Distribution, habitat and conservation status of the freshwater crayfishes, *Euastacus dalagarbe*, *E. girurmulayn*, *E. guruhgi*, *E. jagabar* and *E. mirangudjin*

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ABSTRACT

This paper examines the distribution, habitat and conservation status of five species of the freshwater crayfish genus *Euastacus* from eastern Australia: *E. dalagarbe, E. girurmulayn, E. guruhgi, E. jagabar* and *E. mirangudjin*. Although the five species have discrete distributions, they have similar habitat requirements, occurring only at highland (310-960 m) sites in the Central Eastern Rainforest Reserves of Australia. They all occur in minor or peripheral habitats (i.e. small tributaries, damp gullies and wet soaks) and are sympatric with the much larger species, *E. sulcatus*. On the basis of their restricted ranges, *E. girurmulayn*, *E. guruhgi*, *E. jagabar* and *E. mirangudjin* satisfy the IUCN criteria for listing as 'Vulnerable' (VU D2). *Euastacus dalagarbe* is close to qualifying for listing as vulnerable, and can be considered as 'Near Threatened'. Potential threats for these species are discussed.

Key words: Anthropogenic climate change, cane toads, conservation, crayfishes, highland, hydrology, IUCN, New South Wales.

Introduction

Despite the lack of published biological information on most Australian freshwater crayfishes (Merrick 1993, 1995), it has become apparent in recent years that many species are, or may be, threatened. In a revision of the conservation status of Australian crayfishes, Horwitz (1995) recognized 33 taxa as being of concern. Thirty-six species (approximately one third of the Australian crayfish fauna) are currently listed on the International Union for the Conservation for Nature and Natural Resources (IUCN) Red List of Threatened Species (IUCN 2004). Twenty-two of these are currently listed under relevant State legislation, six of which are also listed under the Commonwealth *Environment Protection and Biodiversity Act 1999*. Although concerns have been identified for over half of the 35 species that occur in New South Wales (Merrick 1993, 1995; Morgan 1997), however, a lack of information pertaining to their distribution and biology has apparently hampered formal assessment of conservation status for these species. Consequently, none of these crayfishes are listed under State or Federal legislation.

This paper examines the distribution, habitat and conservation status of five crayfishes from northeastern New South Wales: *Euastacus dalagarbe*, *E. girurmulayn*, *E. guruhgi*, *E. jagabar* and *E. mirangudjin*. Because these species were only recently described, historical data are not available for assessment of their conservation status. Since their description, however, a thorough field sampling program has been completed in the region (Coughran 2006), and the available data on their distribution and habitat is now sufficient to provide an assessment of their conservation status. The five species are similar in these respects, and are appropriately assessed together here. Implications for their future conservation and management are discussed.

Methods

The data presented herein constitute a subset arising from a broader sampling program across the northeastern New South Wales region (Coughran 2006). During the research program, 245 sites were sampled between May 2001 and September 2004. Crayfish were collected from watercourses and areas of land adjacent to them (up to 20m away). A range of sampling techniques was used, depending on the size and nature of the watercourse involved. These techniques included trapping, dip netting, observation surveys (diurnal and nocturnal) and lifting rocks or excavating burrows to capture crayfish by hand.

Basic information on crayfish habitat was recorded at all sites sampled, and included in-stream vegetation, watercourse size and nature, water quality (pH, conductivity, dissolved oxygen, temperature), substratum, in-stream habitat, riparian vegetation, surrounding land-use, time and weather (cloud cover, rainfall and air temperature). The National Parks and Wildlife Service Frog Hygiene Protocol (NSW National Parks and Wildlife Service 2001) was followed throughout the research program. Where possible, geographic coordinates were recorded with a Gamin

Venturer hand-held GPS. Owing to poor satellite reception at some sites, the coordinates were estimated from 1:25000 topographic maps. Site elevations were determined from 1:25000 topographic maps, and the mapped geology according to the 1:250000 geological map series was also noted for each site. The distribution and habitat data were incorporated into a taxonomic assessment of the regional fauna. The taxonomic assessment followed established methods (e.g. Morgan 1986, 1988, 1997; Austin and Knott 1996; Sokol 1988), discussed more fully elsewhere (Coughran 2005a, b, 2006).

The GPS co-ordinates for all sites of record were used to construct minimum distribution polygons for each species. The area of each species' minimum distribution polygon thus provides an estimate of its extent of occurrence, enabling an assessment of its conservation status according to the IUCN criteria (IUCN 2001).

Results

Distribution and Habitat

The distributions of the five species are presented in Table 1 and Figure 1. All species were restricted to highland sites in the Central Eastern Rainforest Reserves of Australia. The species inhabited minor and peripheral habitats, including damp gullies, wet soaks, minor tributaries and headwater streams. At many sites, surface water was negligible or absent. Although animals can be captured in shallow excavations under surface rocks, they were also recorded in complex burrow networks that wind their way around and down through the underlying rocks and tree roots. These species are small crayfishes (<40 mm OCL) that exhibit a subterranean habit, and only two individuals (one *Euastacus mirangudjin*, one *E. girurmulayn*) were observed out of a burrow during the entire sampling program. All sites have closed forest cover, and all occur within National Parks and State Conservation Areas. The distributions of all species fall within the Border Ranges Biodiversity Hotspot, the most biologically diverse area in New South Wales (Department of Environment and Water Resources 2006).

Discussion

Conservation Status

The known range of the five species is well below 100 km^2, therefore partly satisfying the requirements for listing as 'Critically Endangered' under criterion B of the IUCN guidelines. The absence of similar historical data, however, preclude observations of population dynamics or fluctuation in habitat or distribution, and therefore this criterion cannot be fully satisfied at present. Nevertheless, the distributions for all but *Euastacus dalagarbe* are sufficiently small to numerically satisfy criterion D for listing as threatened.

Euastacus girurmulayn was recorded at three sites and had a restricted extent of occurrence (6.5 km^2). It was not recorded at any of 76 other highland (>200m) sites in similar habitat (i.e. rainforest). The species can thus be classified as 'Vulnerable' under criterion D, giving it a classification of VU D2.

Euastacus guruhgi was recorded at four sites and had a restricted extent of occurrence (7.5 km^2). It was not recorded at any of 75 other highland (>200m) sites in similar habitat (i.e. rainforest). The species can thus be classified as 'Vulnerable' under criterion D, giving it a classification of VU D2.

Euastacus jagabar was recorded at four sites and had a restricted extent of occurrence (2.5 km^2). It was not recorded at any of 75 other highland (>200m) sites in similar habitat (i.e. rainforest). The species can thus be classified as 'Vulnerable' under criterion D, giving it a classification of VU D2.

Table 1. Distribution and habitat of the five species, *Euastacus dalagarbe, E. girurmulayn, E. guruhgi, E. jagabar* and *E. mirangudjin.* The species are restricted to highland sites, known only from the National Parks (NP) and State Conservation Areas (SCA) they are listed under.

Species	Sites of record	Extent of occurrence (km^2)	Area
Euastacus dalagarbe	8	48.5	Border Ranges NP
Euastacus girurmulayn	3	6.5	Nightcap NP, Whian Whian SCA
Euastacus guruhgi	4	7.5	Mt Warning NP, Wollumbin NP
Euastacus jagabar	4	2.5	Border Ranges NP
Euastacus mirangudjin	5	42.5	Toonumbar NP

Table 2. Water quality parameters recorded for water bodies inhabited by the five species, *Euastacus dalagarbe, E. girurmulayn, E. guruhgi, E. jagabar* and *E. mirangudjin.* The ranges given are those ascertained by field monitoring. Note that parameters were not recorded at sites where surface water was absent or generally absent, and that there were such sites for all species.

Species	pH	Water temperature (°C)	Dissolved oxygen (mg/L) (minimum)	Conductivity (µs/cm)
E. dalagarbe	6.82-7.99	10-21	9.6	55-292
E. girurmulayn	7.09-7.20	12.3-17.5	8.0	64-71
E. guruhgi	7.41	20.5	n/a	161
E. jagabar	7.49-7.85	13-23	8.88	88-349
E. mirangudjin	6.08-8.04	7-24	6.08	51-232

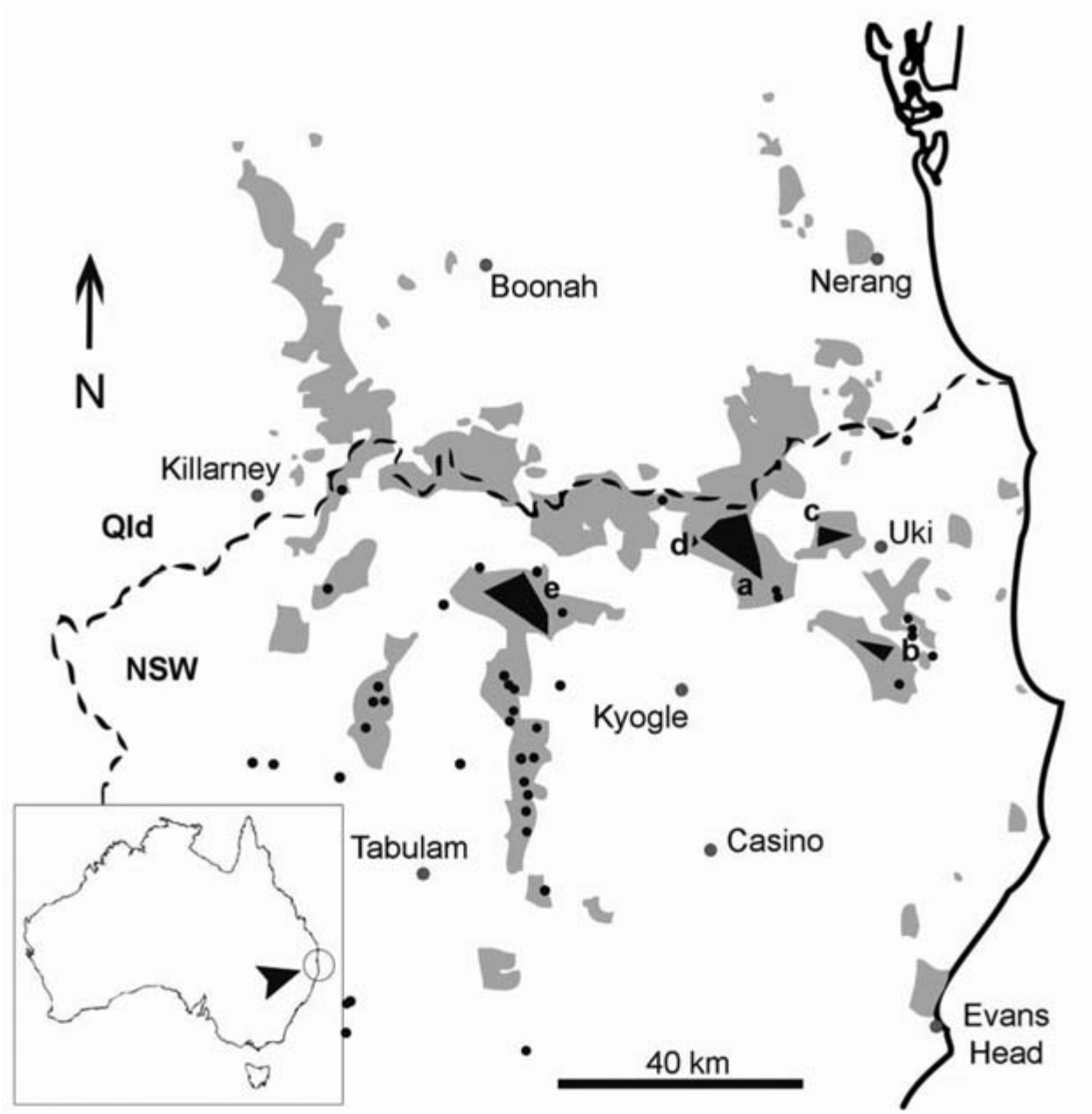

Figure 1. Distributions for the five freshwater crayfish species, presented as minimum distribution polygons (black). The letter beside each distribution polygon denotes the species: a, *Euastacus dalagarbe; b, E. girurmulayn; c, E. guruhgi; d, E. jagabar;* and e, *E. mirangudjin.* The black circles outside the polygons represent sites in apparently suitable habitat (>200 m, rainforest) at which these species were not recorded. The overall area falls within the Border Ranges Biodiversity Hotspot (DEWR 2006). Regional National Park reserves are depicted with grey shading.

Euastacus mirangudjin was recorded at five sites and had a restricted extent of occurrence (42.5 km^2). The species was not recorded at any of 74 other highland (>200m) sites in similar habitat (i.e. rainforest), and can thus be classified as 'Vulnerable' under criterion D, giving it a classification of VU D2.

Although the area of occupancy is uncertain for all these species, it is by definition smaller than the extent of occurrence, being a quantified measure that falls within the overall extent of occurrence (IUCN 2001). As such, *Euastacus girurmulayn*, *E. guruhgi* and *E. jagabar* satisfy criterion D in terms of both the number of sites of record (five or fewer) and the distribution size (area of occupancy < 20 km^2). Although *E. mirangudjin* has an extent of occurrence of 42.5 km^2, the actual area of occupancy may still fall within the allowed range under this criterion. Regardless, the species satisfies this criterion on the basis of the number of sites of record (five sites). Conversely, although its actual area of occupancy may fall within the allowed range, *E. dalagarbe* does not presently satisfy this criterion on either its distribution (extent of occurrence = 48.5 km^2) or the number of sites of record (eight). Further research into the habitat requirements of all these crayfishes, particularly regarding their relationship to surface and groundwater hydrology, will facilitate the assessment of their area of occupancy, and may thus clarify the conservation status of *E. dalagarbe*. An increased understanding of their relationship to hydrology may also facilitate detection of these species in future surveys, and allow for density estimates to be made.

Threats

The IUCN guidelines imply that a species does not satisfy criterion D2 on the basis of restricted range alone, but on the premise that it is threatened because of its restricted distribution (IUCN 2000). As such, in addition to considering their restricted distributions from a numerical perspective, potential threats to these crayfishes are discussed below, according to the four threat categories for invertebrates identified by Wells *et al*. (1983).

Habitat Destruction (and Habitat Loss). Because all species occur within National Parks, they receive indirect protection from habitat destruction. Protected areas, however, are not exempt from anthropogenic influences. The endemicity and vulnerability of these five species increases the conservation significance of the parks in which they occur. It is conceivable that these species may also extend beyond the current boundaries of these protected areas, to sites in suitable habitat on nearby public and private land. In such areas, targeted surveys for these species should be undertaken prior to any development that will result in the loss or degradation of suitable habitat. Many authors have suggested that a need for cool temperatures is a major factor influencing the distribution of highland species of *Euastacus* (e.g. Riek 1959, 1969; Johnson 1982; Carroll 1986; Horwitz 1990; Merrick 1993; Morgan 1997). If this is true, then anthropogenic climate change represents a considerable threat to these species in two regards. First, the increased temperature may restrict these crayfishes to higher altitudes, where the habitat is thermally suitable. Second, anthropogenic climate change may result in the upper extremities of their montane habitats becoming drier, at least seasonally. This could result in the lowering of superficial water tables upon which they apparently rely, thereby restricting their upper altitudinal range. As such, an altitudinal compression of their habitat may occur, potentially leading to population and distribution declines. Similarly, climate change is considered a threat to highland amphibians with restricted distributions (Hero *et al*. 2006). Although there are still uncertainties in climate change modelling, the northeastern New South Wales region is predicted to become both warmer and drier, with potentially increased evapotranspiration and reduced soil wetness and runoff (Chiew and McMahon 2002; Howden 2003; Hennessy 2006). Further research on the thermal tolerances and hydrological requirements of these crayfishes is required, and may enable predictions of potential reduction in their distribution, habitat and abundance due to anthropogenic climate change. Obtaining such information may result in satisfying IUCN criteria for their listing in higher threat categories.

Pesticides and Pollution. These species may be adversely affected by pesticides and pollution associated with the maintenance of the areas (e.g. herbicide/pesticide application), visitation (e.g. sunscreen, vehicle pollution) or illegal activities (e.g. infected trapping gear). All species occur in areas of high visitation, presenting a real mechanism for the introduction of pollutants and pesticides. Wildfire or management burns may also lead to siltation and deoxygenation of habitats.

Exotic Species. There is no apparent threat from exotic aquatic species. Although an introduced crayfish species has been recorded in the region, it occurs in a lowland habitat some distance away (Coughran and Leckie 2007). Introduced predatory fishes, such as salmonids, are not stocked in nearby waterways. The spread of the introduced cane toad *Bufo marinus* throughout the northeastern New South Wales region may threaten these crayfishes. Cane toads have been implicated in the demise of other fauna that prey upon them, and crayfish are generally considered as potential predators of amphibians (Gamradt and Kats 1996; Goddard 1988; Turvey and Merrick 1997; Kats and Ferrer 2003). The recent appearance of cane toads in high altitude rainforest habitats, including sites inhabited by these crayfishes (D. Newell, pers. comm.), is of direct concern. Research on the potential impacts of toads on these crayfishes is required. It is conceivable that exotic terrestrial species (e.g. cattle) may also have some impact on these species or their habitat (Horwitz 1990; Merrick 1993). Given the high visitation in the areas inhabited, there is a potential for the introduction of disease organisms. Future research on these crayfishes should continue to observe the established hygiene protocol for frogs (NPWS 2001). However, this would not prevent the accidental introduction of pathogens by park visitors.

Exploitation. Evidence of poaching (traps, baits, captive animals) from National Parks was observed during the present study. Although they are of small size, and are less notable than the larger *Euastacus sulcatus* with which they co-occur, there is a threat of exploitation for all of these species. I have encountered several individuals who volunteered information about illicit activities undertaken in National Parks, including capturing specimens of *Euastacus* for personal collections of preserved material. There are several discussion boards on the Internet featuring crayfish collectors, in some cases involving members disseminating information on how to locate difficult-to-find species. Although such activity appears to be at a relatively low-level, it may pose a considerable threat to these five species of *Euastacus* given their extremely restricted distributions. Such illegal collection also provides a mechanism for the other threats (habitat destruction, translocation of species, and the introduction of pathogens, pesticides and pollution).

In summary, potential threats to these crayfishes are evident. Two examples (potential impacts associated with anthropogenic climate change and introduced cane toads) are of particular and immediate concern. Their severely restricted distributions suggest that four of these species (*Euastacus girurmulayn*, *E. guruhgi*, *E. jagabar* and *E. mirangudjin*) may be very vulnerable to these threats. Consequently, these four species satisfy the IUCN criterion D2 for classifying as vulnerable.

The reduced dependence on surface water of these five species is of importance in management considerations. At sites lacking surface water, these crayfishes still occur in burrows that access the water table. They can thus be classified as semi-aquatic (Horwitz and Richardson 1986) and would probably be sensitive to water table fluctuations.

This ability to survive without surface water enables the species to live in areas within, adjacent to, and entirely disjunct from, the obvious aquatic habitat. Management decisions should consider their habitat in terms of the broad forest landscape, and not merely the obvious, linear stream channels. Furthermore, given their semi-aquatic nature, these species could appropriately be listed at the State level under the *Fisheries Management Act 1994* (as are fishes and aquatic invertebrates) or the *Threatened Species Conservation Act 1995* (as are amphibians and terrestrial invertebrates). Examples of semi-aquatic invertebrates are currently listed under each act. Both Acts incorporate the IUCN criteria, and therefore the classifications listed above for these crayfishes are directly applicable.

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