

DRAFT - Conservation Advice for *Euastacus balanensis* (Balan spiny crayfish)



Euastacus balanensis in a captive setting. Image does not depict the species' natural habitat © Copyright, Rob McCormack.

Conservation status

Euastacus balanensis is proposed to be listed in the Endangered category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999*.

Euastacus balanensis was assessed to be eligible for listing as Endangered under Criterion 2. The assessment is at Attachment A. The assessment of the species' eligibility against each of the listing criteria is:

- Criterion 1: Insufficient data
- Criterion 2: B1ab(iii, v)+B2ab(iii, v): Endangered
- Criterion 3: Insufficient data
- Criterion 4: D2 Vulnerable
- Criterion 5: Insufficient data

The main factors that make the species eligible for listing in the Endangered category are the impacts of climate change (extreme weather events, increased temperature, increased severity and frequency of bushfire) on its highly restricted distribution, which will very likely lead to a continuing decline in the area, extent, and quality of habitat and number of mature individuals.

Species can also be listed as threatened under state and territory legislation. For information on the current listing status of this species, see the [Species Profile and Threat Database](#).

Species information

Taxonomy

Conventionally accepted as *Euastacus balanensis* Morgan, 1988 (Family: Parastacidae), however genetic studies have demonstrated there are at least three divergent lineages within *E. balanensis* (Ponniah & Hughes 2004; Shull et al. 2005; Austin et al. 2022). One lineage (*E. balanensis* s.s.) is found in the northern (Lamb Range, including the type location) and southeastern (Bellenden Kerr) parts of the species' range. A second lineage (*E. cf. balanensis* 2) is also found at Bellenden Kerr, and a third (*E. cf. balanensis* 1) in the southwestern part of the range at Mount Bartle Frere. Further work is required to clarify the genetics and taxonomic status of the divergent lineages.

Description

Balan spiny crayfish is a poorly spinose species of *Euastacus* (Coughran 2008) and is recorded as reaching at least 33 mm occipital-carapace length (OCL; Morgan 1997) (Morgan 1998; Coughran 2008). The species typically presents as a dark green (or brown, or olive) coloured crayfish overall, with orange and green undersides (Morgan 1988). Spines on the carapace or abdomen may be orange, brown or varying shades of green. The chelae (i.e. claws) are overall green/brown, with green-orange undersides, and orange-tipped spines (Morgan 1988).

The morphological characteristics used to identify *Euastacus* are typically subtle, with the differences often a few spines, and/or the presence of a groove. In general appearance, Balan spiny crayfish most closely resembles *E. eungella* (*Eungella* spiny crayfish) (Morgan 1988). Balan spiny crayfish and *E. eungella* can, however, be distinguished from each other by differences in spination of the chelae and coloration, and different distributions (Morgan 1988). For example, Balan spiny crayfish has one spine above the dactylar cutting edge and one apical mesal dactylar spine whereas *E. eungella* (specimens >20 mm OCL) has a row of 3–8 spines are present above the dactylar cutting edge and 1–3 apical mesal spines present (Morgan 1988).

Accurate and reliable identification of *Euastacus* is challenging and technical terminology is required to describe the subtle morphological features separating these two species. Detailed descriptions, and figures of these two similar looking species can be found in the original 1988 description by Morgan, plus additional details in Coughran (2008).

Distribution

Balan spiny crayfish is endemic to far north Queensland. The species' entire distribution is across six subpopulations (Alterton Tableland west of Cairns, The Bellenden Ker Range, Russell River, Mulgrave River, Davies Creek and Kauri Creek) across three discrete areas, with northern subpopulations in rainforests of Dinden and Danbulla national parks (Lamb Range), and southeastern (Bellenden Ker) and southwestern (Bartle Frere) subpopulations in Wooroonooran National Park (Morgan 1988; Ponniah & Hughes 2004; Shull et al. 2005; Coughran & Furse 2010).

Specimens collected from the southerly extent of the species' range, Summit Creek on Mount Bartle Frere were identified as divergent lineage 1 (*E. cf. balanensis*) and lineage 2 (*E. cf. balanensis* 2) from a tributary of the Mulgrave River on Mount Bellenden Kerr at the eastern extent of the species' range (Ponniah & Hughes 2004; Shull et al. 2005; Austin et al. 2022).

This species is only known from this area at altitudes >700 m above sea level (a.s.l.) where it occupies the headwaters of various streams (Morgan 1988; Coughran & Furse 2010). The species

range is drained by the Mitchell, Walsh and Tate rivers (to the west) and the Barron, Mulgrave, Russell and North Johnson rivers to the east (Ponniah & Hughes 2004; Shull et al. 2005).

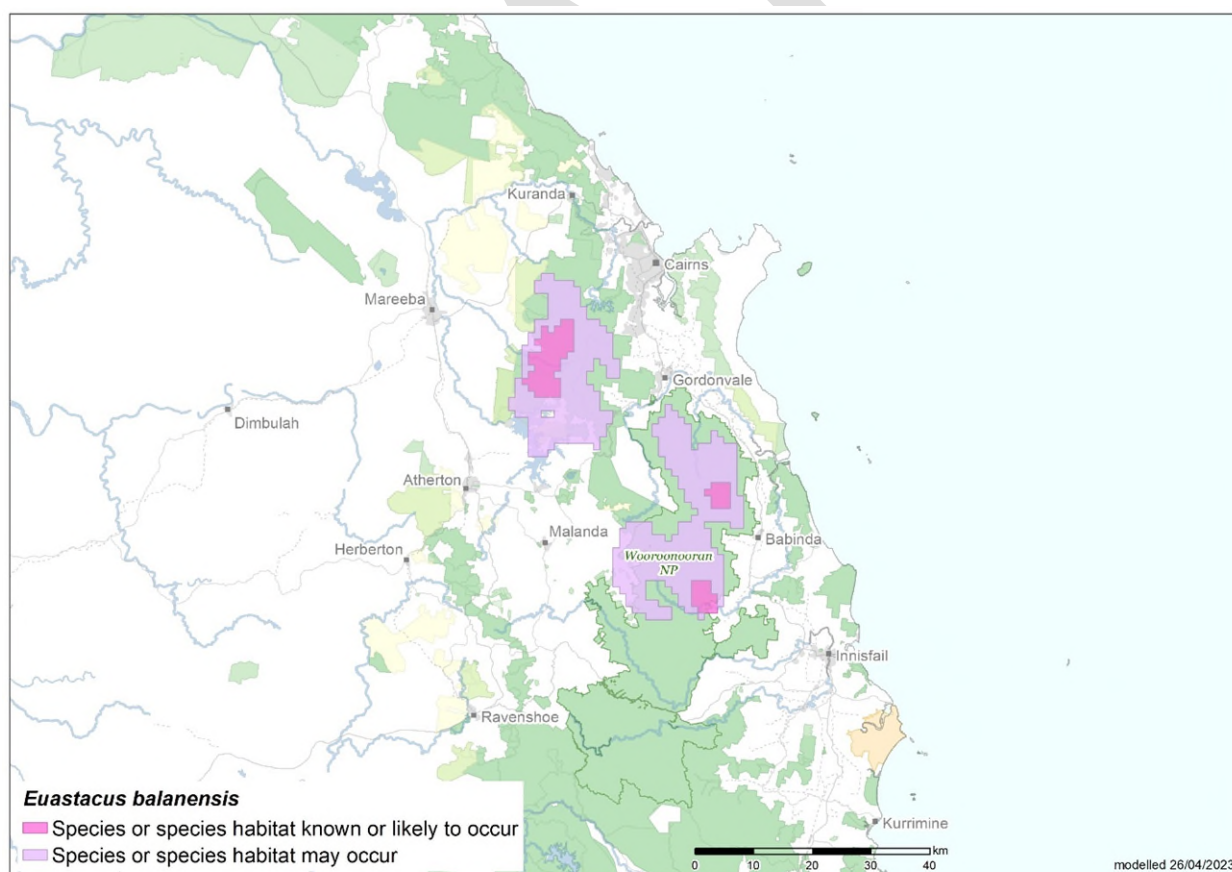
Additional areas of suitable habitat do exist in North Queensland, however they are not adjacent this species habitat, and are already occupied by one of the other species of *Euastacus* known to occur in North Queensland (Furse et al. 2012). This species is not considered to be abundant within its restricted range (Morgan 1988; J. Coughran 2008 unpub; Coughran & Furse 2010) and should be considered a rare species and a short range endemic (Harvey 2002). All indications are that this species is not found outside of its currently known distribution.

The population is afforded a degree of protection as it is contained within the boundary of various national parks and other protected areas, none are actively managed for conservation of Balan spiny crayfish (Coughran & Furse 2010).

This species occupies an area of exceptionally high rainfall, including the wettest place in Australia (Bellenden Ker). Median annual rainfall at the Bartle View Alert Weather Station (Southern Wooroonooran NP) is 3175 mm *per annum*, and at Bellenden Ker median rainfall routinely exceeds 7600 mm *per annum* (BOM 2022).

Mean maximum annual temperature at the Walkamin Research Station, ~22 km Southwest of the Type Locality, is 27.5°C (BOM 2022).

Map 1 Modelled distribution of Balan spiny crayfish



Source: Base map Geoscience Australia; species distribution data [Species of National Environmental Significance](#) database.

Caveat: The information presented in this map has been provided by a range of groups and agencies. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for errors or omissions, and the Commonwealth does not accept responsibility in respect of any information or advice given in

relation to, or as a consequence of, anything contained herein. Due to limited survey effort and information available, *Euastacus balanensis*, and its habitat, may occur in areas where it has not yet been recorded, and the modelled distribution (Map1) should be considered as indicative only.

Species distribution mapping: The species distribution mapping categories are indicative only and aim to capture (a) the habitat or geographic feature that represents to recent observed locations of the species (known to occur) or habitat occurring in close proximity to these locations (likely to occur); and (b) the broad environmental envelope or geographic region that encompasses all areas that could provide habitat for the species (may occur). These presence categories are created using an extensive database of species observations records, national and regional-scale environmental data, environmental modelling techniques and documented scientific research.

Cultural and community significance

The cultural, customary and spiritual significance of species and the ecological communities they form are diverse and varied for the many First Nations peoples that live in the area and care for Country. Such knowledge may be only held by Indigenous groups and individuals who are the custodians of this knowledge and have the rights to decide how this knowledge is shared and used. This section describes some examples of this significance.

Balan spiny crayfish occurs on lands of the Malanbarra Yidinji, Wanyurr Majay Yidinji, Ngadjon-Jii and Mamu Peoples (Queensland Government 2013a). According to Morgan's 1988 description, the specific epithet *balanensis* is derived from "balan", meaning "freshwater" in the Dyirbal language.

Relevant biology and ecology

It is recognised that the *Euastacus* species have a suite of common biological characteristics, and many of these characteristics will apply to this species (e.g. Furse & Coughran 2011a). Various studies have established that *Euastacus* are slow-growing (growth increments of a few mm OCL yr⁻¹), long-lived and can take many decades (35–50 years) to reach the adult sizes that are recorded for some species (Honan & Mitchell 1995a; Turvey & Merrick 1997a; Morey 1998; Furse & Wild 2004; Coughran 2011; Coughran 2013). The biology and ecology of Balan spiny crayfish remain unknown, however. Furse and Coughran (2011c) identified critical knowledge gaps (e.g. biology, ecology, distributions) for the *Euastacus* in general, and the knowledge gaps apply in particular to this poorly understood species.

Reproductive Ecology

Morgan (1988) reported collecting a berried female in the "30–40 mm OCL range" (from a burrow, in July) and suggested female maturity occurs at around 30 mm OCL (Morgan 1988).

Reproductive studies show that *Euastacus* are typically late maturing and have slow reproductive cycles with females only reaching reproductive maturity after 5–10 years (e.g., Honan and Mitchell 1995a; Turvey and Merrick 1997a; Borsboom 1998; Furse and Wild 2004; Coughran 2013). The growth rate, population sizes and generation length of Balan spiny crayfish are not known.

Many species of *Euastacus* are winter brooders, mating in late summer/autumn with females carrying eggs over winter, with brooding periods typically 6–10 months. Some species only breed biennially and pleopodal egg fecundity (number of fertilised eggs attached to underside of a gravid female) varies considerably between species, typically ranging from 20–1500 eggs per female (Clark 1937; Barker 1992; Honan & Mitchell 1995b; Turvey & Merrick 1997b; Borsboom 1998; Honan 1998; Morey 1998; Furse & Wild 2004; Coughran 2006; McCormack et al. 2010; Coughran 2013). The species is likely to be a poor disperser, with slow growth and low fecundity (Harvey 2002). Indications are that this species is a winter brooder (Morgan 1988) and pleopodal egg fecundity is likely in the range 20–80 eggs (e.g. Coughran 2011).

Co-occurring species

Cherax cairnsensis (Cairns yabby) is endemic to the region and has been collected from streams in the area (Morgan 1988) and may co-occur with Balan spiny crayfish. Morgan (1988) also reported *Macrobrachium* and *Australatya* shrimp species were common at lower altitudes (than Balan spiny crayfish), and so these may also co-occur with this species at the upper altitudinal limits of their distribution.

Habitat

Balan spiny crayfish is associated with cool habitats in rainforested areas (Morgan 1988, Coughran & Furse 2010) including gullies and small streams (J. Coughran 2008 unpub.; Coughran & Furse 2010). Balan spiny crayfish occupies small upper headwater streams within a closed rainforest canopy (Morgan 1988, Coughran & Furse 2010). It is not known if this species is typically associated with flowing water, but given the regions' extremely high rainfalls, the streams in the area likely flow year-round (Queensland Government 2013b). Therefore, flowing surface water is likely an important habitat characteristic for this species.

Other highland rainforest-dwelling species of *Euastacus* such as *E. sulcatus* (mountain crayfish), are intolerant of high temperatures (Bone et al. 2014) and this is likely to be the case for this species, too, given its restricted distribution to high altitude areas.

Diet

The diet of Balan spiny crayfish is not known, but the species is likely omnivorous, as with many species of spiny crayfish (McCormack 2012).

Threats

Established threats (habitat destruction, invasive species, human exploitation and climate change) and potential threats (disease *Aphanomyces astaci* [crayfish plague]; Panteleit et al. 2017) may put nearly all species of *Euastacus* at serious risk of population declines, or extinction in less than a decade (Wells et al. 1983; Coughran 2007; Furse & Coughran 2011b; Furse 2014; Richman et al. 2015). Climate change is a key threat to Balan spiny crayfish, with the species having limited capacity to relocate to higher, cooler altitudes, or move overland to other nearby suitably cool habitat which are already occupied by other species of *Euastacus* (Ponniah & Hughes 2004; Furse et al. 2012a). Balan spiny crayfish was assessed as susceptible to the climate conditions modelled for 2050 by Hossain et al. (2018). The highly restricted distribution of this species puts all individuals in the population at considerable risk of extirpation by a single stochastic event (e.g. natural disaster, or disease) impacting the species across its restricted range (Furse & Coughran 2011b).

Table 1 Threats impacting *Euastacus balanensis*

Threats in Table 1 are noted in approximate order of highest to lowest impact, based on available evidence.

| Threat | Status and severity | Evidence |
|--|--|---|
| Climate change and extreme weather impacts | | |
| Increased average temperature | Timing: current/future Confidence: inferred Likelihood: likely Consequence: major | Increased average temperature is a direct, on-going, and persistent long-term impact of climate change. Unlike short-term heatwaves, this is a steady long-term increase in temperature. Most of the years between 2019 and 2028 are projected to be amongst the top 10 warmest years globally with more than 99% probability (Arguez et al. 2020). |

| Threat | Status and severity | Evidence |
|------------------------|---|--|
| | <p>Trend: increasing</p> <p>Extent: across the entire range</p> | <p>Minimum, maximum and average temperatures in Far North Queensland are projected to continue to rise with an annual average warming of 0.5 to 1.4 °C above the climate from 1986-2005 by 2030 (DES 2019). By 2070, mean annual temperature in the Wet Tropics bioregion of Queensland is expected to increase by 1 – 2°C (Representative Concentration Pathway (RCP) 4.5) to 1.9 – 3.1°C (RCP 8.5) (Syktus et al. 2020).</p> <p>A 50% decline in the distribution and extent of highland rainforest environments of north Queensland are projected with only 1 °C rise in temperatures (Hilbert et al. 2001). The cooler upland sections of the Wet Tropics where Balan spiny crayfish occurs provide unique habitat for many heat intolerant and range restricted species (ANU 2009). It is unlikely that these species that have adapted to the cooler conditions on mountain tops and higher tablelands can survive and reproduce under warming conditions (Rainforest CRC 2003; Pearson et al. 2015; de la Fuente & Williams 2022). <i>Euastacus</i> are known to be sensitive to increasing temperatures, with Balan spiny crayfish likely lacking the capacity to physiologically adapt or relocate to cooler habitats as temperatures increase (Lowe et al. 2010; Bone et al. 2015, 2017). This will probably lead to altitudinal compression of habitat as there is limited scope for up-slope migration of this species and overland dispersal to other suitably cool habitats is blocked by the warm lowlands (Morgan 1988; Ponniah & Hughes 2004; Furse et al. 2012a; Bone et al. 2014). Additionally, nearby montane habitats in the region, that may be suitable, are already occupied by other species of <i>Euastacus</i> (Furse et al. 2012a).</p> <p>Projected increases in mean annual temperature in the region will impact this species across its restricted range (i.e. the single location) and puts the species at a very high risk of extinction. Water temperature in the habitat of this species is likely to range between 15–22 °C (winter-summer) (J.M. Furse 2022 unpub). The thermal limit of this species remains unknown, however based on the work of Bone et al. (2014) environmental temperatures may only be a few degrees away from levels that may cause thermal stress in this species (i.e. >23 °C). Balan spiny crayfish was assessed as a crayfish species vulnerable to the climate conditions modelled for 2050 by Hossain et al. (2018).</p> <p>Increasing average temperature associated with climate change will also interact with the other threats:</p> <ul style="list-style-type: none"> - Fire regimes that cause declines in biodiversity - Extreme weather events - Alterations to hydrological regimes |
| Extreme weather events | <p>Timing: current/future</p> <p>Confidence: inferred</p> <p>Likelihood: likely</p> <p>Consequence: major</p> <p>Trend: increasing</p> <p>Extent: across the entire range</p> | <p>Increased intensity and frequency of extreme weather events (heatwaves, storms, cyclones, droughts (and fires – discussed below)) are broad geographic scale threats associated with climate change. These events are not persistent, and may be relatively short-term in duration (i.e. hours to weeks). Extreme weather events have the capacity to seriously impact the population, leading to a decline or extirpation of the species (Coughran & Furse 2010).</p> <p>The highland habitat of Balan spiny crayfish is anticipated to be impacted by an increase in intensity and frequency of extreme heat events. Climate change modelling projects increased length and duration of droughts, longer periods of consecutive wet days, and longer and more frequent heatwaves for the region where this species is found (Syktus et al. 2020). By 2060–79, the Wet Tropics Bioregion of North Queensland is expected to have ~1.5–13 additional hot days (>35°C) <i>per annum</i> compared to the reference period (1986–2005) (Syktus et al. 2020).</p> <p>Bone et al. (2014) reported that when exposed to chronic, steadily increasing temperature, similarly-sized, small specimens of <i>E. sulcatus</i> became sluggish ~23°C and were effectively incapacitated at ~27°C (Bone et al. 2014). Acute exposure to temperatures above the upper thermal tolerance limit of this species could result in deleterious physiological impacts, and mortalities, and could lead to population reductions. The thermal limit of this species remains unknown, however based on the work</p> |

| Threat | Status and severity | Evidence |
|--|---|--|
| | | <p>of Bone et al. (2014) environmental temperatures may only be a few degrees away from temperatures that may cause thermal stress in this species. A single heatwave event could potentially lead to water temperatures reaching the upper thermal tolerance threshold, and result in physiological impacts, or even mortalities.</p> <p>High rainfall events leading to flash floods can scour high-altitude streams and this can be deadly to any <i>Euastacus</i> that seek refuge under leaves/fallen palm fronds, small rocks and logs. Mass mortality was recorded in <i>Euastacus valentulus</i> in the Numinbah Valley (Southeast Qld), when an intense rainfall event and flash flood killed hundreds, and possibly thousands, of crayfish (Furse et al. 2012b). Many of the crayfish killed in that event (30–40 mm OCL) were comparable in size to this species.</p> <p>A single extreme weather event may lead to other localised natural disasters (e.g., flooding, tree falls, landslides, and sedimentation events) (Furse et al. 2012b). Sediment exposure can damage respiratory surfaces of gills and reduce the ability of crayfish to uptake oxygen from the water (Cramp et al. 2021).</p> <p>Soils in the rainforests (including in Wooroonooran and other national parks) of North Queensland are often sandy (Queensland Government 2013a) poor, unstable and susceptible to landslides and erosion in the steep terrain where very high rainfalls, and tropical cyclones, are typical. This may lead to sediment influxes to streams and gullies in high relief montane areas occupied by this species, as is common in other regions with similar geologies and rainfall (Ravindran et al. 2019).</p> |
| Alterations to hydrological regimes | <p>Timing: current/future</p> <p>Confidence: observed</p> <p>Likelihood: almost certain</p> <p>Consequence: major</p> <p>Trend: increasing</p> <p>Extent: across the entire range</p> | <p>Changes in moisture availability and increased ephemerality of hydrological systems due to global climate change, will likely impact the species itself, but also floral and faunal assemblages, across the species' range. <i>Euastacus</i> are known to be sensitive to effects of drought, but also effects of flooding (Furse et al. 2012a). Moisture deficits and excesses are threats that put this restricted range species at high risk of population declines, or extirpation.</p> <p>Changes to rainfall patterns in the tropical rainforest region of North Queensland are too complex to project accurately, but models suggest that areas up to 200 km inland from the coast could experience changes in annual rainfall ranging from -45 to +23 % compared to 1990 (Suppiah et al. 2007). Rainfall patterns in the region occupied by <i>E. balanensis</i> are projected to alter as a result of climate change, with both annual precipitation and mean number of consecutive wet days potentially declining by 2060–2079 (Syktus et al. 2020). Under such drier conditions, a larger proportion of rainfall is lost to canopy storage and evaporation with less rain reaching the forest floor thereby reducing habitat availability for species that rely on moist conditions (McJannet et al. 2007).</p> <p>Furthermore, the duration and frequency of droughts are, on average, projected to increase by 2060–2079 throughout the region where this species is found (Syktus et al. 2020). Shifting precipitation patterns coupled with projected increases in temperature may lower the local water table and may introduce seasonality to the otherwise perennial streams in which this species resides. Changes to availability of water might significantly impact this species.</p> |
| Fire regimes that cause declines in biodiversity | <p>Timing: current/future</p> <p>Confidence: observed</p> <p>Likelihood: possible</p> <p>Consequence: major</p> <p>Trend: increasing</p> <p>Extent: part or across entire range</p> | <p>The frequency and severity of bushfires is projected to increase under climate change (Di Virgilio et al. 2019, DAWE 2022) but in Far North Queensland it is unclear how these changes will manifest.</p> <p>Impacts of bushfires are however well understood and may be immediate (habitat loss) or delayed (siltation and deoxygenation of habitat following a fire, possible change in stream water temperature and light regime due to canopy loss). Crayfish from restricted distributions and cooler climates (e.g., at higher altitudes) are at an increased risk of decline as bushfires can change aquatic thermal and oxygen regimes (Cramp et al. 2021).</p> <p>Fires may increase the occurrence of weed species in the habitat. Various highly invasive non-native species of vegetation are known to exist in the Wet Tropics Region, including in Wooroonooran National Park (e.g., <i>Lantana</i></p> |

| Threat | Status and severity | Evidence |
|---|--|---|
| | | <p><i>camara</i>) (Queensland Government 2013a). This may increase the chance and severity of bushfires (Hines et al. 2020).</p> <p>A single bushfire has the capacity to impact the entire population of this short range endemic species, potentially leading to a population decline across the species' range, or extirpation of the species.</p> |
| Illegal collection | | |
| Illegal take | <p>Timing: current</p> <p>Confidence: inferred</p> <p>Likelihood: possible</p> <p>Consequence: major</p> <p>Trend: static</p> <p>Extent: across the entire range</p> | <p>Illegal collectors specifically target rare species of <i>Euastacus</i> for personal collections and the aquarium trade (Coughran 2007; Coughran & Furse 2012; J.M. Furse 2021 unpub). Their targets include species in national parks (see Coughran & Furse 2012) and extremely remote areas (J.M. Furse 2021 unpub).</p> <p>A series of these activities are known to have occurred and continue throughout eastern Australia, with illegally collected crayfish intercepted (outbound) at Australian international airports (J.M. Furse 2021 unpub).</p> <p>Any collection of rare, slow-growing and short-range endemic species, such as Balan spiny crayfish, has the capacity to quickly lead to negative population-scale impacts. Specifically, removal of reproductive animals from a population, particularly females that may require >5 years to reach sexual maturity, is likely to seriously impact recruitment.</p> <p>Illegal collectors can also act as a vector for diseases/pathogens between catchments, waterways, and into isolated areas of habitat.</p> |
| Invasive species | | |
| Invasive fauna | <p>Timing: current/future</p> <p>Confidence: inferred</p> <p>Likelihood: possible</p> <p>Consequence: moderate</p> <p>Trend: static to increasing</p> <p>Extent: across the entire range</p> | <p>Feral pigs (<i>Sus scrofa</i>) occur in Wooroonooran National Park (Queensland Government 2013a), and disturbance by pigs is common in other National Parks (Queensland Government 2013b).</p> <p>Pigs eat crayfish (Coughran 2021) and are a serious threat to crayfish in general, but species of burrowing crayfish in particular (e.g. <i>Engaeus martigener</i>), both through predation and their rooting and wallowing behaviour (DEH 2017).</p> |
| Invasive weeds and weed incursion | <p>Status: future</p> <p>Confidence: known</p> <p>Likelihood: possible</p> <p>Consequence: moderate</p> <p>Trend: increasing</p> <p>Extent: across the entire range</p> | <p>Weed incursion (i.e. smothering waterbodies and other habitats) is a major concern in streams of the Wet Tropics (Pearson et al. 2015) and has been identified as a potentially serious threat to other species of freshwater crayfish in Qld (J. M. Furse 2021 unpub).</p> <p>Some 17 highly invasive non-native species of vegetation are known to exist in Wooroonooran National Park (e.g., <i>Lantana camara</i>, <i>Miconia calvescens</i> [Velvet tree, Miconia, or Bush currant]) (Queensland Government 2013a). In similar habitats in the subtropical rainforests of the Qld-NSW border, dense stands of lantana quickly establish in the exposed areas created by tree falls and landslides (Stock 2004) and similar infestations are reported in nearby National Parks (e.g. Koombooloomba National Park) (Queensland Government 2013b). These infestations can be very extensive, and persist until a substantial vegetative canopy reestablishes. The incursion of a single weed species has the potential to quickly smother habitat in the distribution of this species.</p> |
| Disease | | |
| Crayfish plague (<i>Aphanomyces astaci</i>) | <p>Timing: future</p> <p>Confidence: projected</p> <p>Likelihood: possible</p> <p>Consequence: catastrophic</p> <p>Trend: unknown</p> | <p><i>Aphanomyces astaci</i> (crayfish plague) is a highly contagious fungal disease that is uniformly fatal (100% mortality) to susceptible species (Panteleit et al. 2017), and it is considered one of the world's worst invasive species (Lowe et al. 2000). Crayfish plague, introduced from North America, has devastated populations of native species of freshwater crayfish in Europe and Asia (Panteleit et al. 2017). In Scandinavia, national declines in crayfish populations were up to 80% and some lakes where crayfish were eliminated became choked with aquatic plants (Abrahamsson 1966).</p> |

| Threat | Status and severity | Evidence |
|--------|-----------------------------|---|
| | Extent: across entire range | <p>Many strains of the disease prefer cooler temperatures, which is characteristic of this species habitat. Crayfish plague is not currently known in Australia, but is documented as fatal to Australian freshwater crayfish (Unestam 1975), and it is listed on Australia's National List of Reportable Diseases of Aquatic Animals (Animal Health Committee 2020). It poses an extremely high risk to native freshwater crayfish species when it reaches Australia (DAWE 2019).</p> <p>The vector for the movement of <i>A. astaci</i> outside of its native range was the translocation of North American crayfish, in particular, <i>Pacifastacus leniusculus</i> (signal crayfish) and <i>Procambarus clarkii</i> (Girard) (red swamp crayfish). Infected crayfish from the Americas are resistant carriers, and are largely unaffected by the disease (DAWE 2019). Illegally imported specimens of red swamp crayfish have been seized in multiple Australian states (Department of Primary Industries & Regional Development 2021; Business Queensland 2021), but not known to be infected.</p> <p>A single, illegally-imported crayfish, infected with crayfish plague has the capacity, via an unlicensed/illegal collector vector (or aquarium discard), to devastate the entire Australian crayfish fauna. Increasing illegal wildlife/aquarium trade appreciably increases the risk of the disease's introduction to Australia (Furse 2014).</p> |

^aTiming—identifies the temporal nature of the threat

Confidence—identifies the nature of the evidence about the impact of the threat on the species

Likelihood—identifies the likelihood of the threat impacting on the whole population or extent of the species

Consequence—identifies the severity of the threat

Trend—identifies the extent to which it will continue to operate on the species

Extent—identifies its spatial context in terms of the range of the species

^bFire regimes that cause declines in biodiversity include the full range of fire-related ecological processes that directly or indirectly cause persistent declines in the distribution, abundance, genetic diversity or function of a species or ecological community. 'Fire regime' refers to the frequency, intensity or severity, season, and types (aerial/subterranean) of successive fire events at a point in the landscape

Categories for likelihood are defined as follows:

Almost certain – expected to occur every year

Likely – expected to occur at least once every five years

Possible – might occur at some time

Unlikely – known to have occurred only a few times

Unknown – currently unknown how often the threat will occur

Categories for consequences are defined as follows:

Not significant – no long-term effect on individuals or populations

Minor – individuals are adversely affected but no effect at population level

Moderate – population recovery stable or declining

Major – population decline is ongoing

Catastrophic – population trajectory close to extinction

Each threat has been described in Table 1 in terms of the extent that it is operating on the species. The risk matrix (Table 2) provides a visual depiction of the level of risk being imposed by a threat and supports the prioritisation of subsequent management and conservation actions. In preparing a risk matrix, several factors have been taken into consideration, they are: the life stage they affect; the duration of the impact; the spatial extent, and the efficacy of current management regimes, assuming that management will continue to be applied appropriately. The risk matrix and ranking of threats has been developed in consultation with experts and using available literature.

Table 2 Risk Matrix

| Likelihood | Consequences | | | | |
|----------------|-----------------|-------|-----------------------------------|---|--|
| | Not significant | Minor | Moderate | Major | Catastrophic |
| Almost certain | | | | Alterations to hydrological regimes | |
| Likely | | | Invasive weeds and weed incursion | Increased average temperature Extreme weather events Illegal take | |
| Possible | | | Invasive weeds and weed incursion | Increased intensity/frequency of bushfire Invasive fauna | Disease <i>A. astaci</i> (Crayfish plague) |
| Unlikely | | | | | |
| Unknown | | | | | |

Risk Matrix legend/Risk rating:

| | | | |
|----------|---------------|-----------|----------------|
| Low Risk | Moderate Risk | High Risk | Very High Risk |
|----------|---------------|-----------|----------------|

Conservation and recovery actions

Primary conservation objective

- Ensure the AOO and EOO of Balan spiny crayfish are stable or increasing, and major threats are effectively managed, and resilience to climate change impacts is maximised.

Conservation and management priorities

The following recommendations involving capture and removal of live specimens from the wild, and/or captive populations are made on the assumption that a suitably large population of this uncommon species exists in the wild.

Extreme weather events

- Investigate feasibility and, if appropriate, plan and establish facilities for potential ex situ short-term, active conservation intervention(s), including:
 - Establishing a capacity to maintain a captive population of this species over the short-term, in response to an extreme weather event, for subsequent re-release to the wild (see Zukowski et al. 2021).
 - Establish an environmental monitoring system in the species' habitat, to provide alerts of dangerous environmental conditions. These could be in-situ monitoring and/or based on model projections.
 - Developing or accessing local weather and climate models to project when extreme weather events might require moving animals to *ex situ* facilities.

Increased temperature

- Determine if the species natural habitat features any relatively “cool” pockets of micro-habitat and if they could act as temporary refuges.

Fire impacts

- Review and revise existing fire management plans, including hazard reduction and fire suppression practices, to ensure they are appropriate for the distribution and habitat requirements of this species. These could include:
 - Actively protect fire sensitive rainforest areas, and manage surrounding areas.
 - Reduce the prevalence of fire-prone lantana where infestations have established, and replant native species where possible.
- Monitor and, if necessary, manage impacts from any upstream fires on the species habitat, including riparian erosion and siltation.

Illegal collection

- Restrict publicity on the species so as to not identify areas of occurrence and mitigate illegal collection.
- Regularly carry out surveillance of species habitat, websites, forums, collectors’ groups, etc. to detect if illegal collection is occurring and if crayfish are offered for sale, and then take action where appropriate.

Invasive species (including threats from grazing, trampling, predation)

- Develop and implement long-term strategies to control introduced predators by implementing eradication programs where feasible.
- Monitor for and control any damage to riparian areas by feral pigs. If required, control numbers and fence sites, where feasible. This may require a collaborative strategy with surrounding land holders and local government authorities to limit feral pigs from crossing into national parks.
- Undertake weed control in the local area and identify and remove weeds that could become a threat to the species, ensuring any possible disturbance/overspray does not adversely impact this species. Replant native species, if possible.

Disease impacts

- Ensure authorised researchers and rangers are aware of required hygiene protocols.
- Take steps (i.e., limit all publicity) to minimise frequency of potential disease vectors entering the species habitat. For example, not facilitating illegal collectors, or members of the public, identifying and visiting the species’ habitat.

Ensure that appropriate guidelines for mitigating spread of disease is communicated to relevant stakeholders (including biosecurity). Habitat loss disturbance and modifications

- Ensure that the habitat quality remains high through management actions (e.g., weed removal, fire management, etc.) where the species is found.

Breeding, propagation and other ex situ recovery action

- If the population size of the species permits, investigate feasibility and plan for potential short and long-term active conservation intervention(s), including *ex-situ* initiatives such as:
 - Establishing captive husbandry methods and protocols for the species.
 - Establishing a capacity to maintain captive populations over the short-term (i.e., in response to extreme weather events) for subsequent re-release to the wild.
 - Establishing a captive breeding population as a source of animals to augment the wild population, if required.
 - Investigate feasibility of translocations to assist conservation of the species.

Stakeholder engagement/community engagement

- Prepare a management and engagement strategy this species and similar species of crayfish in the region with input from *bona-fide* crayfish experts, national park managers, and other identified stakeholders.
- Support Traditional Owners in the conservation of the species and its habitat.
- Limit publicity for this species due to risks from illegal-and- over collection and disease. Information should be restricted until key knowledge-gaps have been addressed, and thus full community engagement may not be beneficial to the species.
- Noting the requirement to limit publicity, adopt best practice for effective threat management through an adaptive management approach based on partnerships around co-design, co-implementation and social learning. Promote wide acceptance and capacity building, including explicit use of local knowledge in planning, management actions and monitoring.

Survey and monitoring priorities

- Establish, and then monitor the population size and trajectory of this species through time.
- Determine the contemporary geographic distribution of Balan spiny crayfish, including divergent lineages.
- Use population genetics to provide an indirect estimate of effective population size, heterozygosity, and structure among the various subpopulations, which can also form a baseline for ongoing monitoring.

Information and research priorities

- Address the previously identified critical knowledge gaps on the population size, biology, ecology and life history of this species (see 'Relevant biology and ecology' above).
- Investigate the species' habitat requirements (including any moisture environmental temperature, dissolved oxygen and shelter/refuge requirements requirements).
- Investigate the potential influence of climate change on the long-term survival prospects of the species, due to altered temperatures, rainfall patterns/moisture availability, bushfires, environmental stressors and diseases. This includes:
 - If the population size permits, assess the thermal tolerance of Balan spiny crayfish(using non-lethal methods) to ascertain its physiological limits, sensitivity and vulnerability. Thermal tolerances are likely to be similar between closely related species occupying

similar environments (Cramp et al. 2021). So use of a more common *Euastacus* species which is physiologically and ecologically similar could be used to inform likely impacts to this threatened species.

- Establish the species' moisture requirements and how these may be affected via changes in precipitation and increased temperature.
- Establish the impacts of climate change on the species' habitat (vegetation assemblages, water availability, water and air temperatures).
- Investigate the threats and impacts of invasive species and diseases on Balan spiny crayfish.

Links to relevant implementation documents

DAWE (Department of Agriculture Water and the Environment) (2019) Australian aquatic veterinary emergency plan (AQUAVETPLAN) for crayfish plague (version 2.0). Commonwealth of Australia, Canberra, ACT, Australia. Viewed 22 June 2021. Available at: <https://www.agriculture.gov.au/sites/default/files/documents/aquavetplan-crayfish-plague.pdf>

DEH (Department of Environment and Heritage) (2017) Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs. Department of Environment and Heritage, Commonwealth of Australia. Canberra, Australia. Viewed 22 June 2021. Available at: <https://www.environment.gov.au/system/files/resources/b022ba00-ceb9-4d0b-9b9a-54f9700e7ec9/files/tap-feral-pigs-2017.pdf>

Conservation Advice and Listing Assessment references

Abrahamsson SAA (1966) Dynamics of an isolated population of the crayfish *Astacus* Linne. *Oikos* 17, 96-107.

Arguez A, Hurley S, Inamdar A, Mahoney L, Sanchez-Lugo A, Yang L, Arguez A, Hurley S, Inamdar A, Mahoney L, Sanchez-Lugo A and Yang L (2020) Should we expect each year in the next decade (2019-2028) to be ranked among the top 10 warmest years globally? *Bulletin of the American Meteorological Society*, BAMS-D-19-0215.1.

Austin C, Whiterod NS, McCormack R, Raadik TA, Ahyong ST, Lintermans M, Furse JM and Grandjean F (2022) Molecular taxonomy of Australia's endemic freshwater crayfish genus *Euastacus* (Parastacidae), with reference to priority 2019-20 bushfire-impacted species - 2022 update. 64 pages. Deakin University and Aquasave-Nature Glenelg Trust, Victor Harbor, South Australia.

ANU (Australian National University) (2009) *Implications of climate change for Australia's World Heritage properties: A preliminary assessment*. A report to the Department of Climate Change and the Department of the Environment, Water, Heritage and the Arts by the Fenner School of Environment and Society, the Australian National University.

Bachman S, Moat J, Hill A, J de la Torre & Scott B (2011) Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. *Zookeys* 150, 117-126.

Bland LM (2017) Global correlates of extinction risk in freshwater crayfish. *Animal Conservation* 20, 532-542.

- Bone JWP, Renshaw GMC, Furse JM & Wild CH (2015) Using biochemical markers to assess the effects of imposed temperature stress on freshwater decapod crustaceans: *Cherax quadricarinatus* as a test case. *Journal of Comparative Physiology B: Biochemical, Systems, and Environmental Physiology* 185(3), 291-301.
- Bone JWP, Renshaw GMC & Wild CH (2017) Physiological and biochemical responses to elevated temperature in a threatened freshwater crayfish, *Euastacus sulcatus* (Decapoda: Parastacidae). *Marine and Freshwater Research* 68(10), 1845-1854.
- Bone JWP, Wild CH & Furse JM (2014) Thermal limit of *Euastacus sulcatus* (Decapoda: Parastacidae), a freshwater crayfish from the highlands of central eastern Australia. *Marine and Freshwater Research* 65(7), 645-651.
- Borsboom A (1998) Aspects of the biology and ecology of the Australian freshwater crayfish, *Euastacus urospinosus* (Decapoda: Parastacidae). *Proceedings of The Linnean Society of New South Wales* 119, 87-100.
- Bruna E M (2004) Biological impacts of deforestation and fragmentation, in J Burley, J Evans & J Youngquist (eds), *The Encyclopaedia of Forest Sciences*. Elsevier Press, London. pp. 85 – 90.
- Clark E (1937) The life history of the Gippsland crayfish. *The Australian Museum Magazine* 6, 186-192.
- Coughran J (2005) New crayfishes (Decapoda: Parastacidae: *Euastacus*) from northeastern New South Wales, Australia. *Records of the Australian Museum* 57(3), 361-374.
- Coughran J (2006) *Field guide to the freshwater crayfishes of Northeastern New South Wales*. Natureview Publishing, Bangalow, NSW.
- Coughran J (2007) Distribution, habitat and conservation status of the freshwater crayfishes, *Euastacus dalagarbe*, *E. girurmulayn*, *E. guruhgi*, *E. jagabar* and *E. mirangudjin*. *Australian Zoologist* 34(2), 222-227.
- Coughran J (2008) Distinct groups in the genus *Euastacus*? *Freshwater Crayfish* 16, 125-132.
- Coughran J & Furse JM (2010). *An assessment of genus Euastacus (49 species) versus IUCN Red List criteria. A report prepared for the global species conservation assessment of crayfishes for the IUCN Red List of Threatened Species*. The International Association of Astacology. Auburn, Alabama, USA. ISBN: 978-0-9805452-1-0.
- Coughran J (2011) Aspects of the biology and ecology of the Orange-Bellied Crayfish, *Euastacus mirangudjin* Coughran 2002, from northeastern New South Wales. *Australian Zoologist* 35(3), 750-756.
- Coughran J (2013) Biology of the Mountain Crayfish *Euastacus sulcatus* Riek, 1951 (Crustacea: Parastacidae), in New South Wales, Australia. *Journal of Threatened Taxa* 5(14), 4840-4853.
- Coughran J & Furse JM (2012) Conservation of Freshwater Crayfish in Australia. *Crustacean Research Special Number* 7, 25-34.
- Cramp R, Mulvey C, Cameron J, Wintour M, Gomez Isaza D & Franklin C (2021) Impacts of postfire ash and runoff sediment on the physiological tolerances of Australian freshwater aquatic fauna. NESP Threatened Species Recovery Hub Project 8.3.7 report, Brisbane.

- DAWE (Department of Agriculture, Water and Environment, Australia) (2022) Fire regimes that cause biodiversity decline: amendments to the list of key threatening processes, Department of Agriculture, Water and the Environment, Canberra, February. CC BY 4.0.
- DES (Department of Environment and Science, Queensland) (2019) *Climate change in the Far North Queensland region. Version 1*. Queensland Department of Environment and Science. Accessed 27 March, 2020 at: https://www.qld.gov.au/data/assets/pdf_file/0025/68371/far-north-qld-climate-change-impact-summary.pdf
- De la Fuente A & Williams S (2022) Climate change threatens the future of rain forest ringtail possums by 2050. *Diversity and Distributions* 29(1), 173 – 183
- Di Virgilio G, Evans J, Blake S, Armstrong M, Dowdy A, Sharples J & McRae R (2019) Climate change increases the potential for extreme wildfires. *Geophysical Research Letters* 46(14), 8517-8526.
- Furse JM (2014) The freshwater crayfish fauna of Australia: update on conservation status and threats. *Crustaceana Monographs* 19 (Advances in freshwater decapod systematics and biology), 273-296.
- Furse JM, Bone JWP, Appleton SD, Leland JC & Coughran J (2012a) Conservation of Imperilled Crayfish - *Euastacus bindal* (Decapoda: Parastacidae), a Highland Crayfish from Far North Queensland, Australia. *Journal of Crustacean Biology* 32(4), 677-683.
- Furse JM & Coughran J (2011a) An assessment of the distribution, biology, threatening processes and conservation status of the freshwater crayfish, genus *Euastacus* (Decapoda: Parastacidae), in Continental Australia. I. Biological Background and Current Status. *Crustaceana Monographs* 15 (Special edition: New Frontiers in Crustacean Biology), 241-252.
- Furse JM & Coughran J (2011b) An assessment of the distribution, biology, threatening processes and conservation status of the freshwater crayfish, genus *Euastacus* (Decapoda: Parastacidae), in Continental Australia. II. Threats, Conservation Assessments and Key Findings. *Crustaceana Monographs* 15 (Special edition: New Frontiers in Crustacean Biology), 253-263.
- Furse JM & Coughran J (2011c). An assessment of the distribution, biology, threatening processes and conservation status of the freshwater crayfish, genus *Euastacus* (Decapoda: Parastacidae), in Continental Australia. III. Case Studies and Recommendations. *Crustaceana Monographs* 15 (Special edition: New Frontiers in Crustacean Biology), 265-274.
- Furse JM, Coughran J & Wild CH (2012b) Report of a mass mortality of *Euastacus valentulus* (Decapoda: Parastacidae) in southeast Queensland, Australia, with a discussion of the potential impacts of climate change induced severe weather events on freshwater crayfish species. *Crustacean Research Special Number* 7, 15-24.
- Furse JM, Dawkins KL & Coughran J (2013) Two new species of *Euastacus* (Decapoda: Parastacidae) from the Gondwana Rainforests of Central-Eastern Australia. *Freshwater Crayfish* 19(1), 103-113.
- Furse JM & Wild CH (2004) Laboratory moult increment, frequency, and growth in *Euastacus sulcatus*. *Freshwater Crayfish* 14, 205-211. Hilbert D, Ostendorf B and Hopkins M (2001) Sensitivity of tropical forests to climate change in the humid tropics of north. Queensland. *Austral Ecology* 26(6), 590-603.
- Hines HB, Brook M, Wilson J, McDonald WJF & Hargreaves J (2020) The extent and severity of the Mackay Highlands 2018 wildfires and the potential impact on natural values, particularly in the

- mesic forests of the Eungella-Crediton area. *Proceedings of the Royal Society of Queensland* 125, 139-157.
- Honan JA (1998) Egg and juvenile development of the Australian freshwater crayfish, *Euastacus bispinosus* Clark (Decapoda: Parastacidae). *Proceedings of the Linnean Society of New South Wales* 119: 37-54.
- Honan JA & Mitchell BD (1995a) Growth of the large freshwater crayfish *Euastacus bispinosus* Clark (Decapoda: Parastacidae) *Freshwater Crayfish* 10, 118-131.
- Honan JA & Mitchell BD (1995b) Reproduction of *Euastacus bispinosus* Clark (Decapoda: Parastacidae), and trends in the reproductive characteristics of freshwater crayfish. *Marine and Freshwater Research* 46, 485-499.
- Horwitz P (1990). The conservation status of Australian freshwater crustacea with a provisional list of threatened species, habitats and potentially threatening processes. pp. 121. Report series number 14. Australian National Parks and Wildlife Service. Canberra.
- Hossain MA, Lahoz-Monfort JJ, Burgman MA, Böhm M, Kujala H and Bland LM (2018) Assessing the vulnerability of freshwater crayfish to climate change. *Diversity and Distributions* 24(12), 1830–1843.
- Kearney M, Phillips B, Tracy C, Christian K, Betts G, & Porter W (2008) Modelling species distributions without using species distributions: the cane toad in Australia under current and future climates. *Ecography* 31, 423–434.
- Lowe K, FitzGibbon S, Seebacher F & Wilson RS (2010) Physiological and behavioural responses to seasonal changes in environmental temperature in the Australian spiny crayfish *Euastacus sulcatus*. *Journal of Comparative Physiology B: Biochemical, Systems, and Environmental Physiology* 180(5), 653-660.
- Lowe S, Browne M, Boudjelas S & De-Poorter M (2000) 100 of the world's worst invasive alien species. A selection from the global invasive species database. *Aliens* 12, 1-12.
- McCormack RB, Coughran J, Furse JM & Van-der-Werf P (2010) Conservation of Imperiled Crayfish - *Euastacus jagara* (Decapoda: Parastacidae), a highland crayfish from the Main Range, South-Eastern Queensland, Australia. *Journal of Crustacean Biology* 30(3), 531-535.
- McJannet D, Wallace J & Reddell P (2007) Precipitation interception in Australian tropical rainforests: II. Altitudinal gradients of cloud interception, stemflow, throughfall and interception. *Hydrological Processes* 21, 1703–1718.
- Morey JL (1998) Growth, catch rates and notes on the biology of the Gippsland Spiny Freshwater Crayfish, *Euastacus kershawi* (Decapoda: Parastacidae), in West Gippsland, Victoria. *Proceedings of the Linnean Society of New South Wales* 119, 55-69.
- Morgan GJ (1988). Freshwater crayfish of the Genus *Euastacus* Clark (Decapoda: Parastacidae) from Queensland. *Memoirs of The Museum of Victoria* 49(1), 1-49.
- Morgan GJ (1997) Freshwater crayfish of the genus *Euastacus* Clark (Decapoda: Parastacidae) from New South Wales, with a key to all species of the genus. *Records of the Australian Museum Supplement* 23, 1-110.

- Panteleit J, Keller NS, Kokko H, Jussila J, Makkonen J, Theissinger K & Schrimpf A (2017) Investigation of ornamental crayfish reveals new carrier species of the crayfish plague pathogen (*Aphanomyces astaci*). *Aquatic Invasions* 12(1), 77-83.
- Ponniah M & Hughes JM (2004) The evolution of Queensland spiny mountain crayfish of the genus *Euastacus*. I. Testing vicariance and dispersal with intraspecific mitochondrial DNA. *Evolution* 58(5): 1073-1085.
- Ponniah M & Hughes JM (2006) The evolution of Queensland spiny mountain crayfish of the genus *Euastacus*. II. Investigating simultaneous vicariance with intraspecific genetic data. *Marine and Freshwater Research* 57(3), 349-362.
- Rainforest CRC, (2003) *Global warming in the Wet Tropics: issues in tropical forest landscapes*. Working Paper. Rainforest CRC, James Cook University, Cairns, Qld, Australia.
- Ravindran S, Gratchev I & Jeng D-S (2019) Analysis of rainfall-induced landslides in northern New South Wales, Australia. *Journal of Australian Geomechanics* 54(4), 85-99.
- Richman NI, Böhm M, Adams SB, Alvarez F, Bergey EA, et al. (2015) Multiple drivers of decline in the global status of freshwater crayfish (Decapoda: Astacidea). *Philosophical Transactions of the Royal Society B: Biological Sciences* 370: 20140060.
- Stock D (2004). The dynamics of Lantana camara (L.) invasion of subtropical rainforest in southeast Queensland. PhD Thesis, 318 pages, School of Environmental and Applied Sciences. Griffith University, Gold Coast campus. Gold Coast, Queensland, Australia.
- Suppiah R, Macadam I & Whetton P (2007) *Climate change projections for the tropical rainforest region of North Queensland*. In: Reef and Rainforest Research Centre Limited. CSIRO Marine and Atmospheric Research, Cairns.
- Syktus J, Trancoso R, Ahrens D, Toombs N & Wong K (2020) *Queensland Future Climate Dashboard: Downscaled CMIP5 climate projections for Queensland*. Accessed from <<https://www.longpaddock.qld.gov.au/qld-future-climate/>>.
- Turvey P & Merrick JR (1997a) Growth with age in the freshwater crayfish, *Euastacus spinifer* (Decapoda: Parastacidae), from the Sydney region, Australia. *Proceedings of the Linnean Society of New South Wales* 118, 205-215.
- Turvey P & Merrick JR (1997b) Reproductive biology of the freshwater crayfish, *Euastacus spinifer* (Decapoda: Parastacidae), from the Sydney region, Australia. *Proceedings of the Linnean Society of New South Wales* 118, 131-155.
- Unestam T (1975) Defence reactions in and susceptibility of Australian and New Guinean freshwater crayfish to European-crayfish-plague fungus. *Australian Journal of Experimental Biological and Medical Science* 53, 349-359.
- Wells SM, Pyle RM & Collins NM (1983) *The IUCN Invertebrate Red Data Book*. 1st edition, The IUCN, Gland, Switzerland.

Other sources cited in the advice

- Animal Health Committee (2020) Australia's National List of Reportable Diseases of Aquatic Animals (June 2020). Viewed 27 July 2021, Available at: <https://www.agriculture.gov.au/animal/aquatic/reporting/reportable-diseases#crustaceans>

- Barker J (1992) The spiny freshwater crayfish monitoring program, 1990. Fisheries management report. No 44, Inland Fisheries Management Branch, Fisheries Management Division, Department of Conservation and Environment. Victoria, Australia.
- BOM (Bureau of Meteorology) (2021) Maps of average conditions. Bureau of Meteorology, Commonwealth of Australia, Canberra, Australia. Available online via: <http://www.bom.gov.au/climate/averages/maps.shtml>
- BOM (Bureau of Meteorology) (2022) Climate Data Online. Bureau of Meteorology, Commonwealth of Australia, Canberra, Australia. Available at: Available online via: <http://www.bom.gov.au/climate/data/index.shtml>
- Business Queensland (2021) Red swamp crayfish. Viewed 27 July 2021, Available at: <https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/land-management/health-pests-weeds-diseases/pests/invasive-animals/prohibited/red-swamp-crayfish>
- Coughran J (2021) Unpublished data on threats to *Euastacus* species. In possession of author.
- Coughran J (2008) Unpublished survey data on *Euastacus balanensis*. In possession of author.
- Department of Primary Industries & Regional Development (2021) Red swamp crayfish seized (Wednesday 21 July 2021). Viewed 27 July 2021, Available at: <http://www.fish.wa.gov.au/About-Us/News/Pages/red-swamp-crayfish-seized.aspx>
- Furse J (2021) Unpublished data on threats to *Euastacus* species. In possession of author.
- IUCN Standards and Petitions Committee (2024). 'Guidelines for Using the IUCN Red List Categories and Criteria. Version 16. Prepared by the Standards and Petitions Committee. Downloadable from <https://www.iucnredlist.org/documents/RedListGuidelines.pdf>. McCormack (2008) Unpublished survey data on *Euastacus balanensis*. In possession of author.
- Queensland Government (2013a). Wooroonooran National Park Management Statement 2013. 12 Pages. Queensland Department of National Parks, Recreation, Sport and Racing. Brisbane, Australia.
- Queensland Government (2013b). *Koombooloomba National Park, Forest Reserve and Conservation Park Management Statement 2013*. 9 Pages. Queensland Department of National Parks, Recreation, Sport and Racing. Brisbane, Australia.

Attachment A: Listing Assessment for Balan spiny crayfish

Reason for assessment

This public nomination was initiated by the World Wide Fund for Nature Australia (WWF). The species was prioritised due to its IUCN conservation status.

Assessment of eligibility for listing

This assessment uses the criteria set out in the [EPBC Regulations](#). The thresholds used correspond with those in the [IUCN Red List criteria](#) except where noted in criterion 4, sub-criterion D2. The IUCN criteria are used by Australian jurisdictions to achieve consistent Listing Assessments through the Common Assessment Method (CAM).

Key assessment parameters

Table 3 includes the key assessment parameters used in the assessment of eligibility for listing against the criteria. The definition of each of the parameters follows the [Guidelines for Using the IUCN Red List Categories and Criteria](#).

Table 3 Key assessment parameters

| Metric | Estimate used in the assessment | Minimum plausible value | Maximum plausible value | Justification |
|------------------------------|---------------------------------|-------------------------|-------------------------|--|
| Number of mature individuals | Unknown | Unknown | Unknown | Not known for this species. |
| Trend | n/a | | | |
| Generation time (years) | Unknown | Unknown | Unknown | The longevity, fecundity, and age of sexual maturity in females is presently unknown for Balan spiny crayfish. In addition, there is little information available from other species of <i>Euastacus</i> . Therefore, generation length cannot be estimated. |
| Extent of occurrence | 461km ² | | | Based on published, unpublished and known survey and collection records (e.g. Morgan 1988; Ponniah & Hughes 2004; Shull et al. 2005; Coughran 2008, unpub; McCormack 2008 unpub). Calculated using GeoCAT (Bachman et al. 2011) |
| Trend | Stable | | | The species is not known outside of the current EOO. Sites in the historical area of record (Morgan 1988) remains occupied by the species (Ponniah & Hughes 2004; Shull et al. 2005; Coughran 2008 unpub; McCormack 2008 unpub). |

| Metric | Estimate used in the assessment | Minimum plausible value | Maximum plausible value | Justification |
|---|--|-------------------------|-------------------------|---|
| Area of Occupancy | 36 km ² | | | Based on published, unpublished and known survey and collection records (e.g. Morgan 1988; Ponniah & Hughes 2004; Shull et al. 2005; J. Coughran 2008 unpub; R.M. McCormack 2008 unpub). Calculated using GeoCAT (Bachman et al. 2011). |
| A00 is a standardised spatial measure of the risk of extinction, that represents the area of suitable habitat known, inferred or projected to be currently occupied by the taxon. It is estimated using a 2 x 2 km grid to enable comparison with the criteria thresholds. The resolution (grid size) that maximizes the correlation between A00 and extinction risk is determined more by the spatial scale of threats than by the spatial scale at which A00 is estimated or shape of the taxon's distribution. It is not a fine-scale estimate of the actual area occupied. In some cases, A00 is the smallest area essential at any stage to the survival of existing populations of a taxon (e.g. breeding sites for migratory species). | | | | |
| Trend | Stable | | | Sites in the historical area of record (Morgan 1988) remain occupied by the species (Ponniah & Hughes 2004; Shull et al. 2005; Coughran unpub. 2008; McCormack 2008 unpub). |
| Number of subpopulations | 6 | | | All records of the species are from 6 distinct non-connected streams/gullies, which are treated as subpopulations. The subpopulations occurring across Alterton Tableland west of Cairns, The Bellenden Ker Range, Russell River, Mulgrave River, Davies Creek and Kauri Creek areas. |
| Trend | Stable | | | As above. |
| Basis of assessment of subpopulation number | Distance and unsuitable habitat between the subpopulations means there is little chance of regular geneflow among them. | | | |
| No. locations | 1 | | | A series of surveys of the type locality and environs have established the species is restricted to a single threat defined location (e.g. Morgan 1988; Ponniah & Hughes 2004; Shull et al. 2005; Coughran 2008; McCormack 2008 unpub). |
| Trend | Stable | | | |
| Basis of assessment of location number | All known sites for the species are adjacent each other within a small geographic range, with an extreme weather event driven by climate change (e.g. severe heatwave, flood, fire) could plausibly lead to loss of the entire population in a single event. | | | |
| Fragmentation | There is not sufficient data to establish if the subpopulations can be considered to be severely fragmented. | | | |
| Fluctuations | Not known to be subject to any fluctuations in E00, A00, number of subpopulations, locations or mature individuals. | | | |

Criterion 1 Population size reduction

| Reduction in total numbers (measured over the longer of 10 years or 3 generations) based on any of A1 to A4 | | | |
|---|--|--------------------------------|-------------------------------------|
| | Critically Endangered Very severe reduction | Endangered Severe reduction | Vulnerable Substantial reduction |
| A1 | ≥ 90% | ≥ 70% | ≥ 50% |
| A2, A3, A4 | ≥ 80% | ≥ 50% | ≥ 30% |
| <p>A1 Population reduction observed, estimated, inferred or suspected in the past and the causes of the reduction are clearly reversible AND understood AND ceased.</p> <p>A2 Population reduction observed, estimated, inferred or suspected in the past where the causes of the reduction may not have ceased OR may not be understood OR may not be reversible.</p> <p>A3 Population reduction, projected or suspected to be met in the future (up to a maximum of 100 years) [(a) cannot be used for A3]</p> <p>A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.</p> <p style="text-align: right;">Based on any of the following</p> <ul style="list-style-type: none"> (a) direct observation [except A3] (b) an index of abundance appropriate to the taxon (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat (d) actual or potential levels of exploitation (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites | | | |

Criterion 1 evidence

Insufficient data to determine eligibility

There is insufficient data to determine eligibility of *E. balanensis* for listing under Criterion 1. The population has not been monitored since its original description. However, a series of collection records from published and unpublished surveys are known in the region, including adjacent to the type locality (Ponniah & Hughes 2004; Shull et al. 2005; J. Coughran 2008 unpub; R.M. McCormack 2008 unpub).

It is projected that there will be a future reduction in population size of *E. balanensis* due to the impacts of climate change. This species, and other likely cool-adapted species of crayfish, do not have the capacity to adapt to the current or projected rates of warming (Bone et al. 2014) (see Threats Table 1 above). A decline in Area of Occupancy (AOO), Extent of Occupancy (EOO) and quality of habitat is anticipated due to climate change as increasing temperatures and reduced moisture availability, especially in the soil, displaces flora and fauna upslope, including the rainforest in which the species is found.

The species' highly restricted distribution, at one location, leaves it vulnerable to extinction from events such as extreme flooding or disease, fires, or other threats (see Criterion 2 below). However, there are no population data to support such an assessment at the present time, with the population size of the species unknown, making it difficult to quantify any previous or likely future changes in the population.

There is insufficient information to determine the eligibility of the species for listing in any category under this criterion.

Criterion 2 Geographic distribution as indicators for either extent of occurrence AND/OR area of occupancy

| | Critically Endangered Very restricted | Endangered Restricted | Vulnerable Limited |
|---|--|--------------------------|--------------------------|
| B1. Extent of occurrence (EOO) | < 100 km ² | < 5,000 km ² | < 20,000 km ² |
| B2. Area of occupancy (AOO) | < 10 km ² | < 500 km ² | < 2,000 km ² |
| AND at least 2 of the following 3 conditions: | | | |
| (a) Severely fragmented OR Number of locations | = 1 | ≤ 5 | ≤ 10 |
| (b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals | | | |
| (c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals | | | |

Criterion 2 evidence

Eligible under Criterion 2 B1ab(iii,v)+B2ab(iii,v) for listing as Endangered.

Extent of occurrence (EOO) and area of occupancy (AOO)

Euastacus balanensis is restricted to habitat in six small streams in the highland rainforests to the East and South of Cairns in Far North Qld. A series of surveys (i.e. J. Coughran 2008 unpub; R.B. McCormack 2008 unpub) confirmed the highly restricted distribution of this species: EOO = 461 km² and AOO = 36 km². The EOO meets the threshold for listing as Endangered under Criterion B1 and the AOO meets the threshold for listing as Endangered under Criterion B2.

Euastacus balanensis is evidently a stream dwelling crayfish; the species occupies small tropical headwater streams (e.g., Morgan 1988; J. Coughran 2008 unpub; Coughran & Furse 2010) that may be perennial due to the typically very high rainfalls in the region. High altitude stream habitat of this type is not common in the rainforests of Far North Qld. This increases the risk of species extinction, with a large-scale meta-analysis by Bland (2017) reporting that small range size is the single most important factor that influence extinction risk in freshwater crayfish.

Number of locations

Euastacus balanensis has been recorded from six sites (all >700 m a.s.l), which are assessed as one threat-defined location (IUCN Standards and Petitions Committee 2024), meeting the threshold for listing as Critically Endangered under subcriterion (a). The proximity of the sites to each other is an important consideration. Sites that are close experience similar conditions over time (e.g., weather, temperature) compared to sites that are at greater distance from each other. Therefore, the major threats to this species, especially those associated with climate change (such as increased temperature), are likely to be experienced in a relatively uniform fashion across the entire range of this species, with the likelihood of any habitat providing refuge from adverse conditions reduced to zero. Some species of *Euastacus* have been identified as having

limited tolerance to abiotic changes (Lowe et al. 2010; Bone et al. 2014; Bone et al. 2017) and are susceptible to ongoing declines in habitat through climate change (Bruna 2004).

The isolation of this species to the headwaters of streams at high altitudes (>700 m a.s.l) increases the risk of extirpation of any individual subpopulations through environmental and demographic stochasticity (Bruna 2004; De Castro & Bolker 2005). Therefore, current and future threats could potentially rapidly eliminate all individuals in the taxon.

Continuing decline

By 2070, mean annual temperature in the Wet Tropics bioregion of Queensland is expected to increase by 1–2°C (RCP 4.5) to 1.9–3.1°C (RCP 8.5) (Syktus et al. 2020). This is likely to lead to altitudinal compression of the species' habitat, as there is limited scope for up slope migration by *E. balanensis*. It is also unlikely that the species can migrate to other suitable habitat further south of its current range as this would involve moving through the warmer valleys that surround the mountain tops inhabited by the species (Rainforest CRC 2003). Furthermore, climate change is projected to increase bushfire risk making rainforest habitat more prone to burning (as was the case during the 2019–20 bushfire season) thereby reducing the availability of suitable habitat.

It is projected that there will be a decline in area, extent and/or quality of habitat due to impacts of climate change (principally increasing temperature, and reduced moisture availability) satisfying subcriterion (b)(iii). Additionally, a decline in the number of mature individuals due to impacts from intense weather events such as heatwaves, plus more frequent and intense fires is projected, also satisfying subcriterion (b)(v).

Conclusion

The species' Extent of Occurrence (EOO) is highly restricted, the species occurs at only one location, and a continuing decline is projected in the area, extent and/or quality of habitat and number of mature individuals. Therefore, the species has met the relevant elements of Criterion 2 to make it eligible for listing as **Endangered**.

Criterion 3 Population size and decline

| | Critically Endangered Very low | Endangered Low | Vulnerable Limited |
|--|---|--|---|
| Estimated number of mature individuals | < 250 | < 2,500 | < 10,000 |
| AND either (C1) or (C2) is true | | | |
| C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future) | Very high rate 25% in 3 years or 1 generation (whichever is longer) | High rate 20% in 5 years or 2 generation (whichever is longer) | Substantial rate 10% in 10 years or 3 generations (whichever is longer) |
| C2. An observed, estimated, projected or inferred continuing decline AND its geographic distribution is precarious for its survival based on at least 1 of the following 3 conditions: | | | |
| (a) (i) Number of mature individuals in each subpopulation | ≤ 50 | ≤ 250 | ≤ 1,000 |
| (a) (ii) % of mature individuals in one subpopulation = | 90 – 100% | 95 – 100% | 100% |
| (b) Extreme fluctuations in the number of mature individuals | | | |

Criterion 3 evidence

Insufficient data to determine eligibility

There are no estimates of numbers of mature individuals or any population-decline data that will allow assessment of *E. balanensis* for eligibility for listing under Criterion 3.

The data presented suggest that there are **insufficient data** to demonstrate if the species is eligible for listing under this criterion.

Criterion 4 Number of mature individuals

| | Critically Endangered Extremely low | Endangered Very Low | Vulnerable Low |
|--|--|------------------------|--|
| D. Number of mature individuals | < 50 | < 250 | < 1,000 |
| D2.¹ Only applies to the Vulnerable category Restricted area of occupancy or number of locations with a plausible future threat that could drive the species to critically endangered or Extinct in a very short time | | | D2. Typically: area of occupancy < 20 km ² or number of locations ≤ 5 |

¹ The IUCN Red List Criterion D allows for species to be listed as Vulnerable under Criterion D2. The corresponding Criterion 4 in the EPBC Regulations does not currently include the provision for listing a species under D2. As such, a species cannot currently be listed under the EPBC Act under Criterion D2 only. However, assessments may include information relevant to D2.

Criterion 4 evidence

Eligible under Criterion 4 D2 for listing as Vulnerable.

There are insufficient data to assess *Euastacus balanensis* against the thresholds for listing under Criterion D1 as there is little information available to determine a robust estimate of the number of mature individuals. However, the species does qualify under Criterion D2 as Vulnerable (VU). This is because it is found in one location, and the combined threats of enhanced climate change, bushfires and feral predators could drive the species towards extinction in a short timeframe. The isolation of this species to the headwaters of streams at high altitudes (>700 m a.s.l) increases the risk of extirpation of any individual subpopulations through environmental and demographic stochasticity (Bruna 2004; De Castro & Bolker 2005). Therefore, current and future threats could potentially rapidly eliminate all individuals in the taxon.

Criterion 5 Quantitative analysis

| | Critically Endangered Immediate future | Endangered Near future | Vulnerable Medium-term future |
|--|--|--|----------------------------------|
| Indicating the probability of extinction in the wild to be: | ≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.) | ≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.) | ≥ 10% in 100 years |

Criterion 5 evidence

Insufficient data to determine eligibility

Population viability analysis has not been undertaken. Therefore, there is insufficient information to determine the eligibility of the species for listing in any category under this criterion.

Adequacy of survey

The survey effort for this assessment is appropriate (i.e. 2004, 2005, 2008) and there is sufficient published scientific evidence to support this assessment.

DRAFT