwitz; and the Lilly Pilly Burrowing Crayfish, *E. australis* Riek; in the Gippsland Regional Forest Agreement Area. A Museum of Victoria Invertebarte Survey Report to the Department of Natural Resources & Environment.

Walsh, N. 1999. *Strzelecki National Park and Wingaroo Nature Reserve Draft Management Plan.* Tasmanian Parks and Wildlife Service.