Distribution, ecology and cultural importance of Gunurru or Cable Beach Ghost Gum *Corymbia paractia* in the Broome area, Western Australia

S. Reynolds, L. Beames, T. Willing, C. Parker

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This report has been prepared by Environs Kimberley staff in collaboration with the traditional owners of the Broome area, the Yawuru people, through Nyamba Buru Yawuru (NBY). The project was assisted by volunteers from Society for Kimberley Indigenous Plants and Animals (SKIPA), funded by Eucalypt Australia with support from the State NRM WA.

Corymbia paractia location data have been provided to the Western Australian Department of Parks and Wildlife, Species and Communities Branch (now Parks and Wildlife Service, Threatened Species and Communities Branch).

For further information on the cultural importance of sites, plants and animals in the Broome area contact the Nyamba Buru Yawuru Land and Sea Unit.

For further information about *Corymbia paractia* contact the Kimberley Nature Project (KNP) at Environs Kimberley, or NBY:

Kimberley Nature Project knp@environskimberley.org.au
Environs Kimberley Ph: (08) 9192 1922

Julie Melbourne
Land and Sea Manager julie.melbourne@nby.org.au
Nyamba Buru Yawuru Ph: (08) 9192 9600

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Summary

The Cable Beach Ghost Gum *Corymbia paractia* is listed as a Priority One flora species while '*Corymbia paractia* dominated community on dunes' is listed as a Priority One Ecological Community (PEC) in Western Australia. *Corymbia paractia* is endemic to the Kimberley region of Western Australia and restricted to the Broome Peninsula and immediate vicinity. The location of many individual trees and patches on the Broome Peninsula was mapped in previous surveys (Willing and Beames, 2015). This project extended the mapping to inland sub-populations to the north and south of the Broome Highway. More than 2800 individual trees have now been mapped over at least 419 hectares of *C. paractia* habitat. Environs Kimberley has also worked with Yawuru people to document eco-cultural information. This information alongside the survey work provides an enhanced understanding of the ecology of *C. paractia*.

Species distribution modelling indicated that *C. paractia* may once have occurred across 10,644 hectares. More simply, drawing a polygon around remaining mapped populations suggests that the original population covered at least 7200ha. By analysing the 2012 DAFWA Native Vegetation Extent database we can determine that more than 1500 hectares (possibly as high as 1668 hectares) of *C. paractia* has been cleared within the Broome township area and minor additional losses have occurred out of town through clearing for quarries and roads. Changes to fire regimes, subtle changes in climate and rainfall, introduced herbivores and other historical clearing events have likely contributed to further contraction of the original range of *C. paractia*. Further losses are anticipated with the expansion of the town and the development of the Broome Road Industrial Area, which includes c.180 ha of dense *C. paractia* habitat.

Using the modelled extent, up to 33.6% of remnant habitat is contained within the Birragun Buru Conservation Estate, Guniyan Buru Conservation Park and Minyirr Buru Conservation Estate. Ground-truthing unsurveyed areas within this 3,013 hectare range will determine the quality and quantity of *C. paractia* that is protected within these conservation areas.

C. paractia is mainly confined to a relatively narrow coastal zone, where beach dunes merge into pindan soils, with some patches occurring across the Peninsula. The coastal sub-population is typical of the PEC denoted as '*Corymbia paractia* dominated community on dunes'. Inland *C. paractia* occur in a broad arc to the east of Buckley's Plain and then south of the Broome Highway in the zone designated as the Broome Road Industrial Area. The northern limit is near Coconut Wells and the south-eastern limit along the Crab Creek Road.

Although differences in plant form (particularly height and erectness) exist between the inland and coastal sub-populations, the sub-populations appear to be contiguous. We now have a comprehensive picture of the distribution of *C. paractia,* with some minor gaps in our knowledge of the boundaries.

There is partial overlap of *C. paractia* with the Wrinkle-leaf Ghost Gum *Corymbia flavescens* in the Wattle Downs and Crab Creek Road areas as well as near Coconut Wells. The Weeping Ghost Gum *Corymbia bella* occurs to the north, and there may be no overlap, with a gap between *C. paractia* on Buckley's Plain and *C.bella* at Nimalaragan.

Modelling indicates that the limits to distribution are linked to the GIS layers depth to regolith and surface geology, with limited influence of slope and relief in what is a fairly subdued landscape. The implication is that the depth of groundwater may limit the plants' range, the estimated depth to regolith being 32 m at the eastern edge of the distribution.

Approximately 60 species of native plants were recorded in association with *C. paractia.* The large *C. paractia* trees often provided shaded canopies that acted as nurseries within the pindan mosaic. Fire is a factor in the pindan and long fire intervals may be necessary for successful establishment of *C. paractia* trees.

The most common weed recorded was Neem *Azadirachta indica,* which was often found growing under and into the canopy of *C. paractia* trees. Buffel Grass *Cenchrus ciliaris* and Stinking Passion Flower *Passiflora foetida* were moderately common.

Traditionally, the bark is used to make coolamons and burn for ash, and the wood for fuel. Flowering is a seasonal indicator. Remnant trees that are culturally important to the Yawuru people occur in the Broome townsite. Elders confirmed that several stands of trees in the town area had been lost, including some near Town Beach and the Oaks, in the area of Hamersley Street, and in the 'back hospital' area near Dora Street.

Our examination of the threatening processes, including weed invasion and inappropriate development, has led us to recommend that the community be listed in Western Australia as a Threatened Ecological Community in the category of Vulnerable.

We also recommend that, following further mapping and quality assessments, an EPBC Act (1999) nomination once again be submitted for *C. paractia* species and/or community, this time under the category of Vulnerable and not grouped with other Eucalypt species or ecosystems.

Mapping of the Cable Beach Ghost Gum was undertaken by Environs Kimberley in partnership with Nyamba Buru Yawuru and others, throughout the Broome Peninsula and immediate vicinity.

Introduction

The Cable Beach Ghost Gum *Corymbia paractia* is a highly restricted species: Priority One flora species in the State of Western Australia. It is endemic to the Broome Peninsula and immediate vicinity. This Priority Ecological Community (PEC) '*Corymbia paractia* dominated community on dunes' is also listed as a Priority One (P1) Ecological Community in Western Australia.

An Ecological Community is defined by the Government of Western Australia as 'A naturally occurring biological assemblage that occurs in a particular type of habitat.' Priority One PECs are 'Poorly-known ecological communities' and are described as follows:

> 'Ecological communities that are known from very few occurrences with a very restricted distribution (generally ≤5 occurrences or a total area of ≤ 100ha). Occurrences are believed to be under threat either due to limited extent, or being on lands under immediate threat (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) or for which current threats exist.'

Priority One flora species are listed by the Government of Western Australia as they are considered to be potentially threatened but are poorly known, do not meet the survey criteria and are generally data deficient. Priority One species are described as follows:

> 'Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.'

The Cable Beach Ghost Gum was thought to be restricted to a relatively narrow coastal zone in the Broome area where beach dunes merge into pindan soils (Hill and Johnson, 1995; Kenneally et al.,1996). Previous surveys throughout the Broome Peninsula identified a series of 63 patches (Willing and Beames, 2015). Most of these trees were recorded in the transition zone between coastal dunes and pindan soils and vegetation; however, some trees were found up to 1.5 km from the coast in the middle part of the Peninsula.

Willing and Beames (2015) reported that:

> 'on the northern outskirts of Broome there is an impressive savanna woodland of large, scattered *C. paractia* trees….'

Willing and Beames (2015) recommended that this area be subject to further survey and mapping. In this report we have mapped the extent of *C. paractia* sub-populations north and south of the Broome Highway and combined both datasets to produce current distribution maps.

Ghost Gums are known by Yawuru people as Gunurru. Flower-buds form during larja (build-up season) and flower clusters are produced mainly during the early part of man-gala (rainy season), usually in December. We conferred with local Yawuru people about cultural aspects of *C. paractia,* and Nyamba Buru Yawuru staff participated in field survey work.

The Weeping Ghost Gum *C. bella* occurs north of Broome and the Wrinkle-leaf Ghost Gum *C. flavescens* to the south and east. Part of the purpose of this project was to document overlap or boundaries with adjacent Ghost Gum species.

Objectives

The objectives of this project were to:

- Map *C. paractia* patches in inland (sub-coastal) areas north-east of Broome
- Collate information from all surveys
- Identify the distribution and extent of *C. paractia* using field data and other means
- Delimit boundaries and areas of overlap between populations of *C. paractia* and sympatric *C. flavescens* and *C. bella.*
- Work with Yawuru people to document eco-cultural values of *C. paractia*
- Enhance the understanding of *C. paractia* ecology, species interactions and threats
- Assemble recommendations to guide the protection, conservation and management of the *C. paractia* community.

Methods

The dataset for this report is based on surveys conducted in the following four locations and survey periods:

- Broome Peninsula: T. Willing with support from C. Howe-Piening and P. Docherty (November 2013 to April 2014).
- Crab Creek Road to Broome Bird Observatory: T. Willing and Yawuru Parks and Wildlife Rangers (2015).
- Broome Highway and Broome Road Industrial Area: S. Reynolds and SKIPA volunteers: P. Mitchell, K. Weatherall, A. Moss, A. McCosh, S. Fletcher and D. Bennett (October-November 2016)
- Coconut Wells, Cape Leveque Road, Buckley's Plain, Broome Highway, Livestock track, Broome Road Industrial Area and old Wattle Downs station: T. Willing with assistance from Environs Kimberley staff and Nyamba Buru Yawuru (NBY) Country Managers J. Smith, E. Maher, J. Mamid, and P. Gregory Jr., along with J. Edgar, N. Gregory and C. Parker (December 2016).

Methods for all surveys were similar to those adopted by Willing and Beames (2015). Potentially suitable areas for *C. paractia* were identified based on aerial photography and local knowledge. Traverses were made through bushland along vehicle tracks and by walking through areas searching for eucalypt trees. A map of the general area including major roads and landscape features is provided in Figure 1.

The location of each *C. paractia* specimen was recorded with a hand-held GPS device. Information recorded (in most cases) included the height, overall shape, the presence of buds, flowers or fruit, native plant associates or weeds present under the canopy, other threats, and in some cases condition of the tree, leaf and bark phenology, and fauna species present. Photos were taken of some trees.

Surveys were largely confined to the larja (build-up) season in November and December 2016 when Ghost Gums come into flower. Identification can be made with certainty only when the trees are in bud, as there is significant variation between individual *C. paractia* trees and occasionally between leaf shapes on a single tree. The narrow, flute-shaped buds of *C. paractia* are arranged in clusters on thin stalks and have characteristic cream-coloured caps. In comparison, the Wrinkle-leaf Ghost Gum *C. flavescens* has wider, pink-capped flower buds while the Weeping Ghost Gum *C. bella* has cup-shaped buds (Figure 2) and is easily distinguished from *C. paractia* by its weeping foliage

Voucher specimens were taken to verify identifications and provide a permanent record. Vouchers of *C. paractia* and *C. flavescens* were taken as well as possible hybrids and unusual variants. These specimens were supplied to the WA Herbarium by T. Willing.

GPS locations were plotted on Google Earth, using the GIS program ArcGIS.

To correspond with the methodology used by Willing and Beames (2015) and in order to identify the area and extent of each of the distinct *Corymbia paractia* community patches, an arbitrary 50m buffer was plotted from the outermost individual trees.

Species distribution modelling using Maxent (maximum entropy method; Phillips et al., 2006; Franklin 2009; Elith et al. 2010), which is based on the environmental conditions of sites of known occurrence, was applied to the *C. paractia* presence data overlaid with GIS layers.

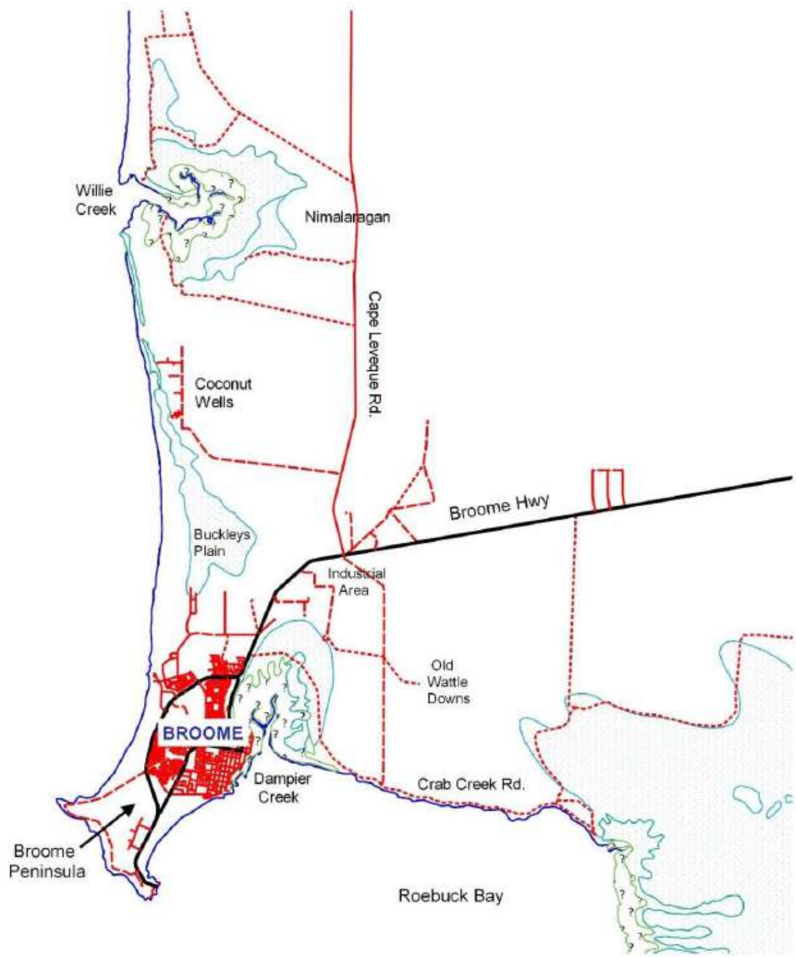

Figure 1. Location of areas and roads mentioned in the report.

Figure 2. The generalised bud shapes of *C. paractia, C. flavescens* and *C. bella.*

Results

As part of the Broome Peninsula mapping conducted by Tim Willing in 2013–2014, a total of 2,095 *C. paractia* trees were recorded across 63 discrete community patches with a further 55 individual trees mapped within the Broome townsite area (Willing and Beames, 2015).

The 2015–16 surveys included traverses along the Broome Highway, up the Cape Leveque Road as far as Nimalaragan Dam, the area of Coconut Wells, the east side of Buckley's Plain, along Crab Creek Road and the Livestock track, the old Wattle Downs area (Figure 3), and throughout the south-west portion of the industrial area (Figure 4). In the previous report (Willing and Beames, 2015) the search area included almost the entirety of bushland areas in the Broome area; in the south-west portion of the Peninsula almost every tree was mapped.

In the Coconut Wells, Cape Leveque Road and Buckleys Plain area, 192 trees were mapped. Along the Broome Highway, old Wattle Downs and Crab Creek Road area 88 trees were mapped. In the Broome Road Industrial Area, a total of 518 trees were individually mapped. This is a total of 798 *C. paractia* trees recorded during the 2015-16 surveys. 72 community patches have been demarcated, defined by 50m buffers around the presence of two or more *C. paractia* trees and a further 70 individual trees also defined by 50m buffers. As a result, a further 167.81 hectares of *C. paractia* is now confirmed within the Broome area, taking the total known area of *C. paractia* to 419.16 hectares.

There were also 29 *Corymbia flavescens* and 3 *C. bella* recorded, along with other tree and shrub species.

Figure 3. Search area for *Corymbia paractia* during 2016 surveys, showing traverses.

Figure 4. Traverses in the central-southern part of the search area during 2016 surveys. Industrial area at centre.

Distribution

The 2015–16 mapping effort provides an enhanced understanding of the current and past distribution of *C. paractia,* with some knowledge gaps remaining around the variation in population densities and some boundaries (refer to discussion). The known distribution of the Cable Beach Ghost Gum is outlined in Figure 5. From north to south the population extends from just south of the settlement of Coconut Wells, in a wide band along the east side of Buckley's Plain to areas north of the Highway and east to the Cape Leveque Road. There is a relatively large grouping of *C. paractia* patches in the Broome Road Industrial Area that extends south and east to the rear of Dampier Creek marshlands and east to Old Wattle Downs. *Corymbia paractia* does not appear to spread far along the Crab Creek Road to the east, where it is replaced by *C. flavescens*.

All surveyed Ghost Gums along Broome Highway east of the Cape Leveque turnoff that occur on both sides of the highway as far as Twelve Mile are *C. flavescens* (Figure 6). At the start of the Cape Leveque Road, there is a small overlap area – mainly *C. paractia* but with occasional *C. flavescens*. There is a possible hybrid with red bud-caps north-west of the telecommunications tower.

There are scattered patches of both *C. flavescens* and *C. paractia* on the firebreak between Wattle Downs and the Bird Observatory (Figure 6). It appears that *C. paractia* and *C. flavescens* do not overlap in the vicinity of Crab Creek Road. Near the clifftop T-junction and for about three kilometres east, trees are all *C. paractia*, while scattered *C. flavescens* occur east of the Broome Bird Observatory towards One Tree. Samples from GPS-located specimens of *C. paractia* in this population have been lodged at the WA Herbarium, Perth.

Corymbia bella occurs north of Coconut Wells and in the area of Nimalaragan Soak. This species is relatively common in near-coastal situations further north on the Dampier Peninsula. East of the Cape Leveque turnoff and extending in a line to the vicinity of the Broome Bird Observatory is *C. flavescens.* At Coconut Wells on the ridge/horticultural blocks, there is an overlap area where some Ghost Gums are *C. paractia* and some are *C. flavescens* (Figure 7).

Along the Cape Leveque Road, *C. paractia* does not extend north past the Coconut Wells turnoff (Figure 7). There is then a major gap (c. 4 kms or more) without any Ghost Gums. Descending the slope down to Nimalarragan Dam (inland of Willie Creek), all the Ghost Gums are *C. bella.*

The distribution of 2016–17 mapped trees and 50m buffer zone is shown in Figures 7–9. 72 patches were defined,that included 2 or more *C. paractia* trees. The remaining 70 patches were defined only by the 50m buffer area around a solitary tree. In total, 167.81 hectares of known *C. paractia* patches have been mapped.

As shown in Figure 10, the highest density of *C. paractia* per patch was 50 trees per hectare (Patch YK = 0.58 hectares), followed by neighbouring patch (YL=1.1 hectares) which contained 24.5 trees per hectare. The largest patch (YF=16.3 hectares) was in the Broome Industrial Area and had 8.4 trees per hectare. The next largest patch (YC=8.7 hectares) also in the Broome Industrial Area, had 13.8 trees per hectare. XML files of the patches and individual trees have been lodged with the Western Australian Department of Parks and Wildlife, Species and Communities Branch. A table of patch names, areas and tree densities is provided within Appendix 4.

The distribution of *C. paractia* patches with their associated communities on the Broome Peninsula has been described in detail by Willing and Beames (2015), and is presented in Figure 11. Although differences in form exist between the coastal and near coastal sub-populations, the sub-populations appear to be contiguous.

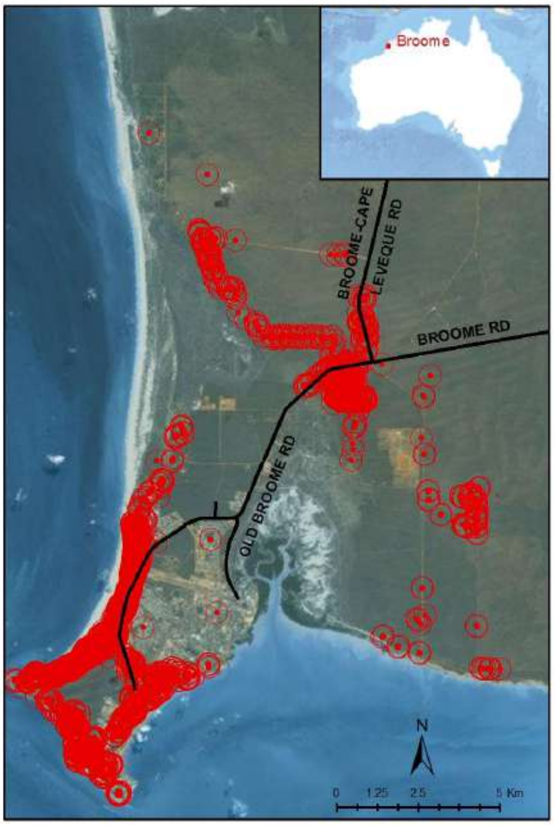

Figure 5. Mapped points indicating the known distribution of *Corymbia paractia.*

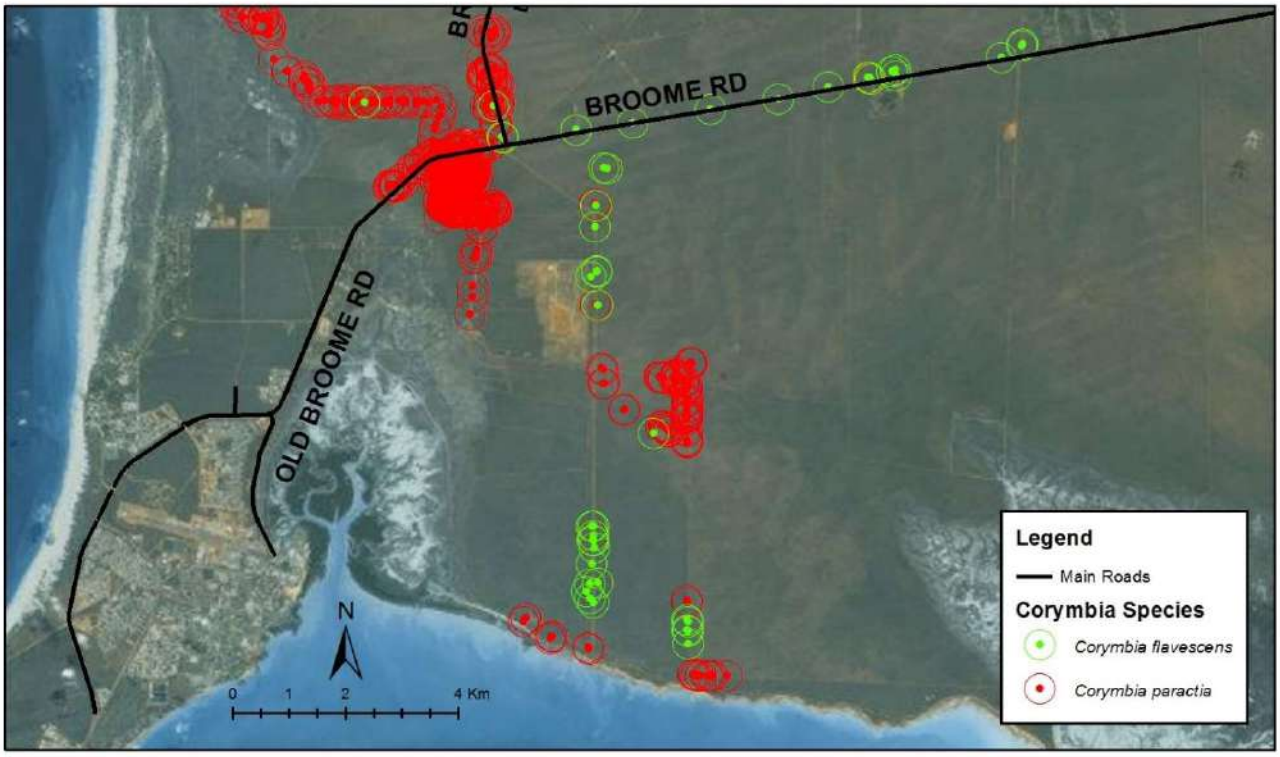

Figure 6. Mapped points in the southern inland distribution of *Corymbia paractia*. Recorded *Corymbia flavescens* are indicated in green.

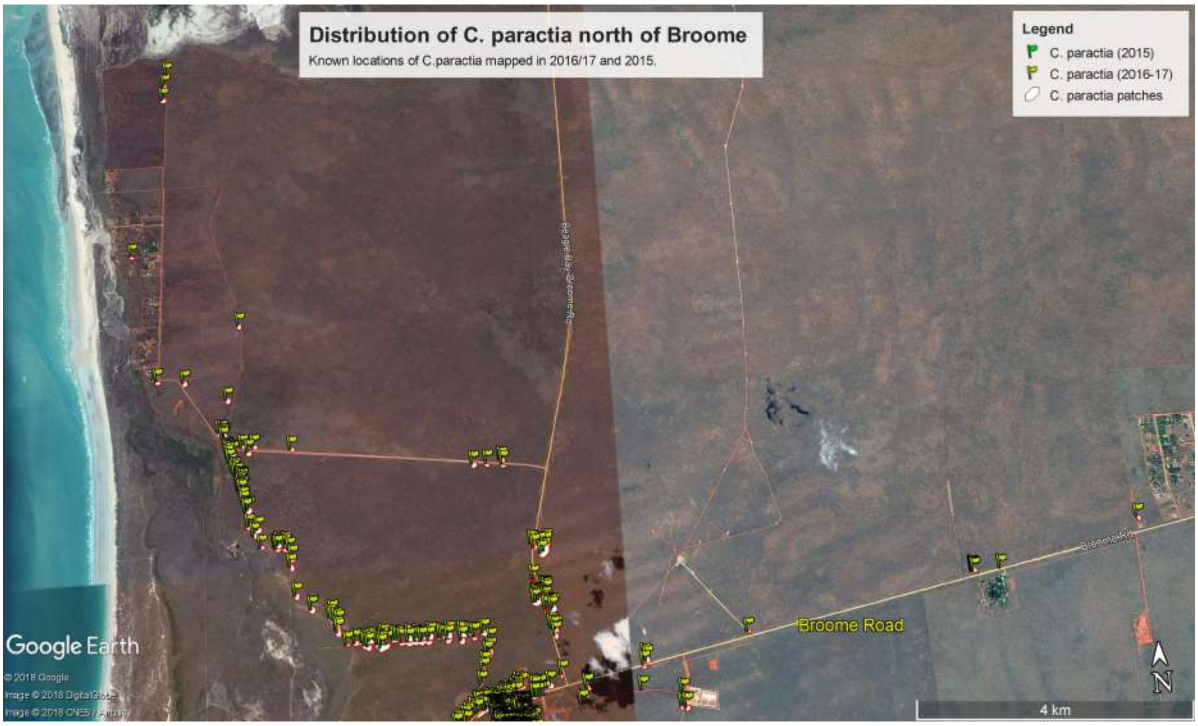

Figure 7. The distribution of *Corymbia paractia* north of Broome, as identified in 2016–17 surveys.

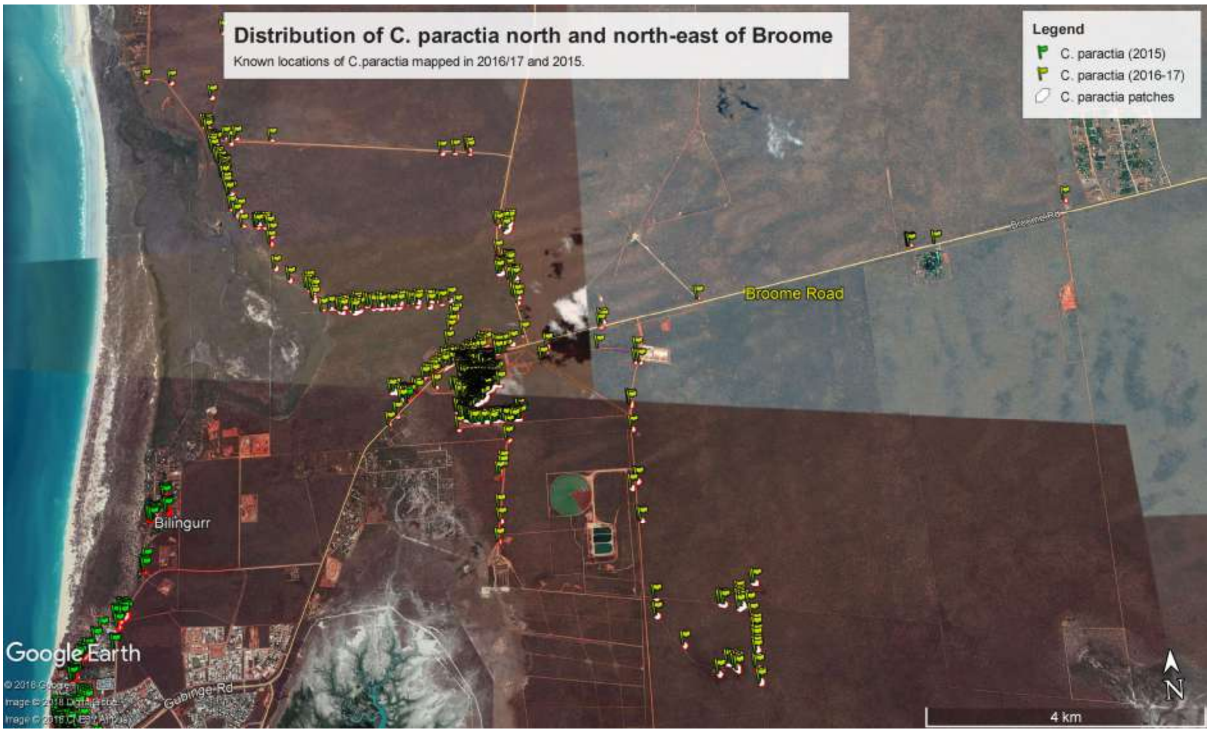

Figure 8. The distribution of *Corymbia paractia* north and north-east of Broome as identified in 2016–17 and 2015 surveys.

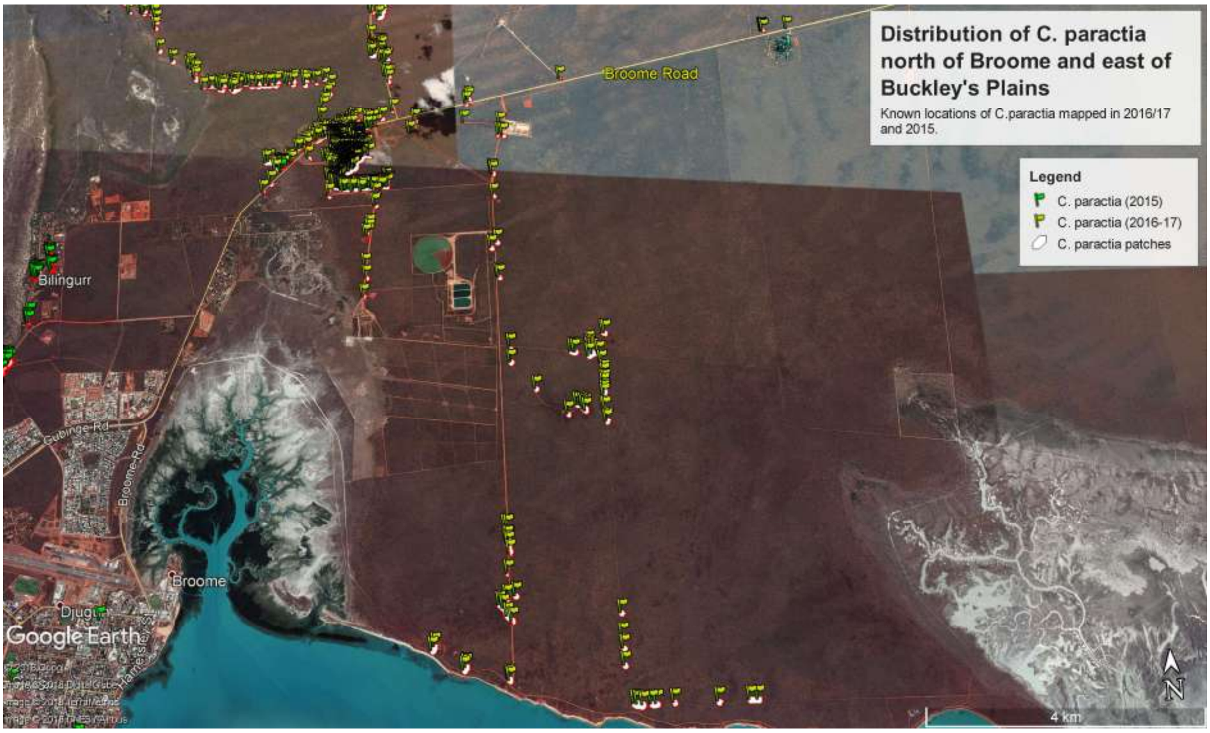

Figure 9. The distribution of *Corymbia paractia* north of Broome and east of Buckley's Plains as identified in 2016–17 and 2015 surveys.

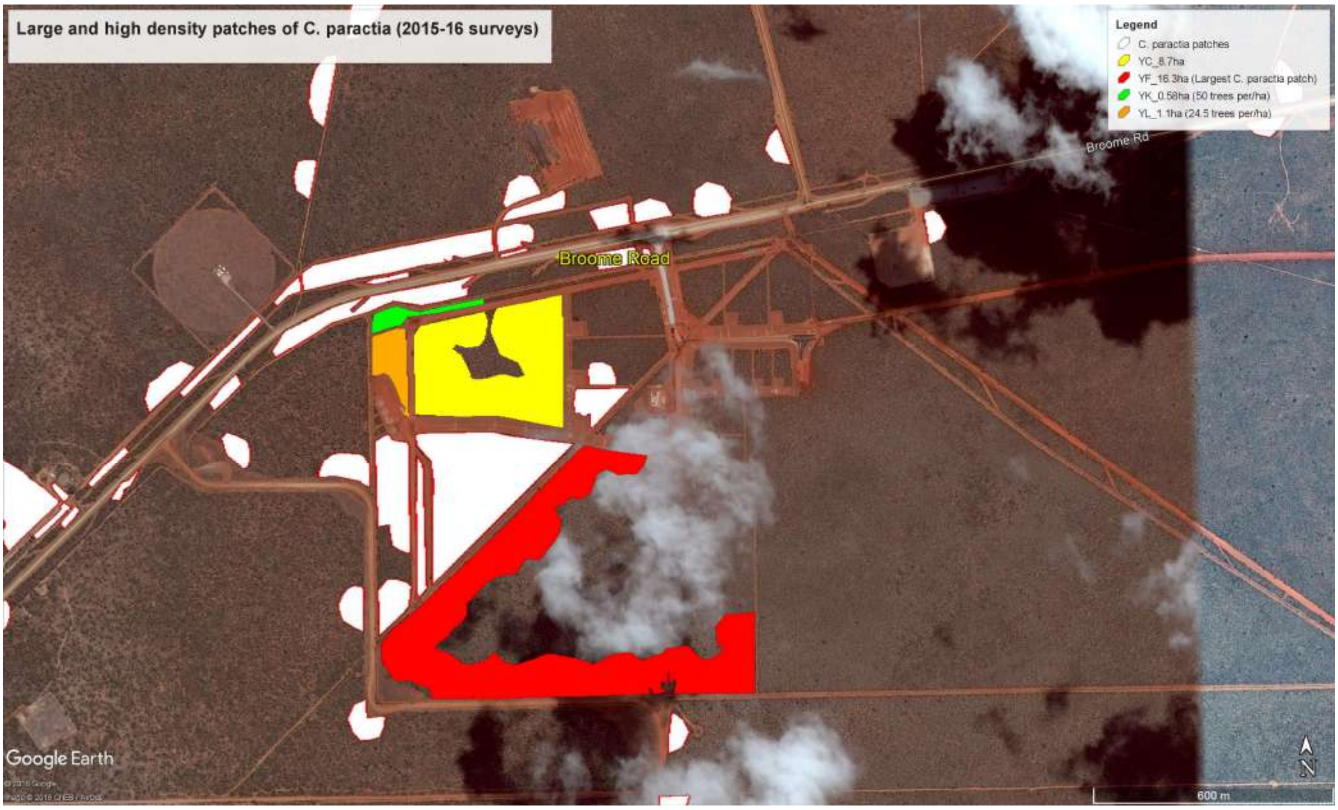

Figure 10. The highest density and largest *C. paractia* patches were found in the Broome Industrial Area. Patch YK, (green), had 50 trees per hectare while Patch YL, (orange), contained 24.5 trees per hectare. The largest patch, YF, (red) contains 138 trees across 8.7 hectares.

Figure 11. The distribution of *Corymbia paractia* on the Broome Peninsula using data from Willing and Beames (2015).

Dense populations occur along the east side of Buckley's Plain and to the north-east of Dampier Creek marshlands. In the industrial area tree size generally increases markedly from NW to SE.

Approximate densities of mapped *C. paractia* trees based on estimates from one hectare (100 x 100 m) squares using Google Earth are between 8 and 13 per ha on the Broome Peninsula east, between 23 and 27 per ha in the west (Minyirr Park), between 17 and 22 per ha in the Broome Road Industrial Area, and between 7 and 8 per ha in the northern part of Buckley's Plain. Distances between trees and thus densities vary greatly across the range.

Based on a polygon drawn around all mapped individual trees, *C. paractia* may once have been distributed over 7,200 ha (Figure 12).

The species distribution modelling indicated a limited relationship between environmental layers such as slope, relief, land systems and the broadscale vegetation mapping of Beard (1979) and the location of mapped *C. paractia*. Instead, the highest estimates of contributions to the model were for the GIS layers depth to regolith (61%) and surface geology (14.4%). Species distribution modelling suggests that the original distribution of Cable Beach Ghost Gum could have been up to 10,645 hectares (Figure 13).

Both Figure 12 and Figure 13 are likely to significantly overestimate the total extent of *C.paractia*. This is because they cover an area wider than where *C. paractia* is known to occur, and because the areas to the east of the distribution (e.g. east of Buckley's Plain and west of the Cape Leveque Road), where trees gradually thin out, remains poorly defined.

Figure 14, also produced using Maxtent, provides an indication of the probability of occurrence across the 95% confidence distribution envelope (10,317 hectares). There is a high probability that *C. paractia* occurs across 3,542 hectares and a moderate probability that *C. paractia* occurs across 5,370 hectares. There is only a low probability that *C. paractia* occurs across a further 1,406 hectares.

More than 1500 and possibly as much as 1668 hectares (>15%) of *C. paractia* habitat is estimated to have been lost since the Broome township was developed. Currently, about 33.6% of the remaining distribution is protected in parks and reserves including Birragun Buru Conservation Estate, Guniyan Buru Conservation Park and Minyirr Buru Conservation Estate (refer to Yawuru RNTBC 2011 for reserve boundaries).

Relatively minor losses have occurred through clearing for quarries (north of the Highway, c.5 ha) and around the ABC tower (c. 9 ha). Road construction for the Broome Highway, Cape Leveque Road, the livestock track and other roads and tracks has also resulted in the destruction of trees. Estimated losses from construction of the Broome Highway are 3 ha, based on an average road width of 15 metres. These losses have divided the once continuous vegetation community.

Other factors, such as Aboriginal fire management, are likely to have played a large role in the historical distribution and extent of *C. paractia*. Changes to the seasonal fire regimes, including the reduction and absence of managed burns and increases in hot, late-dry-season, large-scale fires, are likely to have contributed greatly to reductions to the original range of *C. paractia.* Introduced herbivores, weeds and climatic change will also have influenced the germination and establishment of *C. paractia* and will have played a role in the contraction of the original range.

Figure 12. Outline of the estimated former distribution of *Corymbia paractia* based on a polygon drawn around known occurrences. Question marks indicate remaining survey gaps.

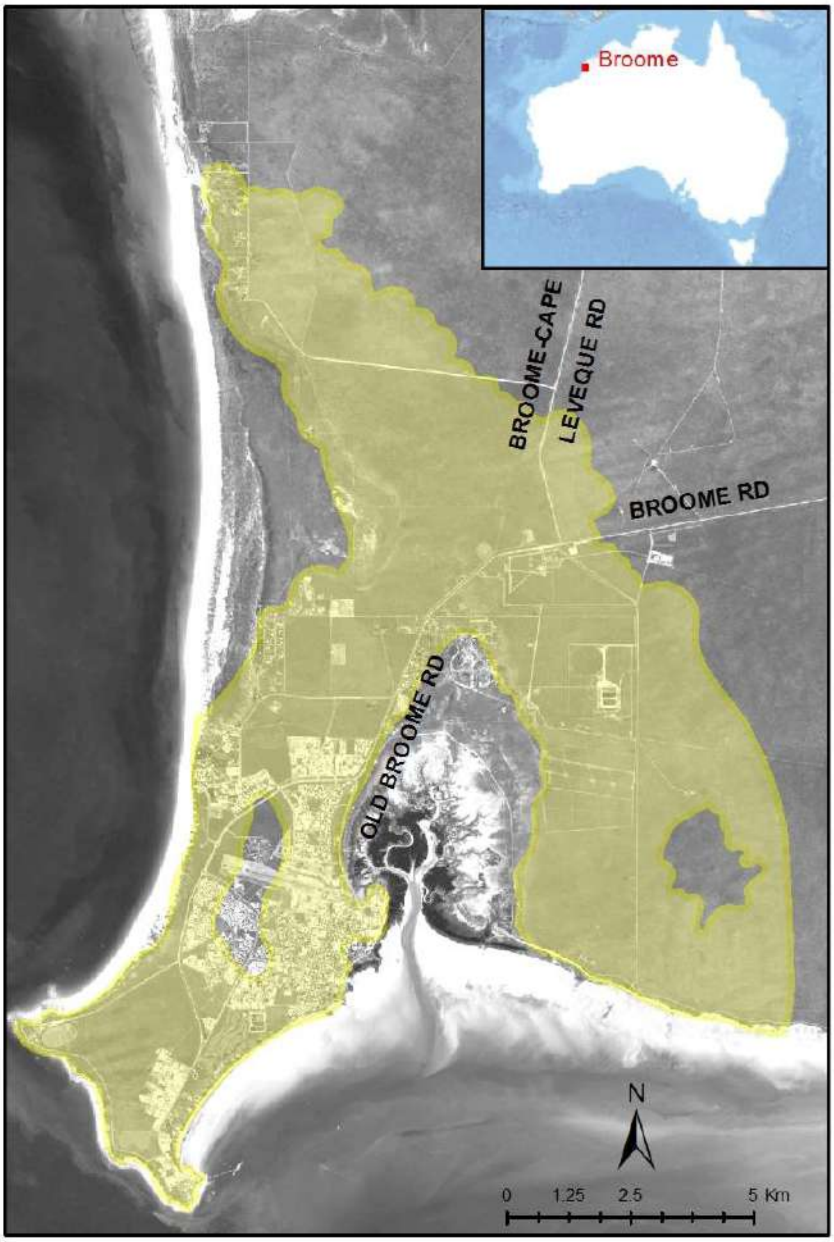

Figure 13. The possible historical extent of *Corymbia paractia* based on species distribution modelling.

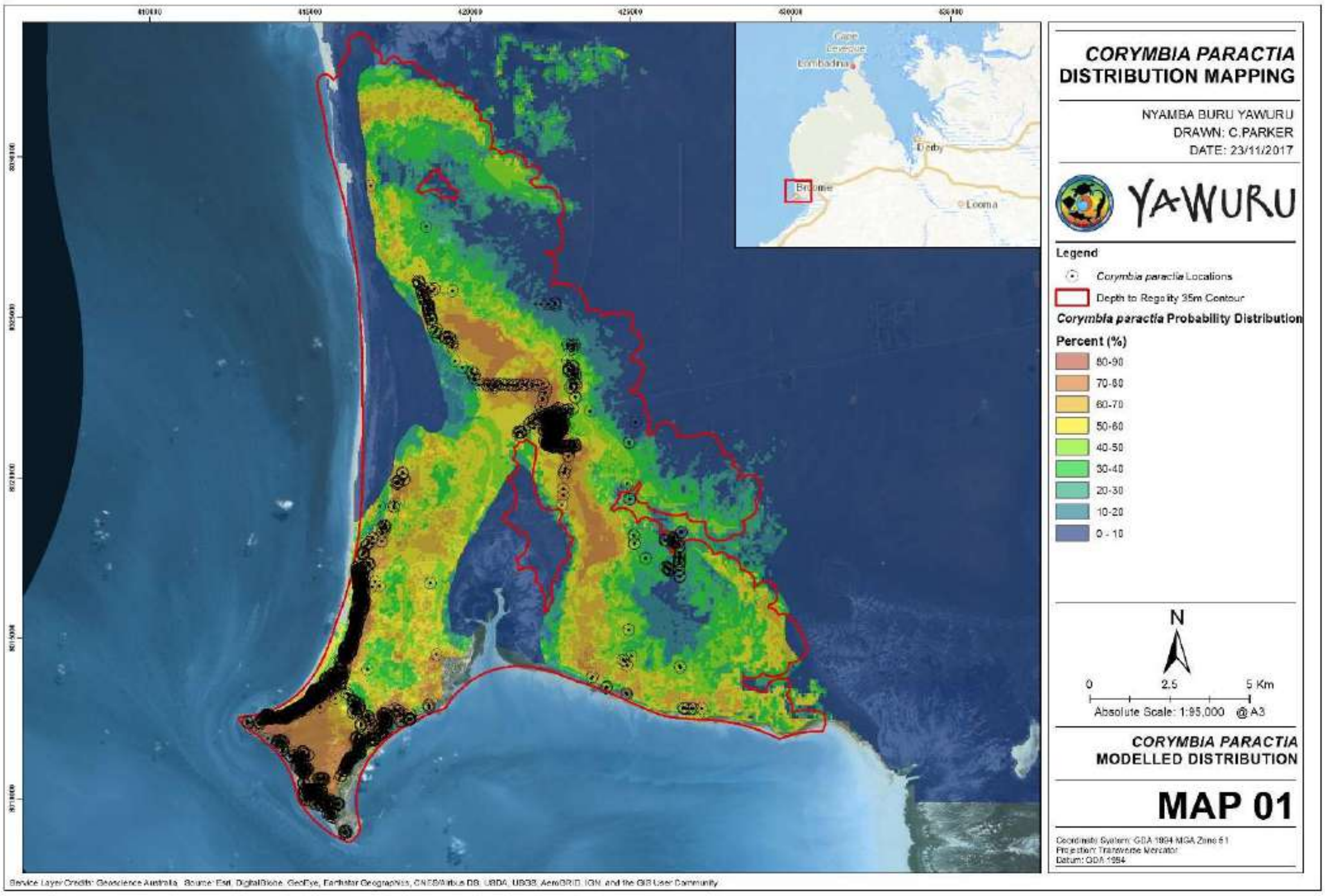

Figure 14. The probable occurrence of *Corymbia paractia* based on the presence of favourable environments and as indicated by known locations.

Biology

No buds were observed on *C. paractia* in early October (4th and 6th). The first buds were observed on the 18th October (2016). From the end of October through to early December most trees (>50%) had buds. Flowers were not observed until 1st December, when over half of the trees were in flower (Figure 15). Although there were no surveys in mid to late November, the data indicate that flowering began in late November. Occasional flowering trees were recorded in mid-December.

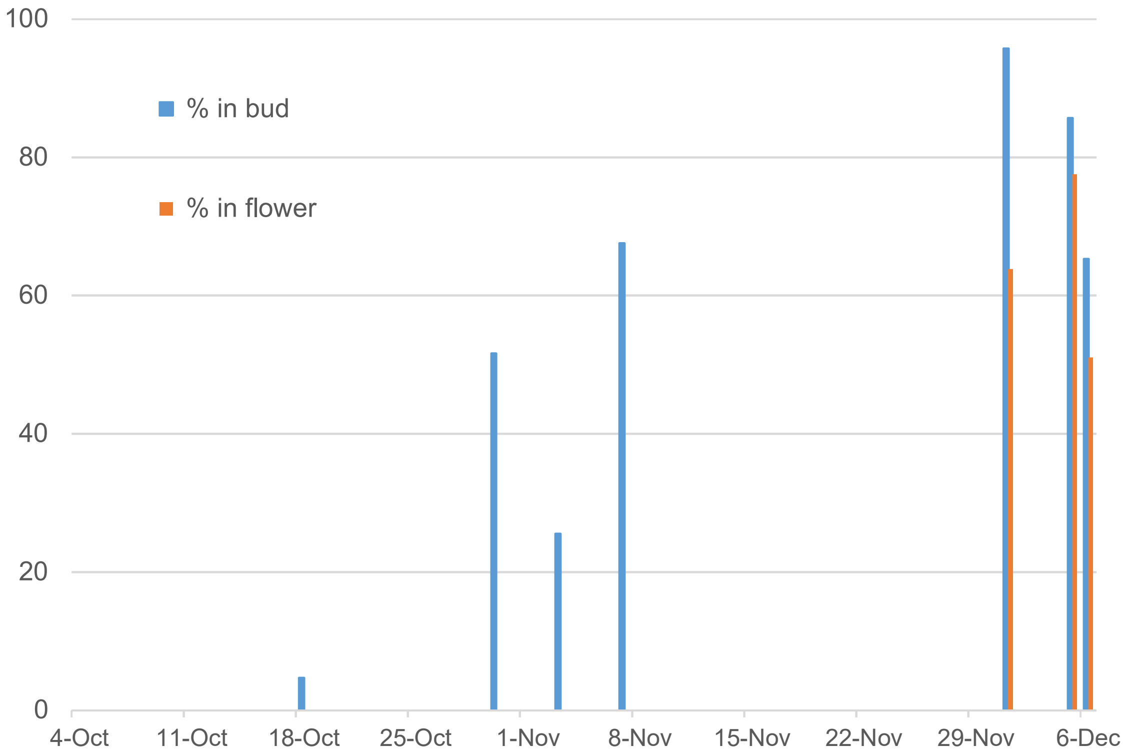

Figure 15. Flowering phenology of *Corymbia paractia* in 2016. There were no surveys in mid-to-late November.

Of the trees for which we recorded height data (n = 500), over half (56%) were 8m or less. As large trees are more likely to be spotted we expect there to be a survey bias towards large trees. Despite this, for the 500 trees where height data were recorded over half (56%) were 8m tall or less. This may reflect a healthy variation in age stands of *C. paractia* within its range and indicate that new trees are becoming established. We also observed that, unlike larger trees, smaller trees more frequently occurred in groups of 2,3 or more.

For the 220 trees of 9m or over (medium to large), most (91%) were 9 to 12m in height with only 19 trees (9%) 13m or above. There were several 15m trees and a single tree to 17m.

Any tree of 12m or above was considered large, and many of these had spreading canopies. In general, saplings grow upright to around six metres and then start to spread, but some trees up to 11m in height were relatively upright, and mature trees take many forms. It is unknown how long trees take to reach a height of eight metres or more, and for the spreading habit to develop. Trees in gardens that are watered regularly reach four metres in 3–4 years, but this process is likely to take much longer in the pindan, where rainfall is highly seasonal and access to groundwater is critical for growth.

Corymbia paractia are partially deciduous; many trees become relatively leafless and/or produce new leaves in October and November. During this period of leaf flush, new leaves are often red on some plants (Figure 16a).

There are various bark forms, and bark colour varies from deep grey to bright white (Figure 16b). Trees shed bark in hot weather (larja or build-up season) and 80% of trees in early December were shedding their bark. Recesses under shedding bark provide shelter for reptiles and invertebrates and the shed bark forms a layer of litter surrounding the tree. Fallen leaves contribute to the litter in the late dry season, when there is little available soil moisture.

Saplings to 4–5 metres were observed commonly in areas that have remained unburnt for 4+ years. Old, large burnt-out stumps were found in several places, and there was some basal regrowth. Fire allows the pindan wattles to regenerate, which, after approximately seven years without fire, reach their maximum height and gradually senesce. The authors hypothesise that as the pindan wattles senesce, *C. paractia* is able to become better established.

Ecology

A wide range of plants were associated with *C. paractia* (Appendix 1). Quite a number of these grow under the canopy of mature Ghost Gums. Occasional trees were found with large clumps of Cymbidium orchids growing in them (Figure 16c). Hollows were more common in large, spreading (and presumably old) trees (Figure 16d).

Vertebrate fauna recorded during surveys (Appendix 2) included birds that use *C. paractia* trees as roosting and nesting sites and honeyeaters that feed on the nectar of the abundant blossom. Most abundant of the honeyeaters were Singing Honeyeater *Lichenostomus* *virescens* and Little Friarbird *Philemon citreogularis.* Various small passerines are found in pindan habitats that support *C. paractia.*

Arboreal mammals (e.g. possums) use tree hollows and terrestrial mammals (e.g. Agile Wallaby *Macropus agilis*) rest in the shade of large trees. Associated wildlife including cidadas, flower beetles, native bees, nesting and feeding birds, flying foxes attracted to blossom and reptiles inhabiting the bark-and-leaf litter have been described by Willing and Beames (2015). Further background about the ecology of *C. paractia*, and vegetation communities of the Broome Peninsula, can be found in Willing and Beames (2015).

Cultural importance

Documented cultural information that relates to Gunurru was collated in Willing and Beames (2015). This included information about liyirr (cicadas; Figure 17e) that use the tree, burning the bark for ash to combine with chewing tobacco, and flowering of Gunurru as a seasonal indicator of sharks and other reef life being ‘fat’ and good for hunting.

Yawuru Traditional Owners said that Gunurru bark was used to make coolamons. This was done by removing an outer section of bark in a roughly rectangular shape, with a hollow that mirrors the curve of the trunk. An example of a tree from which bark has been cut for this purpose is shown below (Figure 17d).

Trees around Broome town were important meeting places in the past. Some large trees near the Shire offices and Town Beach (known locally as ‘the white house’) were amongst them. Yawuru elders explained that Gunurru was once much more common in the Broome township, occurring near Town Beach, in the area of the Oaks Broome on Walcott Street, in the ‘back hospital’ area near Dora Street and in the area of Hamersley Street toward the Courthouse. This information about former distribution further supports the species distribution modelling. Several remnant trees still exist near Herbert Street, suggesting that they were more widespread in old Broome prior to being cleared for houses and roads.

> “Gunurru trees were right through that back hospital area; the best ash was from those trees”
> Jimmy Edgar, Yawuru elder

Figure 16(i). a) Top left: new red leaves

b) Top right: a tree with pale bark,

c) Bottom left: tree orchid *Cymbidium* growing out of a hollow,

d) Bottom right: hollows form in large trees,

Figure 16(ii). e) Left: a cluster of liyirr (cicada) exoskeletons shed by recently emerged imagos,

f) Right: a Gunurru tree with the bark removed to make a coolamon.

Threats

Urban expansion and clearing

As identified by Willing and Beames (2015), one of the greatest threats to *C. paractia* remains the clearing of land as the town of Broome expands. There are proposals to clear areas near the township that will result in the loss of many mature habitat trees and severely harm the vegetation community. In particular, the expansion of the Broome Road Industrial Area across 409 hectares will destroy large stands of *C. paractia,* particularly in the south-west portion of the proposed expansion (Figure 19). Fig. 18 identifies the patches that will be lost or compromised by the development and includes the total area and number of trees associated with each patch. The loss of up to 38.64 ha of *C. paractia* mapped within the development parcel represents 9% of the known *C.paractia area and includes some of the largest patches with the most trees per hectare.* At least 404 individual trees, many at high densities, were mapped in this area, including good numbers of large old habitat trees.

Remnant trees on verges and suburban blocks in Broome provide important habitat and, without any system for protection, are at risk of being removed.

Patch name	**hectares**	**no. of trees**	**trees per ha**
YF	16.3	138	8.466258
YC	8.7	120	13.7931
YH	7.1	66	9.295775
YJ	2.1	18	8.571429
YL	1.1	27	24.54545
YE	0.77	11	14.28571
YG	0.77	7	9.090909
YI	0.68	13	19.11765
ZN	0.44	1	2.272727
YD	0.35	2	5.714286
ZS	0.33	1	3.030303
Total	**38.64 ha**	**404**	

Fig. 18. *C. paractia* patches that will be lost or compromised by the Broome Industrial Estate development.

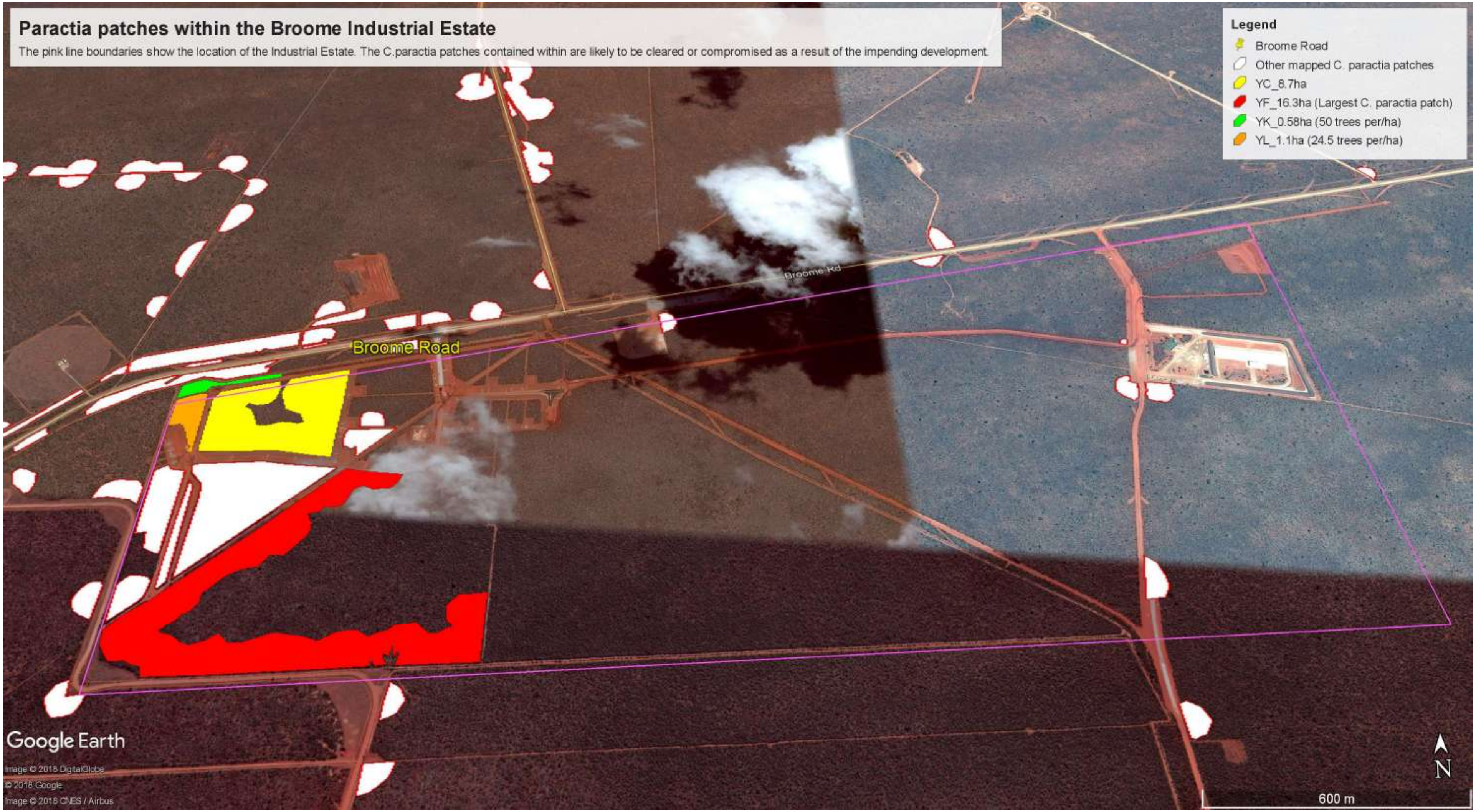

Figure 19. The highest density patches of *Corymbia paractia* located in the 2016–17 surveys were within and surrounding the Broome Industrial Area (bordered in pink).

Weeds

The main weed species growing under *C. paractia* trees was Neem *Azadirachta indica.* Seedlings, saplings and small trees were observed (Figure 20). Some Neems grew over 4 m in height and were pushing into the canopy of *C. paractia* trees. Neem infestations have the potential to significantly reduce the quality and quantity of *C.paractia* habitat by dominating the trees and reducing opportunities for the establishment of new trees.

Neem has been identified as a high priority threat to other significant trees and ecosystems in the Kimberley, including boabs, monsoon vine thicket and riparian vegetation (Beames et. al. 2017), and the rapid establishment, spread and domination of Neem over *C. paractia* patches should be observed and managed with some concern.

Buffel Grass *Cenchrus ciliaris* and Stinking Passion Flower *Passiflora foetida* were also moderately common, and readily invaded disturbed sites. In high densities, both of these plants have the potential to increase the risk of hot and frequent fires within *C.paractia* habitat.

Weeds recorded in *C. paractia* habitat (occurrences):

Neem *Azadirachta indica*	58
Buffel Grass *Cenchrus ciliaris*	8
Stinking Passion Flower *Passiflora foetida*	7
Bush Basil *Ocimum basilicum*	3
Bellyache Bush *Jatropha gossypifolia*	2
Hairy Merremia *Merremia aegyptia*	1
Rubber Vine *Cryptostegia madagascariensis*	1
Shrubby Stylo *Stylosanthes scabra*	1

Other threats

Willing and Beames (2015) noted that refuse, fire and hydrological changes that occur adjacent to roads and developed areas also posed a threat to the *C. paractia* community.

Figure 20. Neem infestation including multiple seedlings and saplings under a mature *C. paractia,* near start of International Livestock Road.

Discussion

The work undertaken within this project complements that by Willing and Beames (2015) in improving the understanding of the historical and present distribution of the restricted *C. paractia* community, once a poorly known ecosystem. This work has also enhanced our understanding of the tree's cultural significance to the community, its general ecology and the threatening processes that are contributing to its decline.

Distribution

Our mapping data, combined with species distribution modelling, indicate that the total original distribution prior to the establishment of the Broome township was less than 10,000 ha, and probably in the order of 7,000 ha. To date we have shown that at least 419.16 hectares of *Corymbia paractia* habitat remains within this area, with significant variations in

tree density and patch size. Ground-truthing other areas identified as potential *C. paractia* habitat will give a clearer indication of the present extent of the distribution.
Corymbia paractia is thus highly restricted, being endemic to the Broome Peninsula and the immediate vicinity of Broome. Populations occur within seven kilometres of the coast and between latitude 17° 51’ S near Coconut Wells and 18° 00’ S at the tip of the Broome Peninsula.

Species distribution modelling assisted in predicting environmental suitability for the species, but overestimated the area in which *C. paractia* occurs, particularly on the Broome Peninsula. Limits to distribution are bounded by distance from the coast, but may be more closely related to depth to regolith (defined as depth to hard rock), which is c. 32 metres at the eastern edge of the distribution, and continues to increase eastward on the Dampier Peninsula (Figure 21). The indication is that tree roots are able to penetrate the unconsolidated material, and that distance from groundwater may be a major limitation to *C. paractia.*

The Broome region’s main sedimentary aquifer (and water supply for the Broome township) is associated with the Cretaceous Broome Sandstone (Laws, 1991), which underlies the whole area. Groundwater flows from the (slightly elevated) central part of the Dampier Peninsula toward Broome. Although likely to vary seasonally, groundwater in the study area is at a depth of less than 10 metres, and for the majority of the area less than five metres (Laws, 1991; map sheet). Recharge from rainfall and percolation to the water table occurs during the wet season, but deep tree-roots are likely to be able to access groundwater year-round. Recharge also occurs in areas behind coastal sand dunes on the Broome Peninsula and the dune system is thought to be in hydraulic continuity with the Broome Sandstone (Laws, 1991).

The modelled distribution of *C. paractia* is strongly driven also by underlying geology. Sub-populations occur inland of the Quaternary estuarine and tidal-delta mudflat deposits (Qe) unit of Buckley’s Plain, the Dampier Creek saltmarsh and Roebuck Plain. They and the Broome Peninsula patches occur exclusively on the Quaternary sand-plain, with dunes (Qd) surface geological unit. On the Peninsula the patches are behind the coastal aeolian sand deposits (Qcd), which form high dunes along the coastline, as at Cable Beach. Much of the area that supports *C. paractia* is underlain by Cretaceous Melligo Sandstone and Broome Sandstone (Gibson, 1983).

The study area is at low elevation (mostly below 25 metres) and in this subdued landscape there appears to be little influence of slope and relief on the overall distribution. However, local topographic variation may influence the location of suitable areas for *C. paractia.* Minor features that influence drainage are likely to influence growth; for example, areas near roads that receive extra runoff support large *C. paractia* trees.

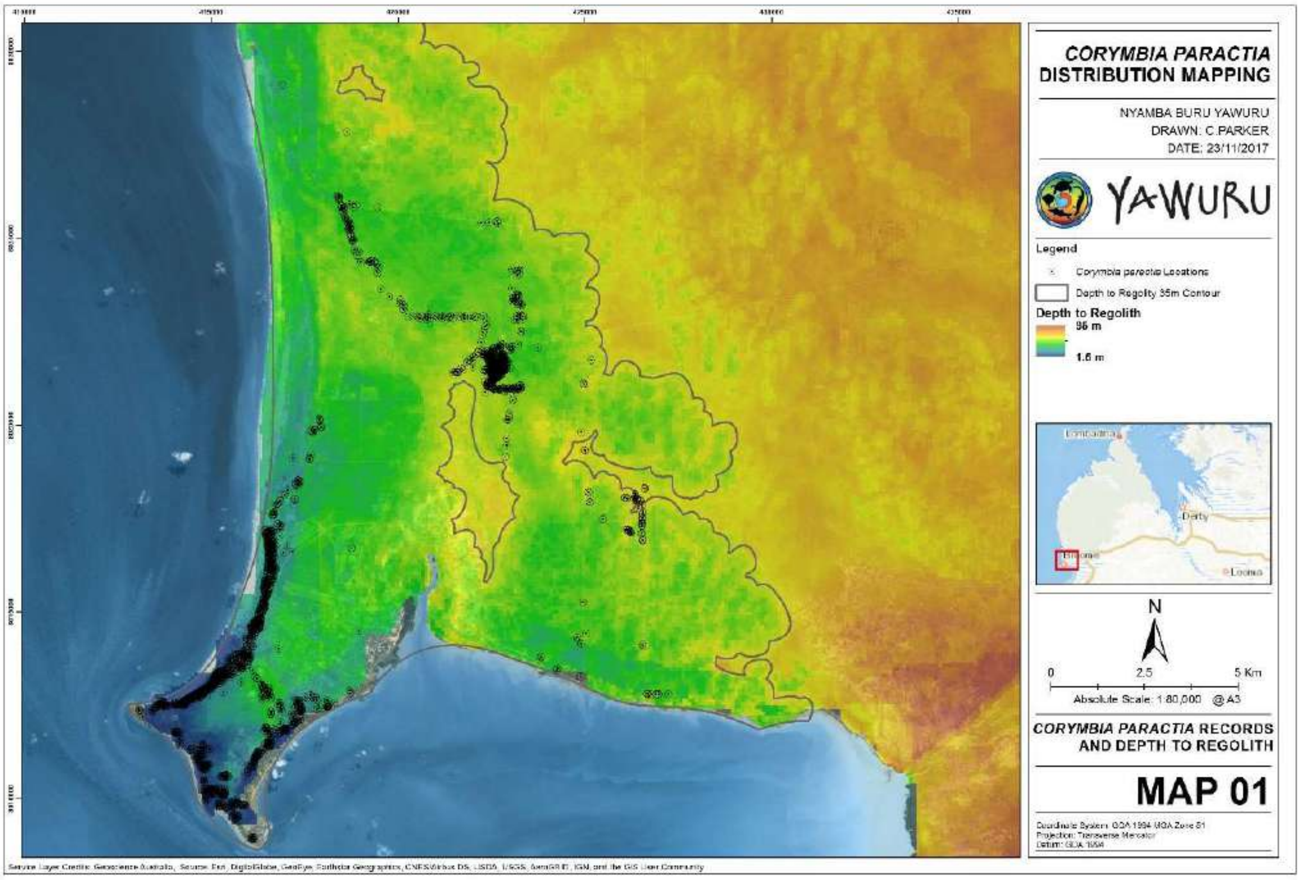

Figure 21. Depth to regolith and Ghost Gum locations. Note that some of the outer dots are *C. flavescens* and *C. bella.*

Sub-coastal areas near Broome and to the north and south are subject to heavy dews and occasional fogs at night in the dry season, when moist oceanic air meets still, cool air from inland. This atmospheric moisture evaporates in the morning within a few hours of sunrise, but water on leaves and shaded surfaces persists for longer. These weather events contribute to the survival of plant species that form monsoon vine thicket communities behind coastal dunes. This type of precipitation may also be used by *C. paractia,* as moisture from fogs can penetrate several kilometres inland, and dews fall widely across the landscape on still, clear nights.

There is an area of overlap between *C. paractia* and *C. flavescens* near the southern section of the Cape Leveque Road, with *C. flavescens* extending eastwards (and south past Roebuck Bay) from this point. The Old Wattle Downs area includes patches of *C. paractia* amongst *C. flavescens* (Figure 6). Further surveys in these areas would help to clarify the overlap zones. In the Coconut Wells area there is a mix of *C. paractia* and *C. flavescens,* whereas *C. bella* begins on the Flat Rock track north of Coconut Wells (17° 47’50” S) and is common surrounding the wetland area of Nimalaragan (Nimalaica). *C. bella* extends north in near-coastal areas of the Dampier Peninsula.

Although a great deal of effort has been expended on surveys, various gaps still exist in our knowledge, as follows:

- OTC Area north of the Highway. Because of Aboriginal law grounds behind here, this area was avoided, but is almost certain to include a population of *C. paractia.*
- Water Reserve — the SE corner near the Cape Leveque turnoff should add information as to where and how *C. paractia* and *C. flavescens* overlap.
- Hidden Valley and west side of Buckley’s Plain. Some *C. paractia* may be growing here.
- near the Broome Waste Management Facility, which would fill the gap between inland and Peninsula sub-populations.
- Extreme northern end of Buckley’s Plain, approaching Coconut Wells — further define probable overlap area with *C. flavescens* and *C. bella*.
- East of Wattle Downs into Roebuck Pastoral Lease — clarify extreme eastern limit of *C. paractia*.
- Southern portion of Broome Road Industrial Area to north-east area of Dampier Creek saltmarsh.

Ecology

The canopy of large Ghost Gums acts as a nursery for native shrubs, herbs and small trees which are able to germinate and survive in the partially shaded microenvironment. Such plants commonly include *Flueggea virosa*, *Breynia cernua*, *Premna acuminata*, *Grewia retusifolia*, *Clerodendrum tomentosum* and *Abrus precatorius*, but also the weeds Neem and *Passiflora foetida*. Some species are more commonly associated with monsoon vine thickets (e.g. *Grewia breviflora, Sersalisia sericea, Bridelia tomentosa, Tylophora cinerascens, Abrus precatorius*), indicating that *C. paractia* may play a role in facilitating re-emergence of vine thicket vegetation. Large Gunurru trees are known as nursery trees and are important within the overall pindan vegetation.

The tree orchid *Cymbidium canaliculatum* was recorded on several occasions growing from hollows of *C. paractia.* These are the southernmost records for this species. See Fig 22.

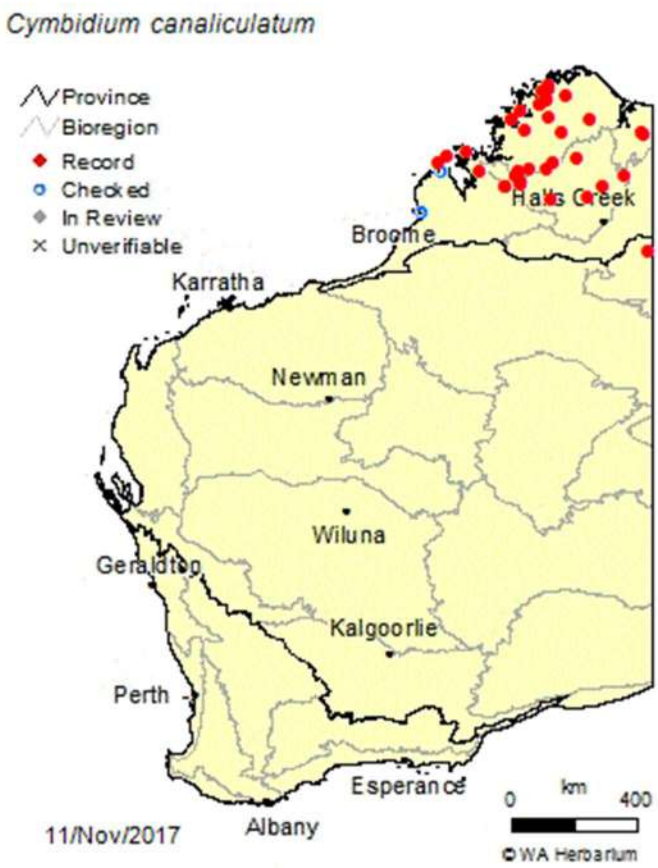

Figure 22. Florabase records for *Cymbidium canaliculatum*—accessed 2017 https://florabase.dpaw.wa.gov.au/browse/profile/1628

The question of the appropriate listing for Cable Beach Ghost Gum at a State and/or National level has been raised by WA Department of Parks and Wildlife staff. It remains unclear whether vegetation with *C. paractia* should be listed as a community, as is currently the case, or if the individual species warrants listing e.g. as Declared Rare Flora. The question arises because *C. paractia* occurs in association with a range of native plants (Appendix 1), in what could be defined as various vegetation communities. Biologists may choose to differentiate between the different *C. paractia*-dominated communities: where they occur behind dune systems, and those found further inland where they are an important part of more general pindan vegetation. Clarification on this issue is required; however, until further scientific investigation warrants a change to the categorisation, we recommend that *C. paractia* remain listed and protected as a community.

Large *C. paractia* trees are an important resource for food (nectar) and shelter in the pindan. Few other plants flower in November–December and the abundant blossom attracts honeyeaters, lorikeets, beetles, native bees and nocturnal fruit bats, possibly including the Northern Blossom Bat *Macroglossus minimus.*

We recorded peak flowering times in early December, with the first buds forming in mid-October and numerous trees carrying buds in early November. Optimal times for targeting surveys to ensure that flower buds can be compared for identification are thus late November to early December, although there may be variation between years.

Cultural importance

Discussions with Yawuru elders reconfirmed the cultural importance of Gunurru in the Broome region, both in terms of traditional uses and as a seasonal indicator. A major finding from these discussions is that many trees in town have been cleared. This provides further confidence in the distribution based on species modelling, which indicates that suitable areas for *C. paractia,* where they previously existed, are present across the townsite.

Aesthetically, many Gunurru trees are attractive, large spreading specimens within an otherwise relatively monotonous landscape dominated by wattles. At night their pale trunks are a striking feature, particularly when viewed in moonlight. They are a suitable tree in gardens where space is available, requiring no watering once they are established.

Threats

Threats are summarised below — further information about threats to individual patches on the Broome Peninsula, including weeds, proposed developments and track proliferation, are detailed in Willing and Beames (2015).

Clearing

The estimated loss of the *C. paractia* vegetation community is at least 1500 hectares (and possibly as high as 1668 hectares), mainly in the area of the Broome township, but including losses to quarries, roads and other out-of-town clearing. There are further likely losses in the

Broome Road Industrial Area, which will occupy 400 ha (Urbis, 2012). Within the Industrial Area it is planned to clear around 180 ha of *C. paractia* habitat, with a core area of c.80 ha in the south-west corner. This could mean the removal of approximately a thousand trees in the core area (crude estimate 80 ha x 20 trees per ha), including many mature (>10 m tall) Ghost Gums. Further clearing is anticipated in the future as the township of Broome continues to expand.

Weeds

Neem is a major weed that is spreading through bushland areas near Broome and elsewhere in the Kimberley. The sweet Neem fruit is eaten by birds and mammals and spread from roosting/shade tree to roosting/shade tree in the animals' faeces. As a result, many Neem seedlings are found directly under *C. paractia* trees. Neems spread rapidly and establish quickly. They can grow into large trees that smother Ghost Gums and other trees and compete with them for water and soil nutrients (Beames et. al. 2017). Neem remains an undeclared weed in WA, despite the neighbouring NT having recognised and declared this weed under their Weed Management Act in 2015. Because of its undeclared status resources are not available for land managers to map and control Neem in the Kimberley. Neem therefore remains a growing and unchecked threat to the *C. paractia* community.

Relatively few Passiflora vines were recorded on trees away from town, and these can be easily eliminated by hand-pulling.

Buffel grass is widespread in the Kimberley and, while it was not recorded as common throughout the *C. paractia* community, it has the potential to slowly dominate areas and alter fire regimes, creating hotter and more frequent fires, which are detrimental to *C. paractia* trees.

Fire

Frequent wildfires harm and eventually kill mature Ghost Gums and reduce the opportunity for new seedlings to grow. Fire is a factor in the pindan and long fire-free intervals may be necessary for successful establishment of *C. paractia* trees. Fire can destroy the ground layer (grasses, herbs and low shrubs) and the middle Acacia layer, but generally leaves the trees intact (Beard, 1979). A mass germination of Acacia species often occurs following fire. Lengthy intervals between fires (potentially > 7 years) can result in the senescence of pindan wattles (mainly *Acacia eriopoda* in the study area). These are often within the same age class, having sprung up following the last fire. The loss of Acacias from the vegetation community reduces competition for light as well as in the root zone, and thus allows *C. paractia* trees to take hold and grow, along with other trees such as Jigal *Bauhinia cunninghamii,* Firestick Tree *Premna acuminata,* Medicine Bark/Supplejack *Ventilago viminalis* and *Clerodendrum tomentosum*. Thus, there are likely to be gradual successional changes in the pindan mosaic. A long-term study would be necessary to determine the pattern of *C. paractia* establishment. Sites within the industrial area where *C. paractia* appears to be establishing have remained unburnt for around eight years according to NAFI imagery (NAFI, 2017).

Off-road driving — tracks

There are a number of tracks (walking and vehicular) in Minyirr Park, and tracks are proliferating in the area of Buckley's Plain and on the outskirts of the Broome township. Individual Ghost Gum trees are at risk of being damaged or killed by off-road drivers. Tracks invite the weeds to invade, particularly Stylo *Stylosanthes hamata* and Buffel Grass *Cenchrus ciliaris.* Vehicle hygiene is vital for road construction vehicles and machinery used for landclearing to ensure that weed seeds are not spread into bushland.

Recommendations

- State protection

1) **We recommend that the *Corymbia paractia* community be listed as a Threatened Ecological Community (TEC) under the category of Vulnerable in Western Australia.**

The C. paractia *community is currently listed in Western Australia as a Priority Ecological Community (PEC—Priority 1) a poorly known ecological community.* C.paractia *is also a Priority 1: Poorly known species, However, given our detailed mapping of many individual trees and a much clearer understanding of the distribution of the species, it may be inappropriate to continue to list the community as poorly known.*

Given the threatening processes of weed invasion and inappropriate development, our recommendation for upgrading the listing from PEC to TEC is based on criteria B and C for Vulnerable ecological communities, as follows:

> *B) The ecological community may already be modified and would be vulnerable to threatening processes, is restricted in area and/or range and/or is only found at a few locations.*
> *C) The ecological community may be still widespread but is believed likely to move into a category of higher threat in the medium to long term future because of existing or impending threatening processes.*

In relation to Criterion B, the community has already been heavily modified and significantly cleared in areas near Broome. Clearing of the community continues apace and there are few protective mechanisms in place to prevent clearing outside conservation areas. It is subject to weed invasion, particularly by Neem, a widely recognised priority weed but at present undeclared and relatively uncontrolled. Neem will continue to compete with C. paractia *where it grows under and then into the canopy. Unmanaged, hot and frequent wildfires persist on the outskirts of Broome and have the potential to significantly contract the remaining range of* C. paractia*. Further, the vegetation community is endemic, being restricted to the Broome Peninsula and the immediate vicinity of Broome.*

Under Criterion C, the expansion of the Broome Road Industrial Area will affect the distribution of the community. The ongoing expansion of housing, roads and industrial developments associated with Broome are current and impending threatening processes.

- Federal protection

2) We recommend that an EBPC Act (1999) nomination for a protected listing once again be considered, but this time as a stand-alone application.

In 2015 C. paractia *was nominated, along with 16 other Eucalypt species, to be listed as Threatened under the EPBC Act (1999). The nomination was largely based upon the work of Franklin and Preece (2014), who rated* C. paractia *as an extremely restricted Eucalypt species and poorly reserved (<10%). The species status was assessed as Vulnerable, as it met a number of IUCN criteria (B1ab (ii,v). The 2015 EPBC nomination, prepared by the Environment Centre NT and Humane Society International, was unsuccessful, mainly owing to insufficient data available across the suite of species nominated in the group application. The present paper provides much more comprehensive data about* C. paractia*, its restricted occurrence, contraction of range and the escalating threats of clearing, weeds and fire.*
An ecosystem must meet at least one of six criteria that determine the status of a threatened ecological community under the EPBC Act (1999). We recommend that C. paractia *at least qualifies as Vulnerable under criterion #2, because the community is limited in its geographic distribution and it is likely that a threatening process would result in its loss in the medium term.*

- Mapping

3) Further mapping must be undertaken to establish current extent and quality of remnant *C.paractia* within and outside conservation reserves.

Whilst over 2800 trees have been individually mapped and almost 420 hectares has been ground-truthed as remnant C. paractia *habitat, the 95% confidence distribution envelope developed through the species distribution modelling predicts a high probability that* C. paractia *habitat occurs across a further 3,122 hectares. Almost 5000 hectares in addition to this may also contain* C. paractia *habitat (medium probability). It is imperative that this projective mapping be ground-truthed to establish first whether remnant* C. paractia *still occurs in these areas and then the relative density and quality of* C. paractia *in remaining patches.*

Ground-truthing and mapping of C. paractia *habitat must also be undertaken within existing conservation reserves so that we can accurately determine the quality and quantity of* C. paractia that *is currently protected.*

- Planning and landclearing

4) Planning and landclearing must be revised to reduce clearing and increase protection of *C. paractia.*

We estimate that just over 30% of the ecosystem is contained within existing conservation reserves. Given that the community is highly restricted and the remaining distribution extent is still to be ground-truthed and subject to a density and quality analysis, it is important that clearing of C. paractia *habitat be curbed as much as possible. Loss of a further 9% of the known habitat in the impending Broome Industrial Estate development would be unacceptable. Surveys of* C. paractia *need to be extended, particularly in areas that are* proposed for development, road widening etc. Protection of dense and/or high quality stands of C. paractia *by making small changes to development zones and conservation areas should be prioritised by local and state government as much as possible. Remnant* C. paractia *in the township need to be protected by way of a local government tree register, as recommended by Willing and Beames (2015). Any clearing should be offset by additional plantings that compensate for the loss of mature habitat trees i.e. offsetting lost hectares or trees by 2x the proposed loss and committing to managing and protecting these areas over the long term (>10years).*

- Weed management

5) Weed control undertaken within conservation areas and in public and private lands should focus on Neem infestations as a priority for control and to reduce spread.

Neem Azadirachta indica *is becoming a major weed within the* C. paractia *vegetation community. This is particularly the case to the east of Buckley's Plain and to the north-east of the Dampier Creek marshlands.*

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- Louise Beames from Environs Kimberley mapped the 2016–17 *C. paractia* patches and co-authored the report.
- Malcolm Lindsay from Environs Kimberley contributed to the final report.
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Appendix 1 Native plant species associated with *Corymbia paractia*

Notes are in relation to association with *C. paractia*

Species	Notes
Abrus precatorius	climber, relatively infrequent
Acacia adoxa	low shrub, infrequent
Acacia colei	shrub, moderately common
Acacia eriopoda	very common tree associate, often dominant in pindan
Acacia tumida	shrub, occasional
Amyema sanguinea	mistletoe on eucalypts including *C. paractia*, relatively infrequent
Amyema bifurcata	mistletoe, single record
Aristida sp. *inaequiglumis* ?	grass, patchily associated
Atalaya hemiglauca	small tree, patchy
Bauhinia cunninghamii	common co-dominant tree
Brachychiton diversifolius	tree, moderately common
Breynia cernua	shrub in thickets, usually under trees
Bridelia tomentosa	shrub or small tree, infrequent
Capparis lasiantha	climber, single record on *C. paractia*
Carissa lanceolata	shrub, infrequent
Cassytha filiformis	climber, infrequent on *C. paractia*
Chrysopogon ?pallidus	grass, infrequent and patchy
Clerodendrum tomentosum	small tree, often in clumps, infrequent
Corymbia zygophylla	tree, occasional
Crotalaria medicaginea	shrub, patchy
Cymbidium canaliculatum	tree orchid, several records
Denhamia cunninghamii	small tree, infrequent
Dicrostachys? pinnate	shrub, single record
Dodonaea hispidula	shrub, moderately common but patchy
Dolichandrone heterophylla	small tree, infrequent
Eucalyptus tectifica	tree, infrequent with *C. paractia*
Ehretia saligna	small tree, moderately common, at times in thickets
Ficus aculeata	small tree, fairly infrequent
Flueggea virosa	spreading shrub, relatively common under trees
Galactia tenuiflora	prostrate vine, patchy
Gardenia pyriformis	small tree, fairly infrequent, usually single trees
Gossypium aff. australe	shrub, infrequent
Grewia retusifolia	low spreading shrub in groundlayer, often under trees
Grewia breviflora	medium tree, infrequent
Gyrocarpus americanus	large tree, occasional in pindan

Hakea arborescens	tree, infrequent
Hakea macrocarpa	tree, infrequent
Jasminum calcareum	understorey low shrub in southern areas, patchily common
Jasminum didymum	low shrub, infrequent
Marsdenia viridiflora	climber, infrequent
Melaleuca viridiflora	tree, infrequent
Melhania oblongifolia	low shrub, patchily common in understorey
Myoporum montanum	shrub, few records, usually near-coastal
Pavetta kimberleyana	small tree, single record
Persoonia falcata	small tree, occasional
Ptilotus polystachyus	herb, single record
Premna acuminata	small tree, often in thickets under trees
Rhynchosia minima	scrambler, patchy
Santalum lanceolatum	small tree, relatively infrequent
Senna costata	shrub, infrequent and patchy
Sersalisia sericea	tree, several records
Solanum cunninghamii	small shrub, occasional
Sporobolus sp.	grass, infrequent
Terminalia petiolaris	tree, single record
Tinospora smilacina	climber, moderately common
Trichodesma zeylanica	herb, patchy
Tylophora cinerascens	climber, single record
Ventilago viminalis	tree, occasional
Waltheria indica	low shrub, fairly common

Appendix 2 Vertebrate fauna recorded in *Corymbia paractia* habitat

MAMMALS

Agile Wallaby *Macropus agilis* (including scrapes under trees)

Bilby *Macrotis lagotis*

Brushtail Possum *Trichosurus vulpecula*

BIRDS

Brown Goshawk *Accipiter fasciatus*

Brown Falcon *Falco berigora*

Crested Pigeon *Ocyphaps lophotes*

Peaceful Dove *Geopelia striata*

Red-winged Parrot *Aprosmictus erythropterus*
Pheasant Coucal *Centropus phasianinus*
Brush Cuckoo *Cacomantis variolosus*
Southern Boobook *Ninox novaeseelandiae*
Blue-winged Kookaburra *Dacelo leachii*
Dollarbird *Eurystomus orientalis*
Rainbow Bee-eater *Merops ornatus*
Variegated Fairy-wren *Malurus lamberti*
Red-backed Fairy-wren *Malurus melanocephalus*
White-throated Gerygone *Gerygone olivacea*
Striated Pardalote *Pardalotus striatus*
Little Friarbird *Philemon citreogularis*
Singing Honeyeater *Lichenostomus virescens*
Rufous-throated Honeyeater *Conopophila rufogularis*
Grey-crowned Babbler *Pomatostomus temporalis*
Grey Shrike-thrush *Colluricincla harmonica*
Rufous Whistler *Pachycephala rufiventris*
Willie Wagtail *Rhipidura leucophrys*
Black-faced Cuckoo-shrike *Coracina novaehollandiae*
Magpie-lark *Grallina cyanoleuca*
Pied Butcherbird *Cracticus nigrogularis*
Olive-backed Oriole *Oriolus sagittatus*
Torresian Crow *Corvus orru*
Double-barred Finch *Taeniopygia bichenovii*
Mistletoebird *Dicaeum hirundinaceum*

REPTILES
Bark Skink *Cryptoblepharus* sp.
Ground Skink *Ctenotus* sp.
gecko spp.
Frillneck Lizard *Chlamydosaurus kingii*
Ta-ta Dragon *Lophognathus gilberti*
Sand Goanna *Varanus gouldii*
Black-headed Python *Aspidites melanocephalus*

Appendix 3

Description of *Corymbia paractia* from Broome and Beyond (Kenneally *et al.,* 1996)

(Eucalyptus) Corymbia paractia Hill & Johnson **Cable Beach Ghost Gum**

Tree or occasionally a mallee to 12 m, trunk stout, somewhat knobbly; bark often persistent on the lower trunk, greyish brown, flaky, smooth and white on the upper trunk and branches; branchlets thickened, often pendulous; leaves large, almost opposite, ovate-lanceolate or broad-lanceolate, the margins often undulate or distinctly twisted, flowers white, borne laterally on leafless lengths of branchlets, mature buds pyriform; fruits ovoid, glabrous.

Common between Gantheaume Point and Cable Beach. Apparently restricted to a narrow coastal zone in the Broome area where beach dunes merge into pindan soils.

Populations of this species exhibit variation in leaf shape, often developing intermediate-phase leaves in the canopy. This species can be almost leafless when flowering.

Flowering and fruiting October–December.

Appendix 4

Patch name	hectares	no. of trees	trees per ha
YF	16.3	138	8.466258
YC	8.7	120	13.7931
YH	7.1	66	9.295775
WI	6.15	28	4.552846
X	4.93	9	1.825558
ZB	4.1	8	1.95122
XE	3.92	14	3.571429
VA	3.91	7	1.790281
YS	3.29	10	3.039514
YA	2.9	12	4.137931
M	2.65	3	1.132075
Y	2.58	7	2.713178
E	2.41	3	1.244813
XQ	2.4	5	2.083333
XR	2.28	4	1.754386
WJ	2.23	9	4.035874
XV	2.12	3	1.415094
YJ	2.1	18	8.571429
H	2	2	1
WN	1.98	6	3.030303
XF	1.94	8	4.123711
YM	1.9	13	6.842105
XU	1.77	3	1.694915
XD	1.63	5	3.067485
R	1.62	5	3.08642
ZC	1.54	4	2.597403
F	1.53	2	1.30719
WG	1.53	2	1.30719
WE	1.51	4	2.649007
XX	1.47	7	4.761905
YZ	1.46	4	2.739726
A	1.41	2	1.41844
B	1.4	3	2.142857
XP	1.34	3	2.238806
XM	1.15	2	1.73913
YL	1.1	27	24.54545
W	1.1	2	1.818182
C	1	2	2
ZD	1	2	2
XT	1	2	2

Patch name	hectares	no. of trees	trees per ha
XI	0.93	2	2.150538
XS	0.92	2	2.173913
ZV	0.9	3	3.333333
V	0.88	2	2.272727
VH	0.88	2	2.272727
ZF	0.84	2	2.380952
XY	0.82	2	2.439024
XH	0.79	2	2.531646
VD	0.78	10	12.82051
ZH	0.78	2	2.564103
WY	0.78	2	2.564103
YE	0.77	11	14.28571
YG	0.77	7	9.090909
XN	0.76	1	1.315789
ZI	0.75	2	2.666667
D	0.75	1	1.333333
G	0.75	1	1.333333
I	0.75	1	1.333333
J	0.75	1	1.333333
K	0.75	1	1.333333
L	0.75	1	1.333333
P	0.75	1	1.333333
Z	0.75	1	1.333333
ZA	0.75	1	1.333333
ZE	0.75	1	1.333333
ZJ	0.75	1	1.333333
XZ	0.75	1	1.333333
WO	0.75	1	1.333333
WP	0.75	1	1.333333
WC	0.74	2	2.702703
WS	0.74	1	1.351351
YT	0.73	3	4.109589
XK	0.73	1	1.369863
WW	0.69	1	1.449275
YI	0.68	13	19.11765
YO	0.68	2	2.941176
o	0.68	1	1.470588
ZU	0.67	1	1.492537
WB	0.67	1	1.492537
N	0.63	1	1.587302
WK	0.63	1	1.587302
ZQ	0.59	2	3.389831

Patch name	hectares	no. of trees	trees per ha
WR	0.59	1	1.694915
WT	0.59	1	1.694915
YK	0.58	29	50
ZL	0.58	5	8.62069
ZZ	0.57	3	5.263158
YW	0.56	1	1.785714
YV	0.55	2	3.636364
XJ	0.55	1	1.818182
WA	0.54	1	1.851852
XO	0.53	1	1.886792
ZM	0.52	1	1.923077
ZX	0.5	3	6
WL	0.5	1	2
VE	0.5	1	2
ZW	0.49	5	10.20408
VF	0.49	1	2.040816
WH	0.48	1	2.083333
WV	0.48	1	2.083333
ZK	0.47	1	2.12766
ZY	0.47	1	2.12766
WQ	0.47	1	2.12766
YN	0.45	5	11.11111
T	0.45	1	2.222222
XB	0.45	1	2.222222
ZG	0.44	1	2.272727
ZN	0.44	1	2.272727
WF	0.43	1	2.325581
WM	0.42	1	2.380952
YY	0.41	2	4.878049
YS	0.41	1	2.439024
XG	0.41	1	2.439024
S	0.4	1	2.5
XL	0.39	1	2.564103
WX	0.39	1	2.564103
VJ	0.39	1	2.564103
WD	0.37	1	2.702703
WZ	0.37	1	2.702703
YR	0.36	7	19.44444
Q	0.36	1	2.777778
YD	0.35	2	5.714286
U	0.35	1	2.857143
XA	0.35	1	2.857143

Patch name	**hectares**	**no. of trees**	**trees per ha**
XW	0.35	1	2.857143
YX	0.34	1	2.941176
XC	0.34	1	2.941176
ZR	0.33	1	3.030303
ZS	0.33	1	3.030303
ZT	0.33	1	3.030303
VB	0.29	1	3.448276
YU	0.27	1	3.703704
VI	0.26	1	3.846154
VC	0.24	1	4.166667
ZP	0.23	1	4.347826
YP	0.22	2	9.090909
WU	0.22	1	4.545455
YB	0.17	2	11.76471
YQ	0.13	1	7.692308
ZO	0.1	1	10
VG	0.1	1	10
Total	**167.81**	**784**	
Total (Willing and Beames, 2015)	**251.35**		
Inclusive total	**419.16**		

- Patches highlighted in pink are within the Broome Industrial Estate development parcel.