Threatened Species Recovery Hub

National Environmental Science Programme

Pre-management actions baseline report for Artemis Antbed Parrot Nature Refuge

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*Cover image: Golden-shouldered parrot (*Psephotellus chrysopterygius*). Image: David Cook CC BY-NC 2.0, Flickr*

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1. Introduction

1.1 Parrot ecology and threats

The endangered Golden-shouldered Parrot (*Psephotellus chrysopterygius*, known by the Indigenous names Alwal, Arrmorral, Thaku and Minpin) continues to decline on Cape York. Since the 1920s they have disappeared from more than half of their range. The species' total population size is thought to be about 1000 individuals (Golden-shouldered Parrot Recovery Team 2021). Beef cattle station "Artemis Station" is now recognised to be the species' northern limit. Once considered a strong-hold, the Artemis population is now down to approximately 50 birds, including sub-adults, as they contract further southwards inside the property. Successive recovery plans have specified securing the northern limit of the species' distribution as a priority, which occurs on Artemis (Crowley et al. 2004; Garnett and Crowley 2002; Golden-shouldered Parrot Recovery Team 2019). It seems that supplementary feeding – where individuals can feed quickly protected by predator proof mesh – might be the only reason parrots still occur on Artemis.

It is thought that the parrots are declining because their habitats have become overgrown by woody native plants (Crowley and Garnett 1998; Crowley et al. 2009; Neldner et al. 1997). Personal observations, photo points and remote sensing all illustrate that large areas of habitat on Artemis are now thick with woody plants. Furthermore, nest survey data (S. Shephard unpublished data) show that many of these areas are no longer occupied by parrots. Similarly, there have been no parrot records from thickened habitats at Silver Plains near Coen since the 1950s (Crowley et al. 2004; Garnett and Crowley 2002; Golden-shouldered Parrot Recovery Team 2021) suggesting that the Artemis population may be headed down the same pathway to extinction.

Vegetation thickening is largely the result of infrequent, low intensity fires, interacting with cattle grazing (Crowley and Garnett 1998; Neldner et al. 1997). Fires naturally occurred at the break of the wet season (storm-burns), either started by lightning or lit by Indigenous people (Bassani et al. 2006). Such fires prevented recruitment of young plants and suckers to the canopy by allowing rapid recovery of the grass layer before suckers could re-establish (Crowley and Garnett 2001; Crowley et al. 2009). Even without a shift in fire regimes, the reduction in grass biomass caused by grazing is likely to advantage woody plants through the removal of competition (Riginos 2009).

Vegetation thickening has not only affected Golden-shouldered Parrots, but its co-dependent Antbed Parrot Moth (*Trisyntopa scatophaga*; Threatened Species Scientific Committee 2016). It has possibly also affected several other endangered species in the region including Red Goshawks (*Erythrotriorchis radiata*; Department of Environment and Resource Management 2012) and Buff-breasted Button-quail (*Turnix olivii*, Webster et al. 2021). Local populations of other granivores, such as Black-throated (*Poephila cincta*) and Masked Finches (*P. personata*) have also declined (S. Shephard personal observations).

The mechanistic impact of woody thickening on the parrots is that it is thought to increase the success of ambush predators (Crowley et al. 2004). It is not known whether the density of such predators has also increased, or their hunting success, or both. In fact, in this context increased hunting success can be viewed as increased productivity, of which higher density (~ smaller territories) is a direct result. Whatever the precise mechanise driving increased predation levels, it seems clear that Golden-shouldered Parrots are essentially a grassy woodland species that now finds itself in a far denser woodland setting in which woodland ambush predators can be more effective. There are multiple observations of woodland predators taking eggs, nestlings, fledglings and adults. Predators include a mix of native (e.g. butcherbirds *Cracticus* spp., kookaburras *Dacelo* spp.) and introduced species (e.g. feral cats *Felis catus*). Parrots seem to be especially vulnerable to ambush predation in the early wet season, when the change of season causes a natural food shortage, forcing the parrots to spend more time looking for food on the ground (Crowley et al. 2004; Garnett and Crowley 2002).

Additional effects of thickening are the apparent declines of Black-faced Woodswallows (*Artamus cinereus*) and termite mounds used for nesting from parrot habitats. Woodswallows perform important sentry duties for parrots, alerting them to the presence of any predators. Woodswallows are also an open country species and their decline further increases predation pressure (Crowley et al. 2004). The vegetation in the former nesting area near Coen is now so dense that no nesting mounds can be found (Crowley et al. 2004).

Another key threat to arise from altered fire regimes and grazing pressure is the decline of critical early wet season foods such as Cockatoo Grass (*Alloteropsis semialata*; Crowley and Garnett 2001). Food shortage forces birds out of areas and/or leads to nutritional stress and sub-optimal foraging (and exposure to further predation pressure).

1.2 Artemis habitat management model

Despite the lack of relatively more intense storm-burns being one of the key drivers of woody thickening in parrot habitat, previous research has demonstrated that application of these fires alone does not cause significant mortality of individual plants of most size classes, from canopy plants to suckers (Crowley et al. 2009). The only class that can be killed by fire reliably is seedlings without well-developed lignotubers. While storm-burns do not result in significant mortality, they are effective at preventing the recruitment of smaller individuals into sub-canopy and canopy classes. This knowledge forms the basis of a relatively clear set of management actions for parrot habitats that have not yet suffered woody thickening and need to be maintained in an open state. However, for areas that have already been altered by moderate to severe woody thickening – like most parrot habitat on Artemis – additional management actions are required. More specifically, our habitat management model is that some kind of initial and once-off action (or set of actions) is required to restore parrot habitat to a point where it can then be maintained in an open state by the regular application of storm burns.

Over the next few years, habitats on Artemis will be restored to an open state by physically clearing using hand-tools, strategic use of different herbicides and high intensity but small scale storm burning. The concept of restoring habitat to its original open structure has been ratified by the current Golden-shouldered Parrot Recovery Plan (Golden-shouldered Parrot Recovery Team 2019). Furthermore the IUCN Parrot Action Plan specifically recommends the following action for restoring Golden-shouldered Parrot habitat: *"Experimental habitat management [to] provide information on the species' response so that a management plan [can] be formulated. Procedures to be tested are those designed to halt the decline in occupied areas and allow colonization of new areas"* (Snyder et al. 2000, p. 49).

1.3 Adaptive management – the importance of baseline data

The habitat restoration work on Artemis will be set within an adaptive management framework in order to ensure the actions are achieving the desired result. Ideally, a response in the parrots themselves would be monitored, and indeed this is being attempted through an approved colour-banding study, which should permit monitoring of survivorship and population size. However, it must be acknowledged that the signal from colour-banding alone may not be sensitive enough to provide sufficient feedback about the effectiveness of operations, especially as the parrot's decline has been widespread, and recolonisation will depend on the reversal of a number of threatening processes in addition to vegetation thickening (i.e. wet season food and nest availability, woodswallow losses) across the broader landscape. To provide more sensitive indicators of the ecological response to the management actions, we are also monitoring vegetation change and predator response; in particular, Pied and Black-backed Butcherbirds *C. nigrogularis* and *C. mentalis* which are suspected to be two of the most important parrot predators (Crowley et al. 2004).

For vegetation, a historical data-set from 1998-2001 exists that includes quantitative (plot and transect sampling) and qualitative (photo monitoring points) information about floristics and structure (Crowley et al. unpublished data). The work supported by NESP 3.2.6 and described in this report aims to build on the historical quantitative and qualitative vegetation work that will permit us to:

1. Describe the changes in vegetation structure and floristics in habitats on Artemis over a 20 year period when parrots went from being comparatively secure to endangered on the property, and;
2. Monitor the response in vegetation after we implement management actions.

For butcherbirds, ultimately we are trying to reduce predation pressure on parrots by restoring an open habitat structure. As such, we are collecting pre-management baseline information about density, home range and habitat use of Pied and Black-backed Butcherbirds. As well as being important parrot predators in their own right, the butcherbirds also act as model species for a range of other parrot predators (e.g. kookaburras, accipiters etc.). A proportion of the butcherbird work was supported by NESP 3.2.6, and it also has on-going co-support from Cape York Natural Resource Management. We aim to repeat these measures post-management, in order to gauge the effectiveness of actions on reducing predation pressure.

2. Vegetation

As discussed above, one of the main suspected drivers of the decline of Golden-shouldered Parrots is fire- and grazing-mediated changes in vegetation structure and floristics (Crowley et al. 2004; Garnett and Crowley 2002; Golden-shouldered Parrot Recovery Team 2019). It is thought that habitats have become thicker with native encroaching woody species (Crowley and Garnett 1998), which has reduced nest site availability and woodswallow populations, and elevated predation pressure. Also, some key food plants, especially early wet season grasses such as Cockatoo Grass (*Alloteropsis semialata*), have been negatively impacted by sustained grazing pressure (Crowley and Garnett 2001), further increasing exposure to predators in the early wet season or weakening birds, particularly young birds inexperienced in finding food at this time of year.

Between 1998 and 2001, woody plants and ground cover were measured at 20 sites on Artemis (Crowley et al. unpublished data; Figure 1). Photographs from known points at each site were also taken. These data provide an opportunity to describe quantitatively and qualitatively the amount of vegetation change within Golden-shouldered Parrot habitat.

2.1 Vegetation methods

2.1.1 Sampling

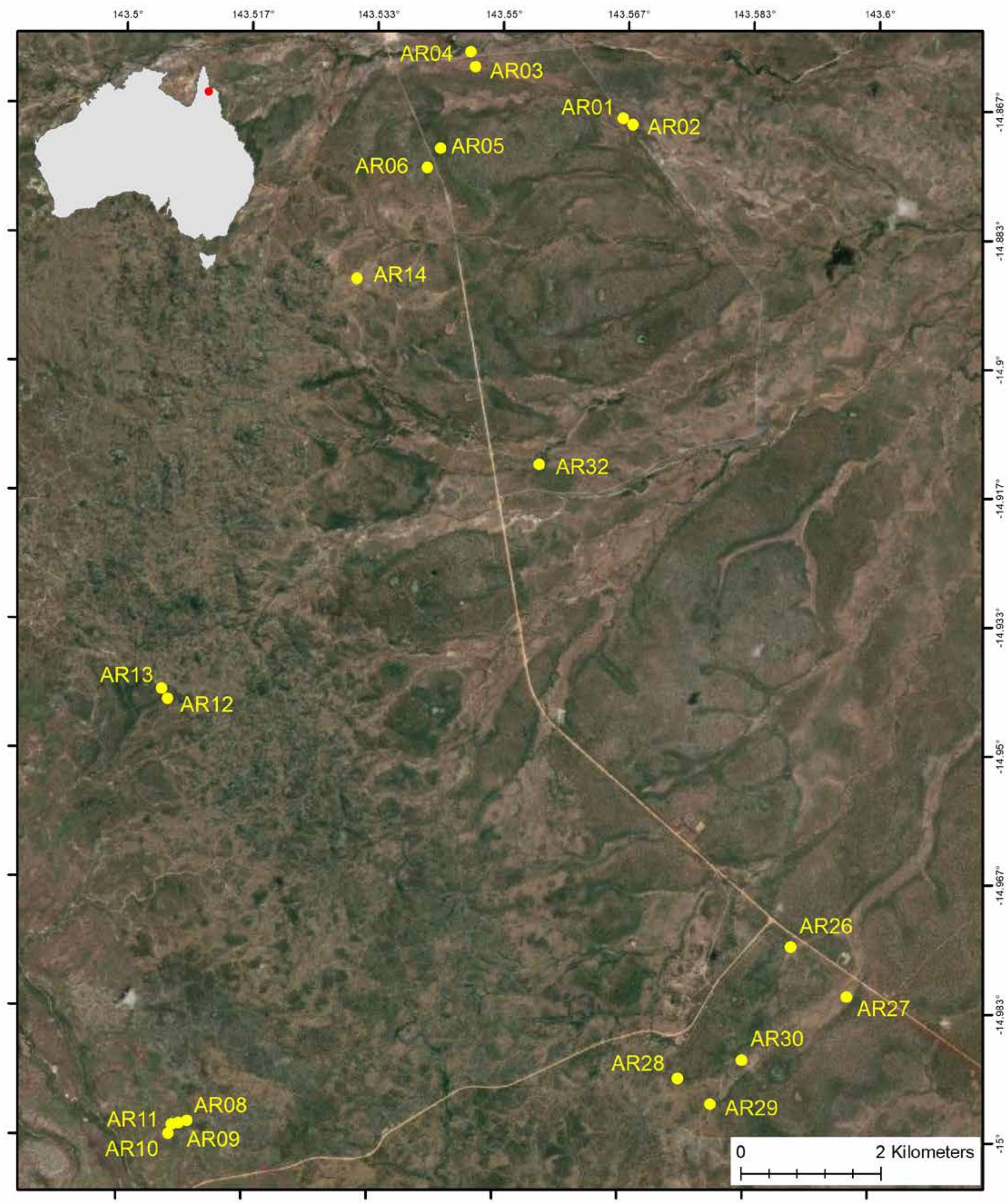

Figure 1. *The location of vegetation monitoring sites on Artemis, re-surveyed in May 2021.*

The contemporary collection of data followed the protocols established by Crowley (2002) under the "SavMon" protocol, which was also used to collect the 1998-2001 data.

Photographs were taken from one end of the 50 m midline, typically with the horizon positioned two-thirds up the frame.

At each sample site, a 50 m midline was established in the late 1990s between two fixed star pickets. All woody plants (hereafter termed "trees" for simplicity; defined as having a diameter of ≥ 10mm at 30cm above ground) within 2 m either side of the mid-line were recorded, including:

- Species (unknown species were collected with field numbers and later identified)
- Diameter at breast height (DBH, in mm) using calipers or DBH tape
- Height (in m) using either a 2 m measuring staff or laser measurer ("Disto X4™, Leica Geosystems, St. Gallen, Switzerland)
- Distance along the midline
- Distance out from the midline
- For multi-stemmed plants (branching at ground level), the DBH of up to 4 stems were measured and the highest stem measured. Plants with ≥5 stems were recorded as "9" stems.
- The status (dead or alive) of each stem was also recorded (although not used in analyses presented here).

As Golden-shouldered Parrots excavate their nests in termite mounds, these were also recorded and measured. These were identified as either boulder termites (*Nasutitermes triodeae*), conical (*Amitermes scopulus*, the most common nest site at 96.7% of nests (Higgins 1999) or magnetic (*A. laurensis*). Height was recorded and diameter at ground level for boulder and conical species. Magnetic mounds are planar in shape and so the length of the longest dimension at ground level was recorded.

To record ground vegetation, twenty 25 cm x 25 cm quadrats were placed at 2.5 m intervals alternately either side of the midline (Figure 2 and Figure 3). Within each quadrat, the three most dominant ground cover species were recorded. Additionally, the presence of key species was recorded in each quadrat, irrespective of how common they were. These key species were those that are known to be important parrot food plants and/or are invasive weeds and have the potential to cause fundamental ecosystem disturbance (e.g. Gamba Grass *Andropogon gayanus*):

- *Schizachyrium* spp.
- *Themeda triandra*
- *Alloteropsis semialata*
- *Sorghum plumosum*
- *Heteropogon triticeus*
- *Heteropogon contortus*
- *Andropogon gayanus*
- *Chrysopogon fallax*
- *Themeda quadrivalvis*
- *Hyptis suaveolens*
- *Stylosanthes* spp.

The percentage of bare ground in each quadrat was also recorded (note analyses not reported here due to strong seasonal effects; see more about the issue of seasonal effects on ground layer composition in the Discussion).

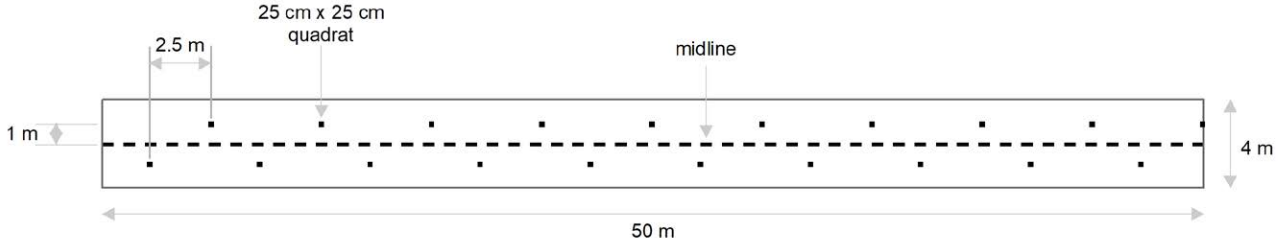

Figure 2. *Schematic diagram of vegetation sampling transect (for woody plants) and quadrats (for ground) layer.*

Figure 3. *(L-R) Wendy Cooper, Rigel Jensen and Sue Shephard surveying ground layer vegetation as part of the baseline monitoring on Artemis, May 2021.*

2.1.2 Statistical analyses

Trees and termite mounds

In terms of potential change in the structure and floristics of trees over the past 20 years, we had three main questions. First, we simply wanted to know if there were more trees now than there were 20 years ago, irrespective of habitat type (Regional Ecosystem, RE) or species. We looked at three size classes: > 1m, > 3m and >5m. Mean number of trees per site was calculated, and unpaired Wilcoxon rank sum tests used to examine whether any change was significant. Second, we wanted to know if any detected change was related to RE type, and third if some species are now more common than others. We used the >1m, >3m and >5m cohort partitioning for the latter two questions, and also used Wilcoxon tests for significance.

For termite mounds, the small sample size precluded stratification by RE and so we simply asked whether there was any change in frequency of occurrence between the two sampling periods, again using Wilcoxon tests.

Ground cover

A species recorded as dominant or key within a quadrat received a score of 5. Scores were then summed for each site and treated as a frequency of occurrence, with 100 being the highest score (i.e. occurred in every one of the 20 quadrats). Frequency scores were grouped by species across all sites. Data were not normally distributed and the sampling between periods was not truly paired. As such, unpaired Wilcoxon rank sum tests were performed for both dominant and key species to assess change through time.

2.2 Vegetation results

Nineteen of the original 20 vegetation monitoring sites were resampled in May 2021. In the intervening ~20 years, one site (AR07) had a fence built through it and resampling was therefore not considered worthwhile.

2.2.1 Photo-points

Qualitatively, many sites showed obvious evidence of thickening by woody plants. This includes sites that were once sparse open woodlands (e.g. Figure 4) and open grasslands (e.g. Figure 5). Not all sites were thicker, particularly those on granitic slopes (e.g. Figure 6).

Appendix 1 shows photo points for each of the 19 sites. On each page is also a map showing the site's approximate location and the site as appears in the 1955 series of aerial photographs.

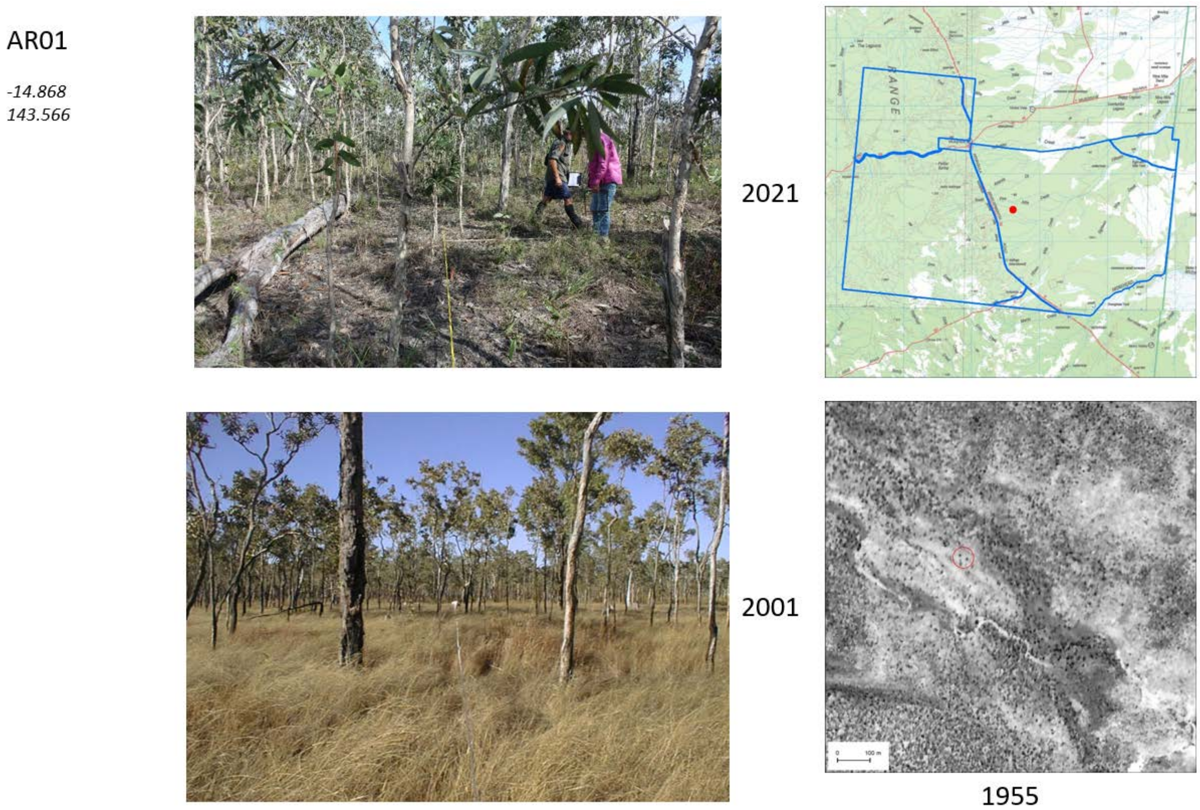

Figure 4. *An example of a sparse open woodland that has become thick over the past 20 years.*

AR03

-14.862
143.545

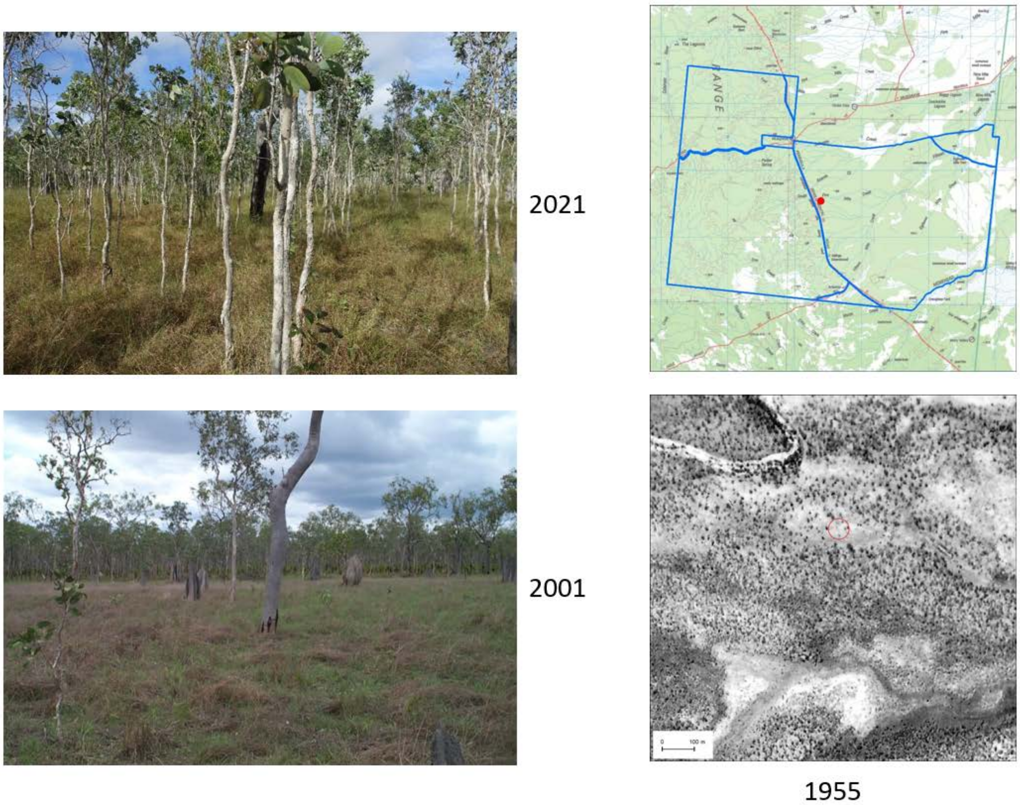

Figure 5. *An example of an open grassland that is now dominated by* Melaleuca viridiflora.

AR13

-14.942
143.505

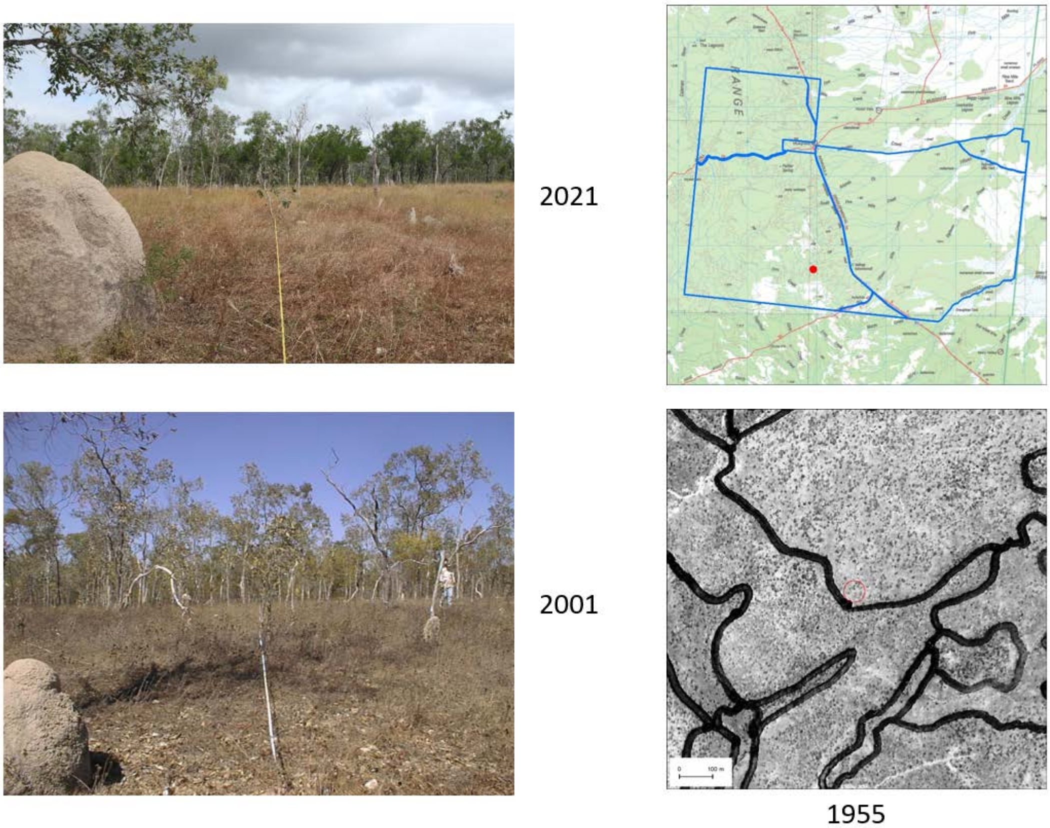

Figure 6. *An example of a sparse open woodland that has maintained its open structure through time. (Black lines are artefacts from past digitisation).*

2.2.2 Trees

At the 19 sites sampled in May 2021, 912 trees were recorded, representing 36 species. In the historical dataset, each site was visited in successive years between 1998 and 2001. The total number of trees measured across all historical sampling was 5668, representing 37 species. The mean number of all trees in each size class increased significantly through time (Table 1).

Table 1. *Change in number of trees through time*

Size class	Historical Mean No. Trees (Std. Dev.)	Contemporary Mean No. Trees (Std. Dev.)	W Statistic	p-value
>1	14.5 (10.2)	43.7 (26.9)	37.5	<0.0001
>3	7.0 (5.3)	19.8 (15.8)	65	0.0008
>5m	4.5 (4.9)	7.4 (5.1)	86.5	0.047

Sampling among REs was not well balanced, and so stratifying by RE resulted in some small sample sizes. Nonetheless, two REs (3.3.49 and 3.3.56) showed a significant increase in the number of trees in the >1 m and >3 m size classes (Table 2).

Table 2. *Regional Ecosystems that have significantly more trees now than 20 years ago, by size class*

RE	Size class (m)	Sample size	Historical Mean No. Trees (Std. Dev.)	Contemporary Mean No. Trees (Std. Dev.)	W Statistic	p-value
3.3.49	>1	4	18.8 (6.9)	58.3 (43.9)	0	0.0115
3.3.56	>1	5	17.6 (28.9)	81.8 (56.4)	3	0.0124
3.3.49	>3	4	13.6	33.7	2	0.0241
3.3.56	>3	5	9	32.8	6.5	0.0874

Two species (*Melaleuca viridiflora* and *Corymbia clarksoniana*) increased significantly between the historical and contemporary sampling periods (Table 3). Two other species (*C. dallachiana* and *Dendrolobium umbellatum*) showed a significant decrease, although they both went from being rare (one stem recorded at multiple sites) to not recorded at all. In the >5 m size class, no species increased significantly.

Table 3. *Species which have significantly changed in density through time*

Species	Size class (m)	Historical Mean No. Trees (Std. Dev.)	Contemporary Mean No. Trees (Std. Dev.)	W Statistic	p-value
Melaleuca viridiflora	>1	11 (8.3)	32.2 (22.3)	148.5	0
Corymbia dallachiana	>1	1 (0)	0 (NA)	7	0.0233
Corymbia clarksoniana	>1	1 (0)	3.6 (4.2)	7	0.033
Dendrolobium umbellatum	>1	1 (0)	0 (NA)	5	0.0736
Melaleuca viridiflora	>3	5.9 (4.1)	15.7 (12.9)	225	0.0001

2.2.3 Termites

There were fewer mounds of the conical forming termite species *Amitermes scopulus*, which is species most often used by Golden-shouldered Parrots for nesting (Higgins 1999). This change was relatively weak, but significant nonetheless (at $p < 0.1$). There was no change for either of the other two species (Table 4). Small samples sizes precluded stratification by RE.

Table 4. *Change in the number of termite mounds at the sites. Conical mounds showed a weak but significant decline. boulder* = Nasutitermes triodeae*; conical* = Amitermes scopulus *magnetic* = A. laurensis

Species	Historical count	Contemporary count	Historical mean (Std. Dev.)	Contemporary mean (Std. Dev.)	W statistic	p-value
boulder	17	22	3.4 (2.2)	3.7 (2.7)	14	0.9266
conical	7	4	1.8 (0.7)	1 (0)	14	0.0689
magnetic	18	18	1.9 (1.7)	1.6 (0.9)	54	0.9665

2.2.4 Ground layer vegetation

A total of 380 ground cover quadrats were sampled at 19 sites on Artemis in May 2021, within which 80 species were identified. A full species list from the contemporary (i.e. May 2021) and historical (1998-2001) sampling periods is included in Appendix 2.

Table 5 shows those species which had a significant ($p < 0.05$) or a near significant ($0.1 < p < 0.051$) change in frequency of occurrence between the two sample periods. W statistics and associated p-values for all species appear in Appendix 2.

Table 5. *Ground layer species that showed significant change in frequency of occurrence between historical (1998-2001) and contemporary (2021) sample periods*

Species	Key or Dominant	Trend	W statistic	p-value
Eriachne stipacea hirsuta	Dominant	decrease	209.5	0.065
Heteropogon triticeus	Key	decrease	64	0.051
Panicum sp.	Dominant	decrease	28	0.037
Schizachyrium sp.	Key	decrease	412.5	0.082
Themeda triandra	Both	decrease	6	0.041
Pseudopogonatherum irritans	Dominant	increase	19	0.017
Scleria rugosa	Dominant	increase	257.5	0.012

3. Butcherbirds

As outlined above, the key reason Golden-shouldered Parrots are thought to have declined is the encroachment of native shrubs and trees into once more open habitats through changed fire patterns and land use (grazing). It is thought that this has elevated predation pressure either by allowing predators, such as butcherbirds, to increase in density and/or increase their hunting success. Thickening is also thought to be responsible for the decline in other open country species (such as woodswallows) that perform an important predator sentry function. As such, a key objective of our work is to understand how butcherbirds respond to the intensive habitat management actions that are scheduled to occur on Artemis over the next few years.

We are collecting pre- and post-management information about population size, home range and movements. We are doing this through colour-banding and call play-back census, and GPS tracking. This information is critical for assessing the degree to which habitat management actions have reduced the threat of predation to Golden-shouldered Parrots.

Work is being conducted in two experimental areas within "Artemis Antbed Parrot Nature Refuge" (Figure 7). The southern-most area ("10 Mile") is approximately 570 hectares and will be the first of the two areas where habitat restoration work will occur. The second area ("5 Mile") is 240 hectares and will act as the control site for the 10 Mile area in the first year, until it will also receive management attention in subsequent years.

The work on butcherbirds is being supported by NESP 3.2.6 and Cape York Natural Resource Management, through the National Landcare Program's "Biodiversity Bright Spots Program". Pre-management baseline measures of butcherbirds will continue for the remainder of 2021; that is, post-June 30 2021 when NESP 3.2.6 officially winds down. As such, the results presented below should be considered preliminary.

3.1 Butcherbird methods

3.1.1 Population census

To measure butcherbird distribution, group size, population size and density, we are capturing as many individuals as possible in mist-nets and bow-nets, and fitting them with individual combinations of coloured leg bands. Individuals are then resighted at a later time, either through systematic call play-back or incidental encounters. The location, time, group size and individual identity of all encounters are recorded as an "interaction". Call play-back censuses that do not elicit a response are recorded as zero interactions. Captures and recaptures are also recorded as interactions.

3.1.2 Home range size

A subset of both species of butcherbirds is also being fitted with GPS tracking devices to estimate home range size with greater precision than can be achieved with the census work. GPS tags (PinPoint-10, Lotek, New Zealand) are glued to trimmed dorsal feathers just above the synsacrum with a flexible hypoallergenic cyanoacrylate glue (Vetbond™ Tissue Adhesive, 3M, Minnesota, U.S.). GPS tags are programmed to record a location every 10 minutes at two time periods 0630-0830 hrs and 1600-1800 hrs. The small size of the battery typically means we obtain data over 4-6 days. Data are stored on-board the tag (i.e. remote data access is not possible) and so tags have to be recovered. Each tag also incorporates a VHF beacon (PicoPip Ag337, Lotek, New Zealand) which aids in tag recovery or recapture.

3.2 Butcherbird results

3.2.1 Pre-management (baseline) population census results

To date, we have captured and colour-banded 37 Pied Butcherbirds and 33 Black-backed Butcherbirds within the two main project areas (see Figure 7). We have documented 312 "interactions", including 146 with Black-backed Butcherbirds and 166 with Pied Butcherbirds. The locations of butcherbird interactions are shown in Figure 7.

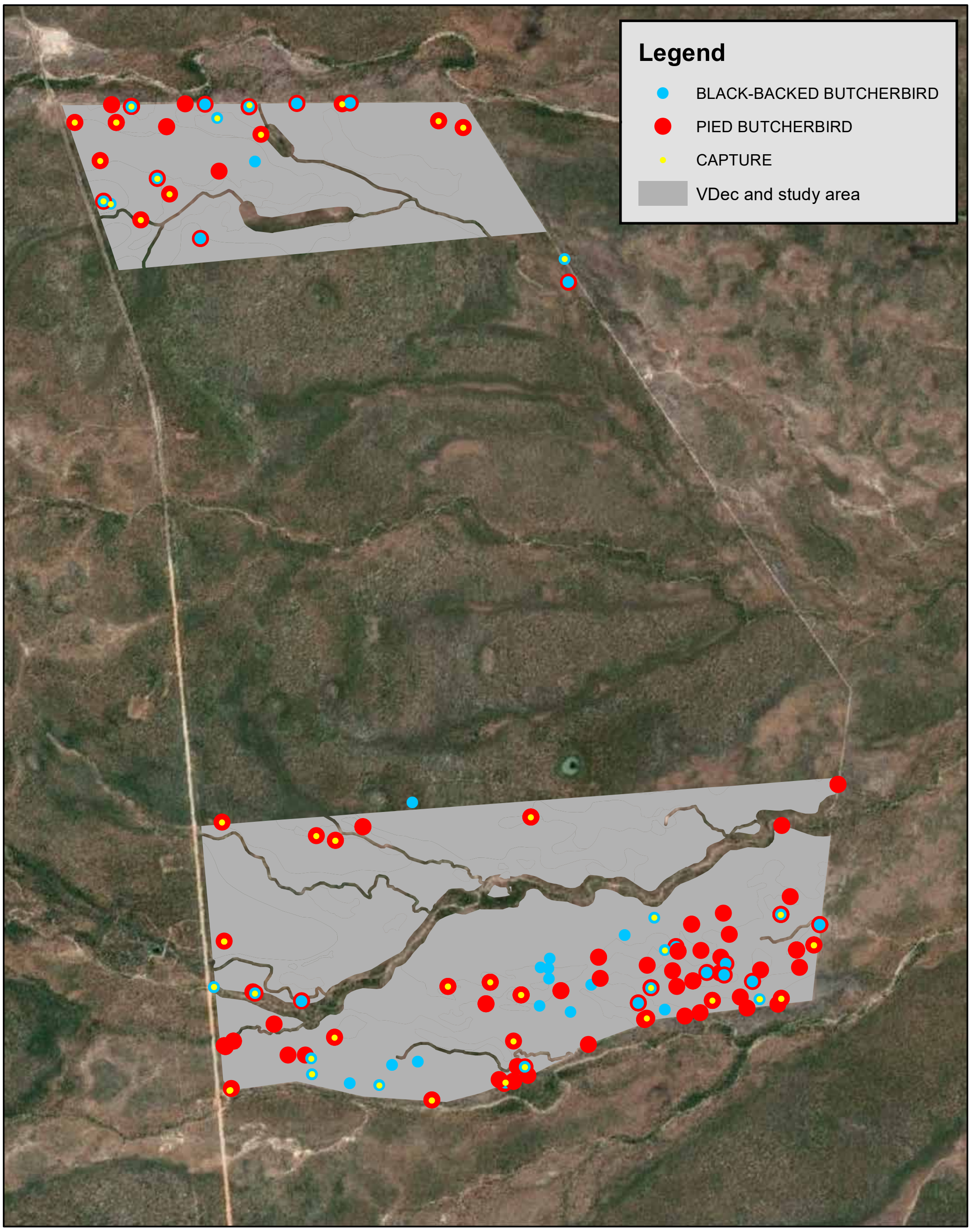

Figure 7. *The butcherbird study areas within Artemis Antbed Parrot Nature Refuge (grey) and locations of butcherbird interactions. 70 individuals (including both species) have been banded within this area (yellow dots = capture locations), but despite this most birds that are seen are unbanded. The southern section is 570 hectares, and the northern section is 240 hectares.*

The mean group size for both species is approximately 3 individuals, suggesting group living and possibly cooperative breeding (Table 6). Group living and cooperative breeding has been observed in Pied Butcherbirds but there is hitherto no evidence for it in Black-backed Butcherbirds (Higgins 2006).

Table 6. *Group sizes observed for butcherbirds during interactions.*

Species	n	Mean Group Size (sd)	Maximum Group Size
Black-backed Butcherbird	120	2.61 (1.27)	6
Pied Butcherbird	138	2.69 (0.985)	5

Of the 166 interactions with Pied Butcherbirds, call play-back elicited a strong response by birds 83% of the time. It was similar for Black-backed Butcherbirds, with call play-back eliciting a strong territorial response also 83% out of 146 interactions.

The majority of interactions to date have involved unbanded birds. In May 2021, when the most number of birds have been banded, out of 30 interactions with Black-backed Butcherbirds, 67% involved unbanded birds. There were more interactions with banded Pied Butcherbirds during the same period, however 37% of birds were still unbanded (n = 37 interactions).

Census data also provides some indication about the size of home-ranges that is further refined with GPS tracking data (see below). For the colour-banded Pied Butcherbirds we have re-sighted to date, (n = 7), the mean maximum distances individuals moved was 171 metres. For Black-backeds, it was 72.5 m. All maximum distance data are shown in Table 7. These are small distances and suggest small home ranges.

Table 7. *The maximum distance (m) between points of resighted butcherbirds. (n = number of times bird has been observed)*

Species	Colours	n	Maximum distance between resighting locations(m)
Black-backed Butcherbird	RGB	2	139
Black-backed Butcherbird	RNN	2	150.8
Black-backed Butcherbird	RPP	2	44.1
Black-backed Butcherbird	ROO	2	44.1
Black-backed Butcherbird	NBR	2	47.6
Black-backed Butcherbird	RGG	2	9.3
Pied Butcherbird	YBR	2	209.7
Pied Butcherbird	RRO	2	209.7
Pied Butcherbird	RBN	3	342.5
Pied Butcherbird	XXR	2	140.7
Pied Butcherbird	ROB	3	112.4
Pied Butcherbird	RRR	3	228.2
Pied Butcherbird	YBB	3	297.8

3.2.2 Pre-management (baseline) home range sizes

To date, 11 butcherbirds have been fitted with GPS tags: 5 Pied and 6 Black-backed. The small size of the tag we need to use means that we must recover the GPS after deployment, either by finding the tag once it has dropped off or recapturing the bird if they are still wearing it. Two tags on Black-backed Butcherbirds could not be recovered because the birds could not be recaptured. The VHF beacon on these tags (which aids recovery should the tag be dropped) lasted only 16 days, and stopped working while still attached. As such, these tags could not be relocated after they had fallen off the birds. We have extended the life of a second batch of VHF beacons which will be used from now on. Four of the Pied Butcherbird tags are still on birds and we expect to recover them in early July.

Table 8 shows the main details of the tags for which we have data. The key point is that each bird has a small home range, which supports the findings from the colour-banding study which have so far shown that the maximum distances between re-sightings are small.

Figure 8. *Details of the 5 GPS tags recovered to date*

Tag	Species	No fixes	Days tracked	Home range	Note
50270	Pied	84	4	8 ha	Includes 2 outliers 500m from core range
50271	Black-backed	91	4	3.0 ha	Breeding season
50271	Black-backed	88	5	2.9 ha	1 outlier 370m from core range
50270	Black-backed	120	6	3.8 ha	Overlapped with BB 50271
50273	Black-backed	47	2	1.9 ha	Stopped prematurely; sent to manufacturer in UK for testing

4. Discussion

4.1 Trees

The purpose of this work, and the investment by NESP 3.2.6, was to establish a pre-management baseline dataset to inform forthcoming management actions on Artemis Station. These actions are designed to restore the habitat quality of the endangered Golden-shouldered Parrot.

This work was able to build on a historical vegetation dataset that was collected from 1998 to 2001, when Golden-shouldered Parrots were more common on Artemis. In May 2021, we resampled all but one of these historical survey points, and in doing so, we are able to make some solid inferences about habitat changes over the past two decades.

Qualitative and quantitative data presented here show that woodlands and grasslands on Artemis have become thicker with trees over the past 20 years. This supports the findings of previous published work (Crowley and Garnett 1998; Neldner et al. 1997). In our study, the effect is strongest for the sub canopy and suckers (< 5m high, see Table 1 Change in number of trees through time) which is expected given that this has been a gradual process which has taken time to manifest itself in larger cohorts. Nonetheless, we have shown that there are also now more canopy trees (>5 m, although the effect is slightly weaker, $p = 0.047$) which suggests that the thickening process is fundamentally changing the demography of trees.

Vegetation thickening was significantly more likely to be detected in two REs: 3.3.49[1] and 3.3.56[2] (based on RE mapping v 11.0; Queensland Herbarium 2019). Both occur in lower "run-on" parts of the landscape, while adjacent upland and better draining communities showed no significant increase in tree density. This finding echoes that from earlier work (Crowley 2002; Crowley and Garnett 1998; Neldner et al. 1997). However, we note that sampling was limited in some upland REs in our work and previous published work (Crowley and Garnett 2001), while some other published studies which have demonstrated thickening were entirely focussed on grassland communities on run-on areas (Crowley and Garnett 1998; Neldner et al. 1997). As such, the degree to which thickening may be occurring in upland communities remains uncertain and requires further sampling.

Despite our limited sampling and that of others (Crowley et al. 2009), there is evidence that some upland REs, (for example RE 3.12.10[3]) do appear to be thickening. Unpublished time series analyses using remote sensing products illustrate a significant positive trend in the amount of persistent green vegetation through time in some of these upland REs (S. Murphy, unpublished data, Figure 8). Personal observations at such places show that species such as *Petalostigma* spp. appear to be growing at high density (personal observations S. Shephard, S. Murphy; S. Garnett; Figure 9). This is potentially problematic because Golden-shouldered Parrots do breed in these habitats as well as the lower lying run-on areas (Crowley et al. 2004). It is also in these areas that Black-faced Woodswallows are most likely to breed in the early wet season. It is at these sites at which the parrots gather and feed on the ground during the early wet season when they are particularly susceptible to predation.

[1] *Melaleuca viridiflora* +/- *Corymbia clarksoniana* low open woodland on floodplains and alluvial plains

[2] *Aristida* spp. and/or *Eriachne* spp. tussock grassland in drainage depressions

[3] *Eucalyptus cullenii* +/- *Corymbia clarksoniana* woodland or *E. chlorophylla* woodland on granitic ranges

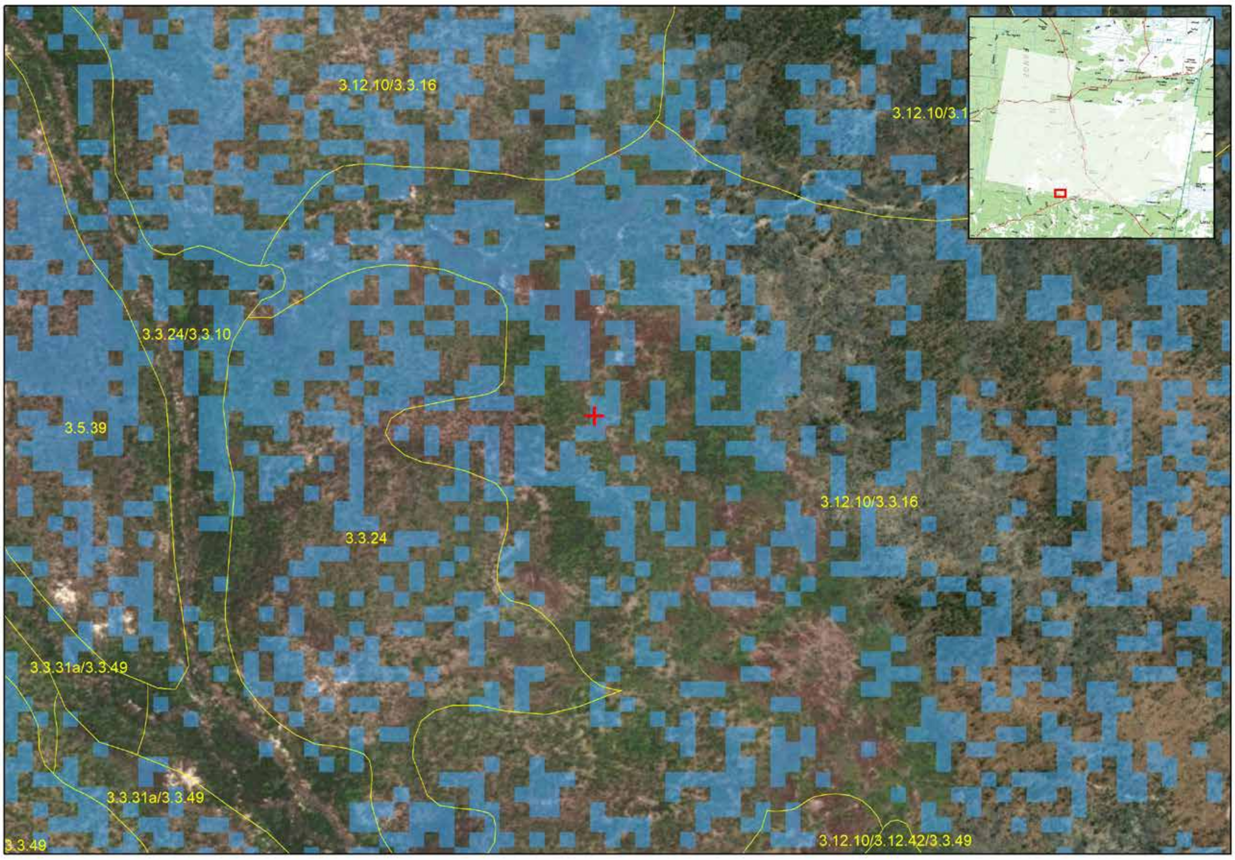

Figure 8: *Figure 8 Areas which have a significant increase in persistent green vegetation through time (blue squares). The red cross is the location of the photograph shown in Figure 9.*

Figure 9. *Evidence of thickening by* Petalostigma spp. *at the location shown in Figure 8.*

4.2 Termites

Our results show that the number of conical termite mounds of the species *Amitermes scopulus* has declined significantly through time (see Table 4); 96.7% of all Golden-shouldered Parrot nests have been found in this species' mounds (Higgins 2006). Although our result is relatively weak (p = 0.0689), it aligns with previous research that also shows a decline in the availability of suitable nesting mounds (Crowley et al. 2004). Parrots will only re-use an individual mound if it is large enough to accommodate a completely new chamber (Crowley et al. 2004) and so any decline in the availability of termite mounds is likely to present a significant problem for the parrots.

Crowley et al. (2004) state that conical mounds are likely to be declining due to a combination of physical damage by feral pigs and cattle, and changes to grass layer ecology wrought by grazing, excessive low intensity fire and shading by thickening.

The sample sizes for termite mounds we encountered by repeating the historical vegetation surveys were small. Prior to commencing management, we intend to build on this dataset by marking and measuring an additional sample of mounds, stratified by RE and grazed/non-grazed. Previous attempts to mark mounds outside of vegetation plots have not withstood the test of time (S. Shephard pers. comm.) and so we intend to circumvent this problem by using highly accurate GNSS-RTK positioning receivers.

4.3 Ground layer vegetation

Our results show significant declines in five grasses. Two are perennial (*Heteropogon triticeus* and *Themeda triandra*), two can be either annual or perennial (*Eriachne stipacea* and *Panicum* spp.) and one is actually a group of related species from a predominantly annual genus (*Schizachyrium* spp.). The decline of the perennial species is a common response to cattle grazing (Walker et al. 1997) and so is not altogether surprising. We did not detect a significant change in the occurrence of *Alloteropsis semialata*, which is another perennial species that has been shown to decline in other research on Artemis and is known to be an important food for Golden-shouldered Parrots and other granivores (Crowley and Garnett 2001). Analyses for this species is shown in Table 9. There are a few possible explanations for the lack of significant change in this important species. First, it's possible there has indeed been no real change in occurrence, which could either mean the species was already suppressed in the historical period and we are simply reporting the same pattern. Second, inter-annual variation in abundance might be masking a long-term trend. In other words, 2021 might have been a good year for *Alloteropsis* within an otherwise long-term downhill trajectory. Inter-annual variation has been shown to be a significant issue for ground layer sampling in tropical savannas (Neldner and Butler 2021) and we intend to address this by additional surveys in forthcoming years.

Table 9. *Analyses for* Alloteropsis semialata

Sample type	Historical mean	Contemporary mean	W statistic	p-value
Dominant	13.5	8.6	118	0.3
Key	16.2	14.2	169	0.7

We have reported a weak, although significant decline of *Schizachyrium* spp. (Table 5), which is the most important dry season food plant for parrots (Crowley and Garnett 1999). This is noteworthy because it is traditionally thought to be a superabundant group of annuals that are fairly resistant to grazing pressure (S. Shephard, personal observations). Our sampling in May 2021 was in the early part of the dry season, which followed significant April rain (~400mm). This meant that *Schizachyrium* was obvious and easily detected within plots. Furthermore, some of the samples in the historical period were taken later in the year when it's possible that *Schizachyrium* was actually less detectable (e.g. through grazing or trampling by cattle (Crowley and Garnett 1999) though fluffy seeds and the tone of the brown leaves can make it easier to detect when dry).

There are two explanations for our result: first, we may have indeed detected a real change in abundance. Crowley and Garnett (1999) showed that early dry season burning reduces seed availability by 85% and so it's possible that a long history of such burning might cause population decline over time. Alternatively, and we think more likely, given the late wet season and obvious occurrence of many other species (such as *Scleria rugosa*) it could be that these species displaced *Schizachyrium* as a dominant species at the time when quadrats were sampled. That there was no significant change in reporting between the two periods when *Schizachyrium* was recorded as a key species (i.e. recorded irrespective of dominance) supports this notion. Similarly, it is not clear if the apparent increase in *Scleria rugosa* and *Pseudopogonatherum irritans* relates to a seasonal sampling effect, or a true change in occurrence. Additional sampling in forthcoming years may help tease this apart.

4.4 Butcherbirds

Pre-management baseline data collection for butcherbirds will be on-going for the remainder of 2021. This will bolster some components which are currently suffering from small sample sizes (e.g. total proportion of the populations that are banded, and re-sightings of banded birds). As such the results presented below should be considered preliminary. Despite these limitations, some important information is already beginning to emerge.

All evidence points to butcherbirds living at high density within the project area, thus supporting the notion that there are more butcherbirds now because of thickening. To date, 37 Pied and 33 Black-backed Butcherbirds have been colour-banded, and, based on the location of captures shown in Figure 7, we estimate there are at least three to four times that number within the project area. This gives an estimated population size of 120 individuals of each species within the combined 810 ha project area, which equates to a population density of ~ 0.15/ha.

Based on limited GPS tracking data to date, we cautiously suggest that this population estimate may be reasonably accurate for Pied Butcherbirds: the single bird for which we have tracking data had a home range size of ~8ha. Assuming this is typical, this gives a population size for Pied Butcherbirds of ~100 individuals.

In contrast, the mean home range for Black-backed Butcherbirds is ~3 ha (n = 4) which gives a population size of ~ 270 individuals (density = 0.3/ha).

We are confident that our estimates for home range size are reasonably accurate despite the short life of the GPS tags (~4-6 days), because of the small maximum distances between locations for colour-banded birds that were resighted months apart (in some cases).

A high population density is likely to mean that there are few, if any, empty butcherbird territories within the project area. Such habitat or territory saturation often relates to group living, where offspring remain on the natal territory to increase their fitness, hone skills and/or increase their chance of inheriting the territory (Barve et al. 2019; Kingma 2017; Komdeur 1992). As shown above (Table 6), butcherbirds within the project area are frequently recorded living in groups, which is further evidence of high population density. This has been observed previously in Pied Butcherbirds, but not for Black-backed, although this species is comparatively poorly known (Higgins 2006).

4.5 Conclusions

The information presented within this Baseline Report supports the conceptual model of decline of Golden-shouldered Parrots on Artemis. The data collected forms a solid foundation for an evidence-based recovery of the species, involving highly practical actions. The main findings are:

1. There has been significant and on-going thickening of once sparse woodland and grassland habitats. This provides additional justification for the habitat restoration works that are planned to occur over the coming years.
2. Thickening is most evident in lower elevation, run-on parts of the landscape where *Melaleuca viridiflora* has increased significantly over time in the >1 m and >3 m size classes.
3. Sampling has been biased towards lower run-on habitats, and there is emerging evidence that the same process is occurring in upland habitats, involving species such as *Petalostigma* spp..
4. Results from tracking individually marked and GPS tagged Pied and Black-backed Butcherbirds are suggestive of high population densities. Whether this is an effect of thickening will be tested when habitat modification is undertaken, and territory size and density remeasured. Nonetheless, preliminary baseline data presented here supports the notion that predation pressure is likely to be high.
5. We detected a decline in mounds of the termite *Amitermes scopulus* which is the predominant nest site for Golden-shouldered Parrots (96.7% of nests). The drivers of this change are speculative and as such a systematic ecological study of this species is considered a high priority. This will in part be satisfied by on-going monitoring of termite mounds as habitat management works are undertaken over the coming years.
6. We detected changes in ground layer composition over the past 20 years. There has been on-going decline of some perennial species, which is expected in a grazed system. We did not detect change in the key grass *Alloteropsis semialata* and possible reasons for this are given. We detected a slight, but significant decline in the annual dry season parrot food *Schizachyrium* spp. which may be related to persistent early dry season burning, or inter-annual sampling effects. On-going monitoring may help disentangle this.

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Research is being conducted under University of Queensland Animal Ethics Approval, Australian Bird and Bat Banding Colour Marking and Project Approvals, and Department of Environment and Science Scientific Purposes Permits.

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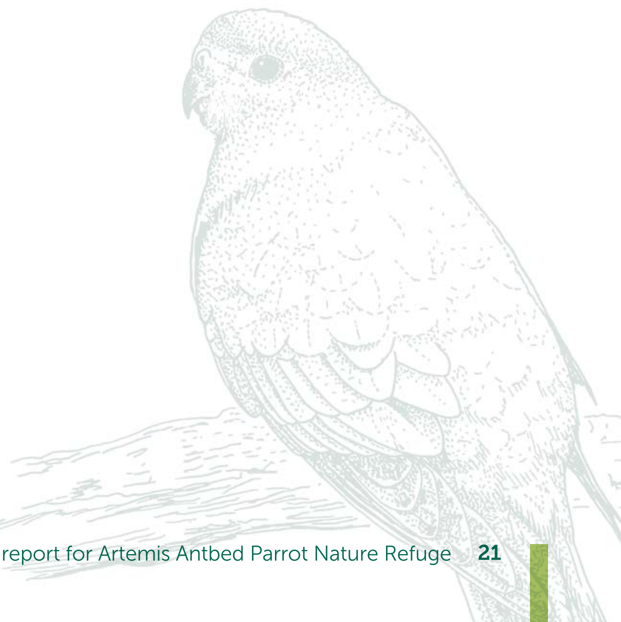

7. Appendix 1: Photo monitoring points

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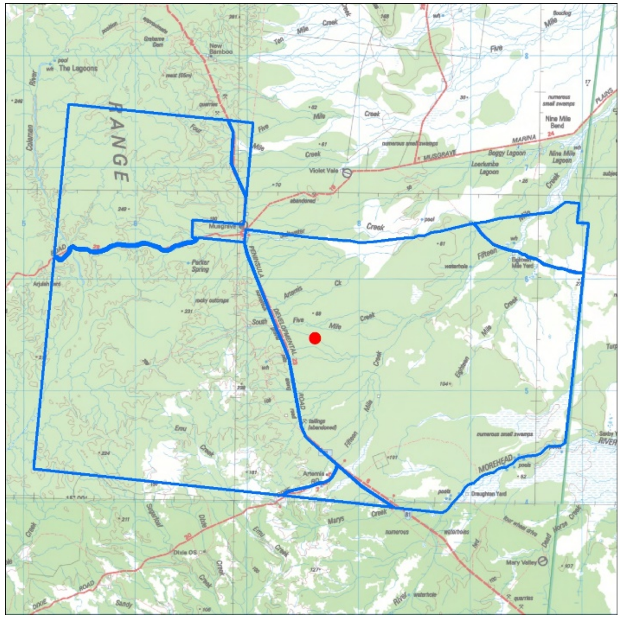

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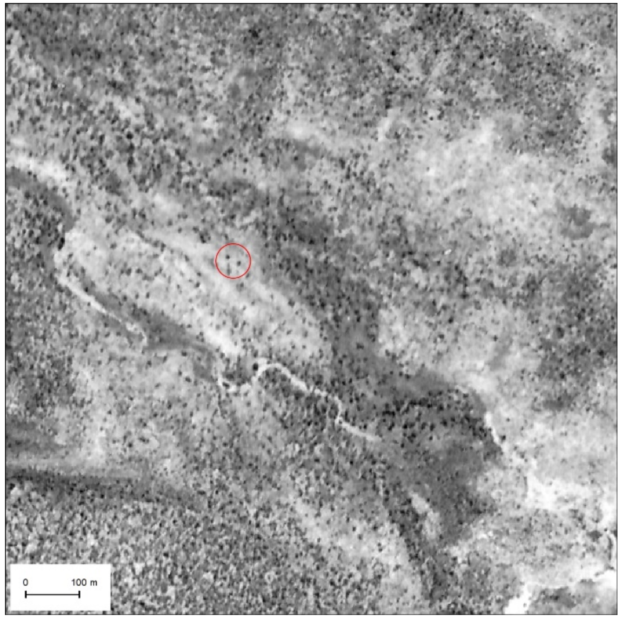

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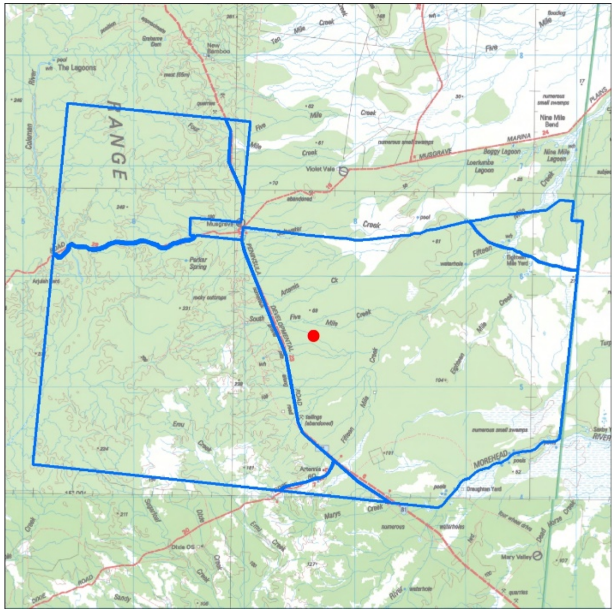

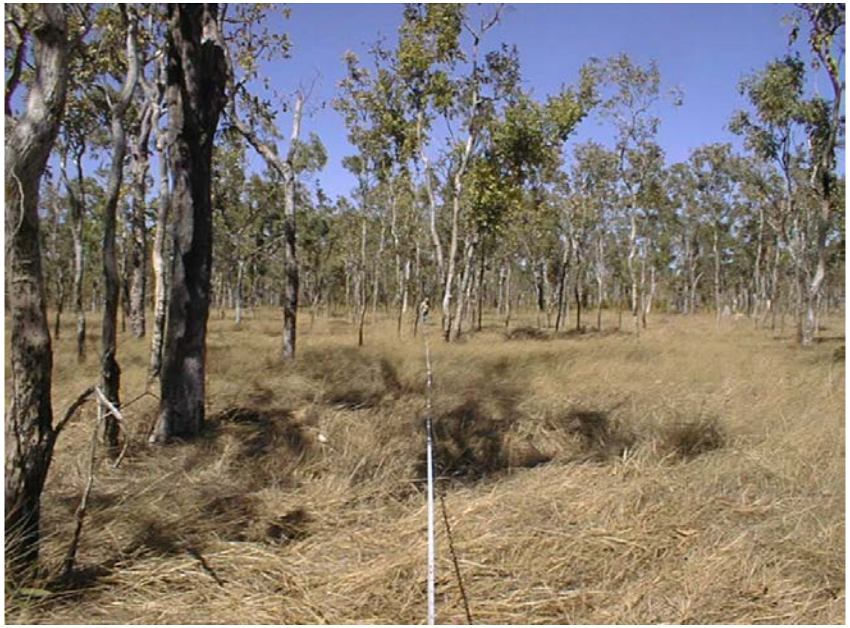

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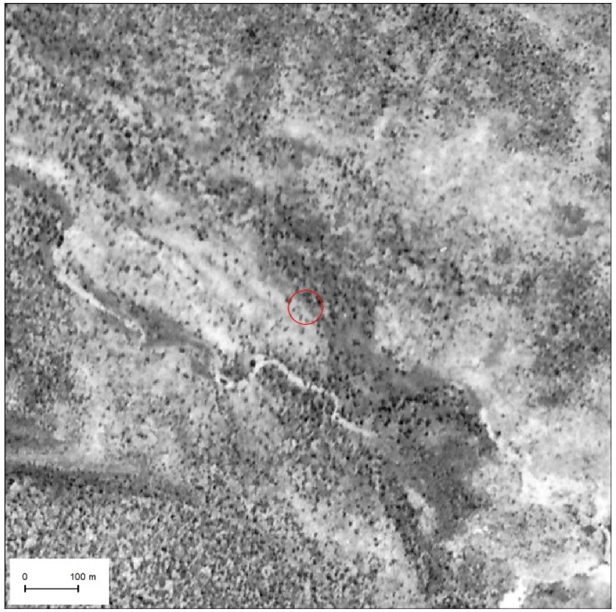

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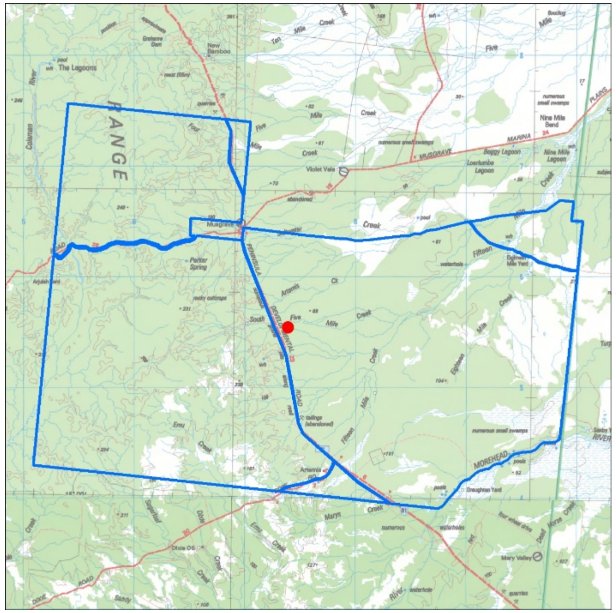

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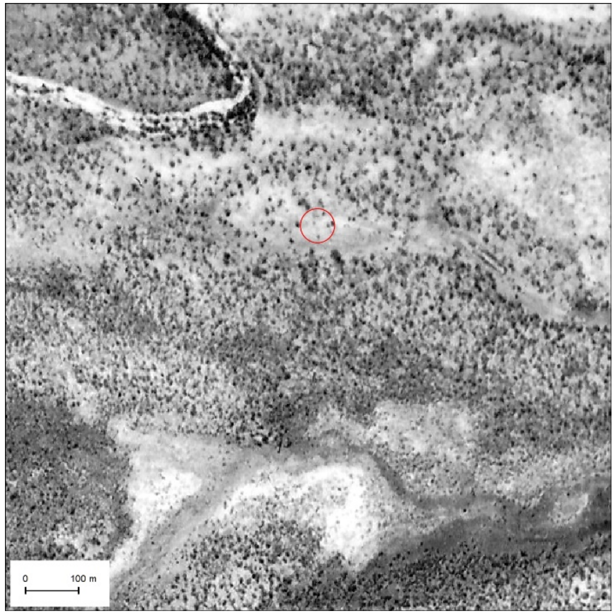

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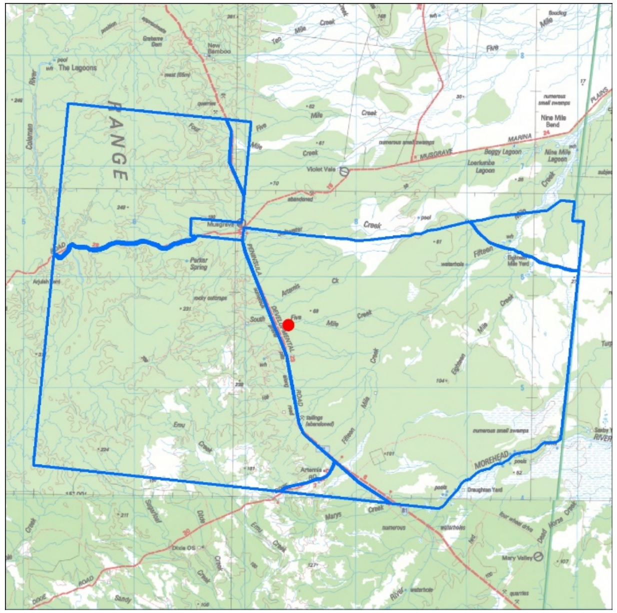

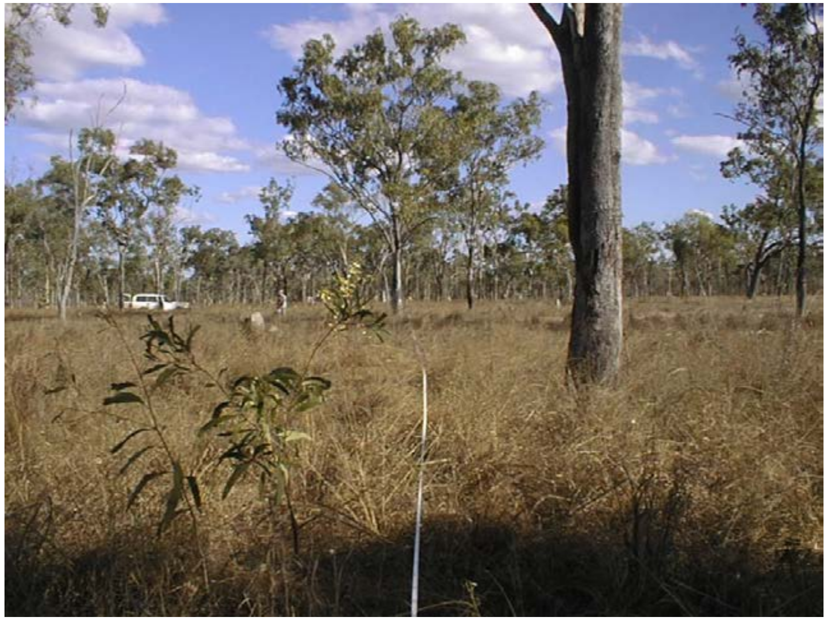

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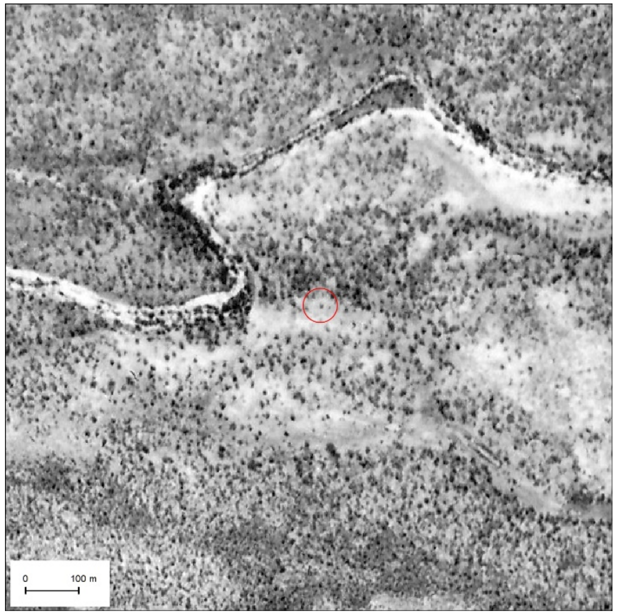

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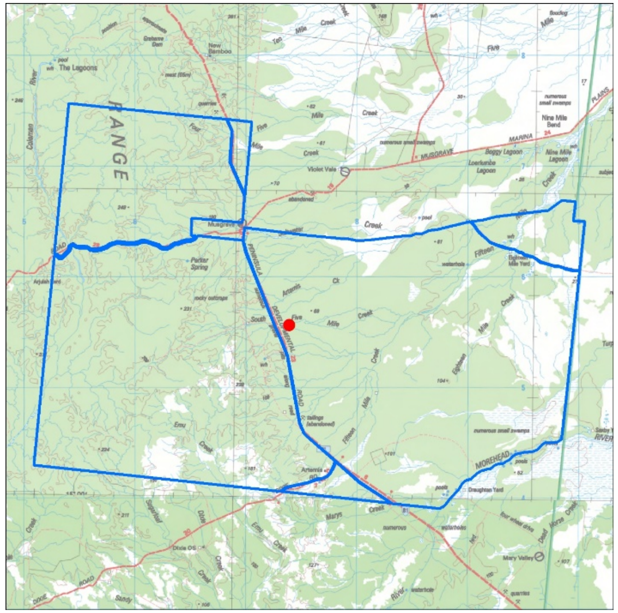

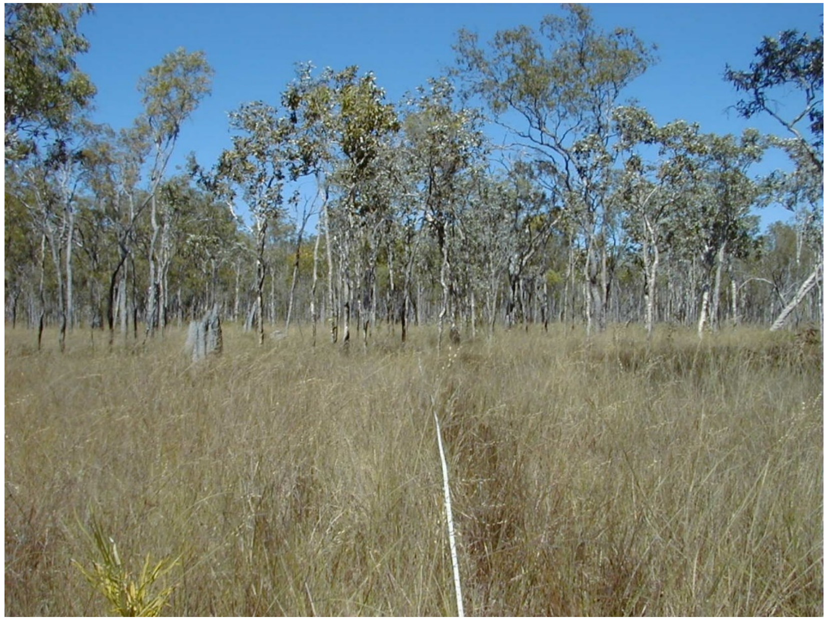

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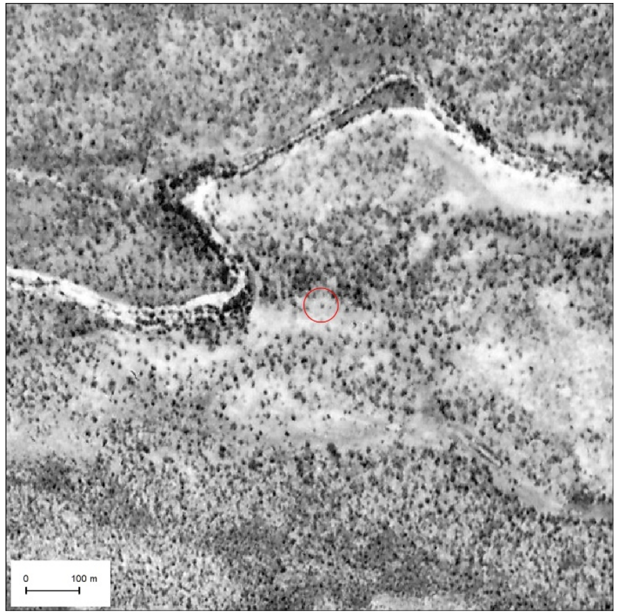

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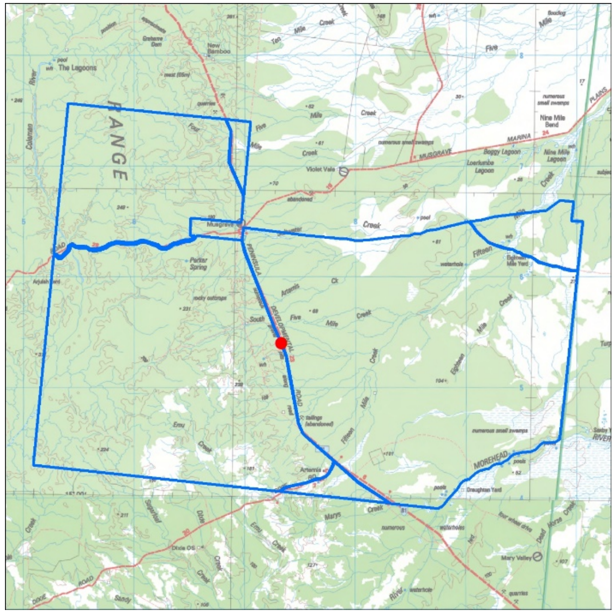

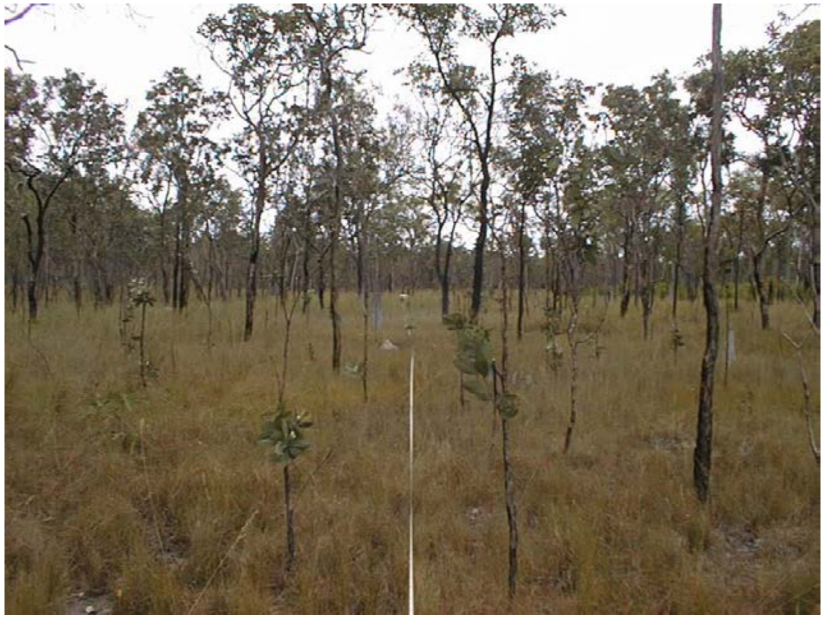

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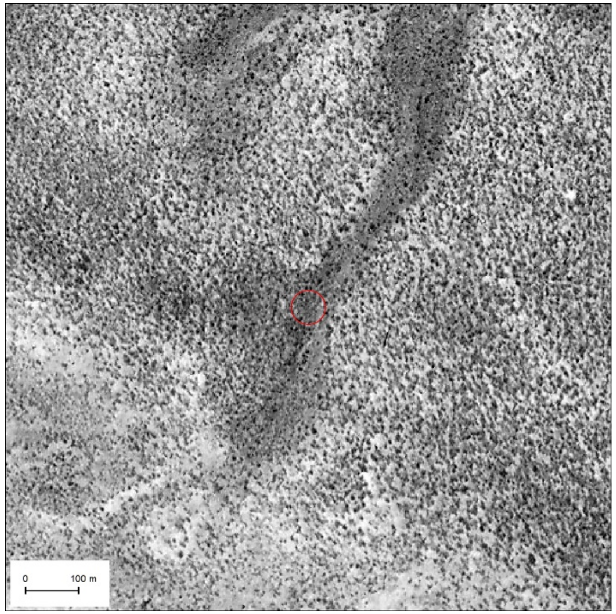

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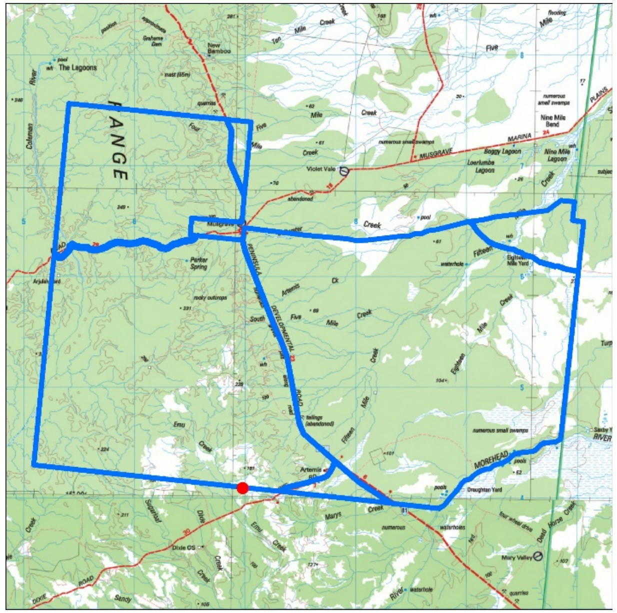

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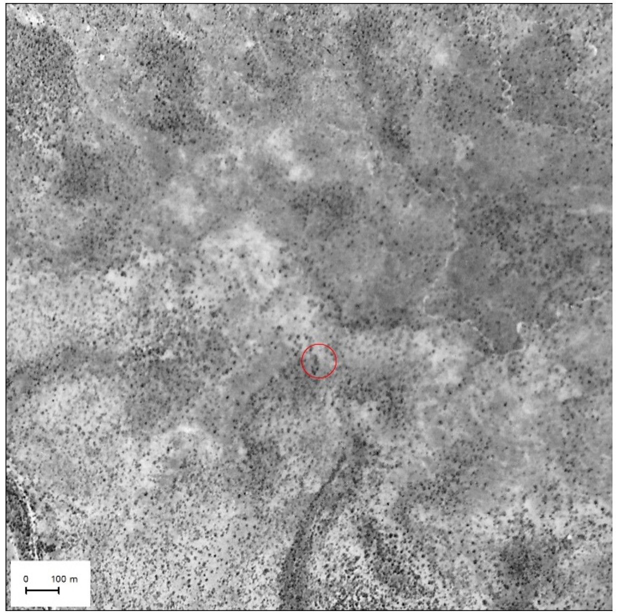

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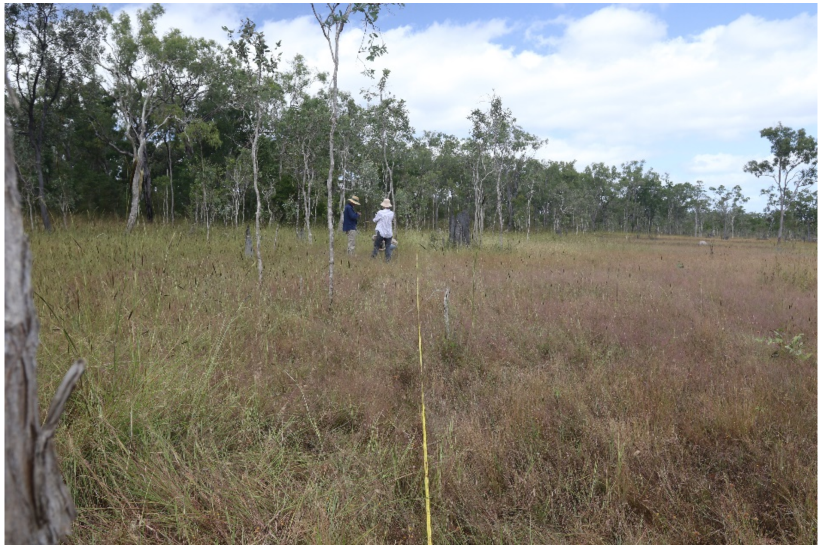

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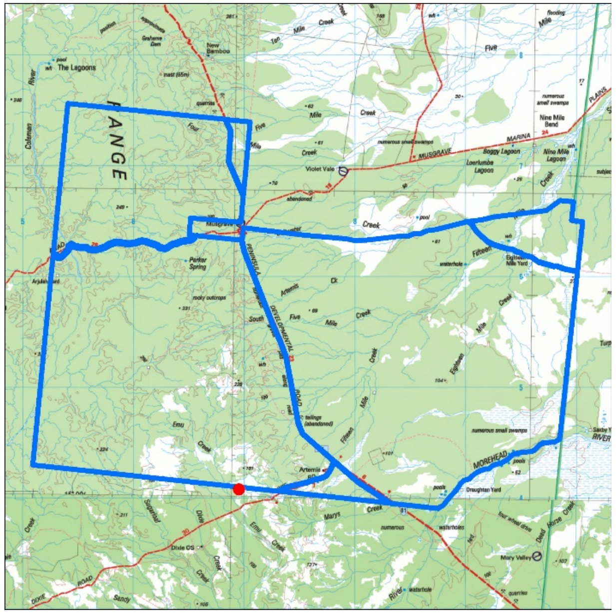

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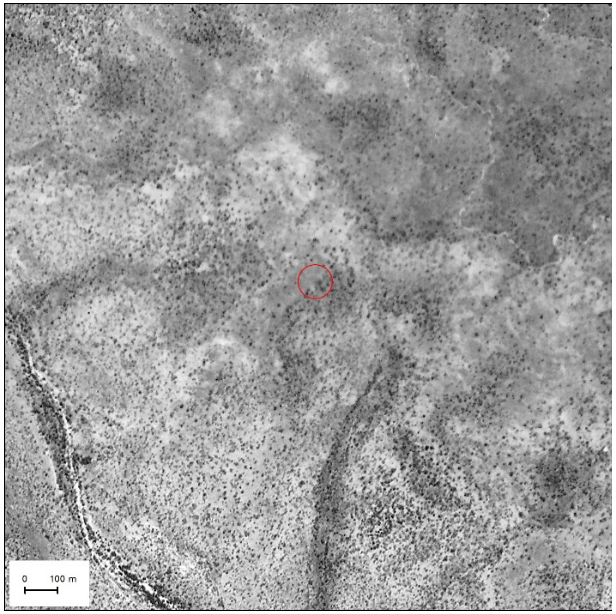

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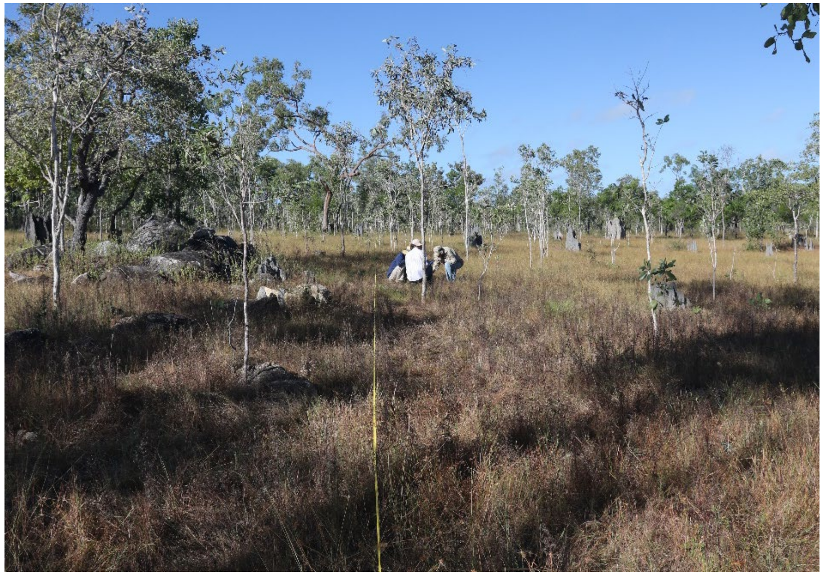

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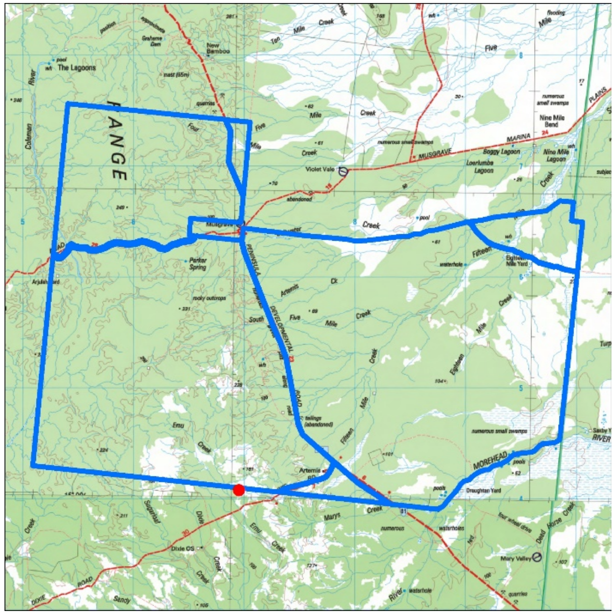

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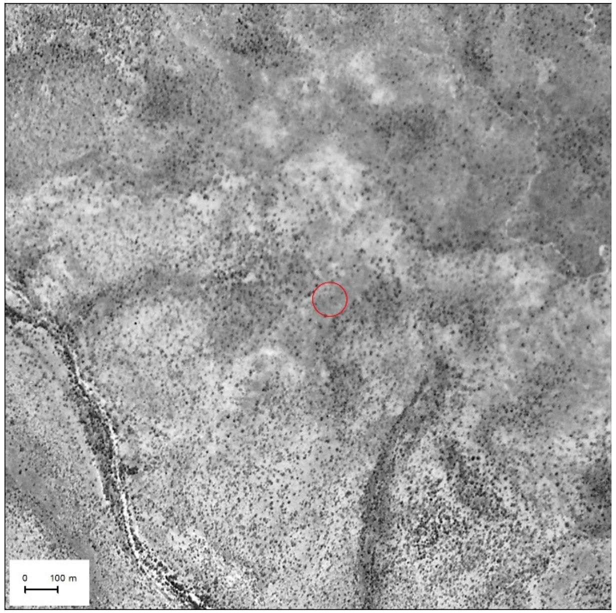

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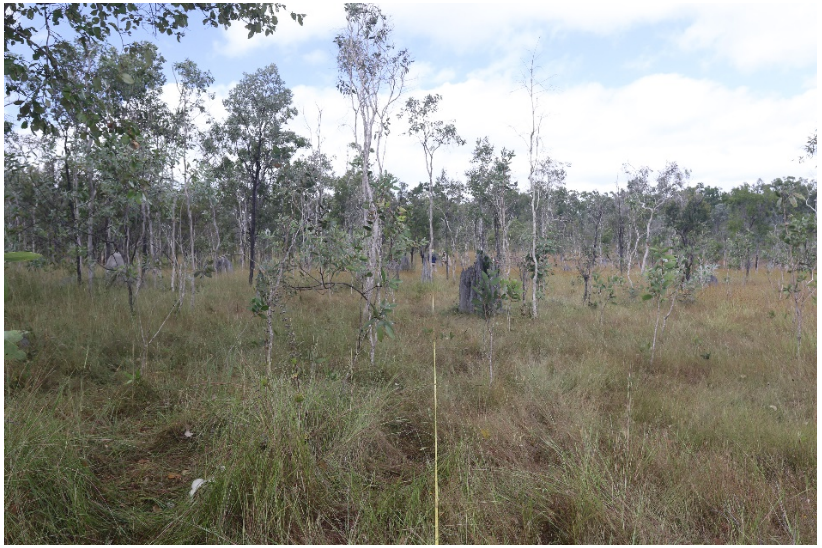

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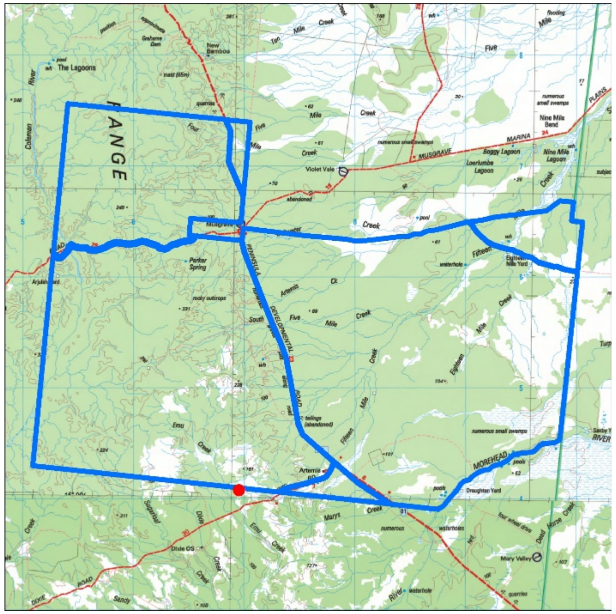

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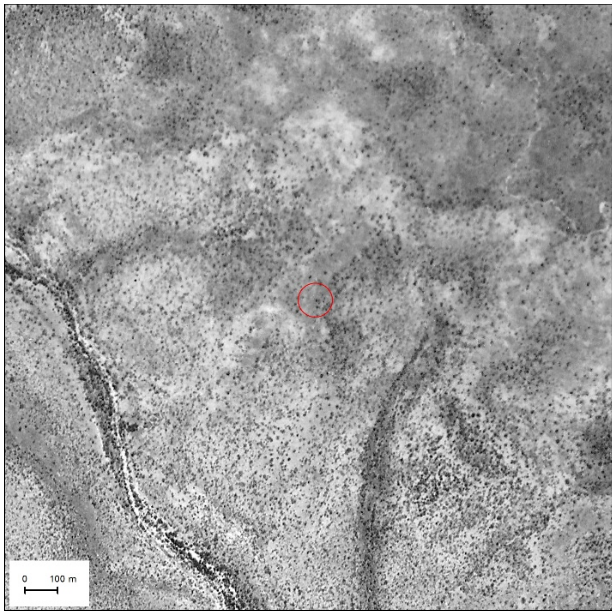

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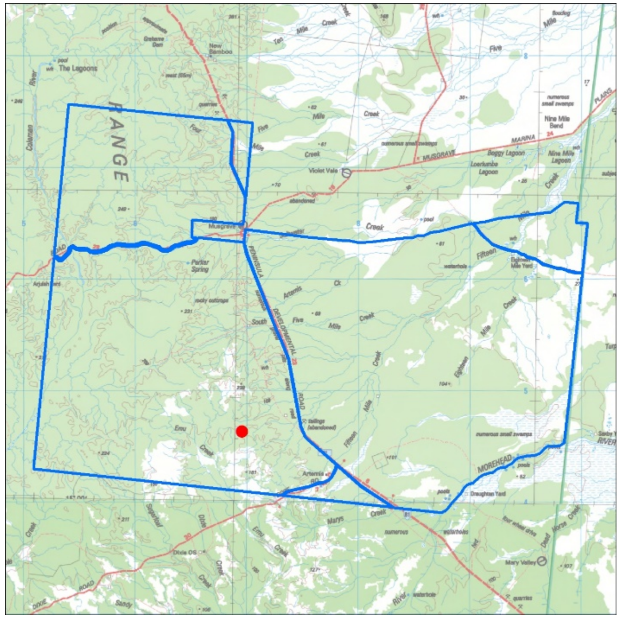

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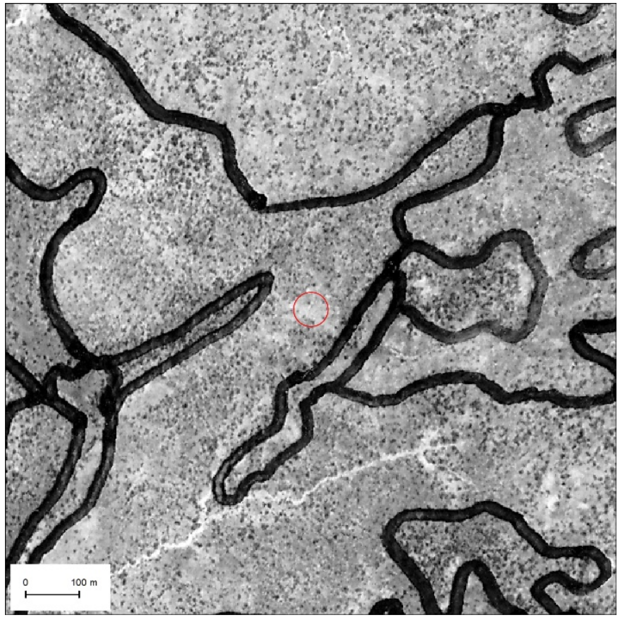

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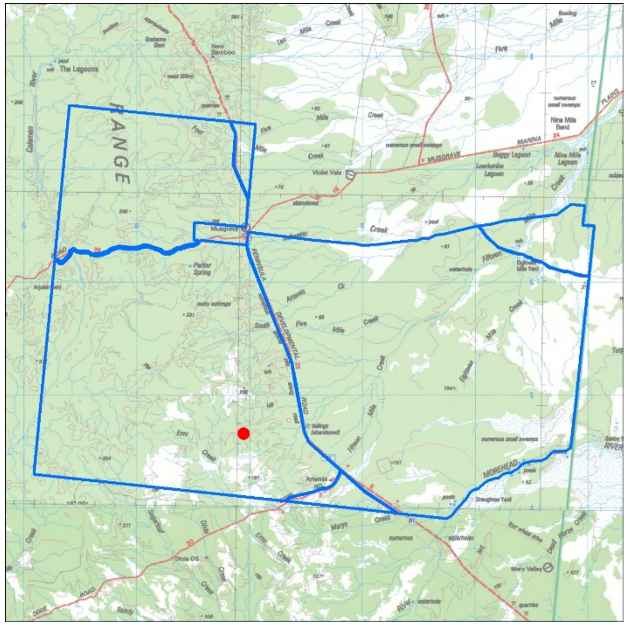

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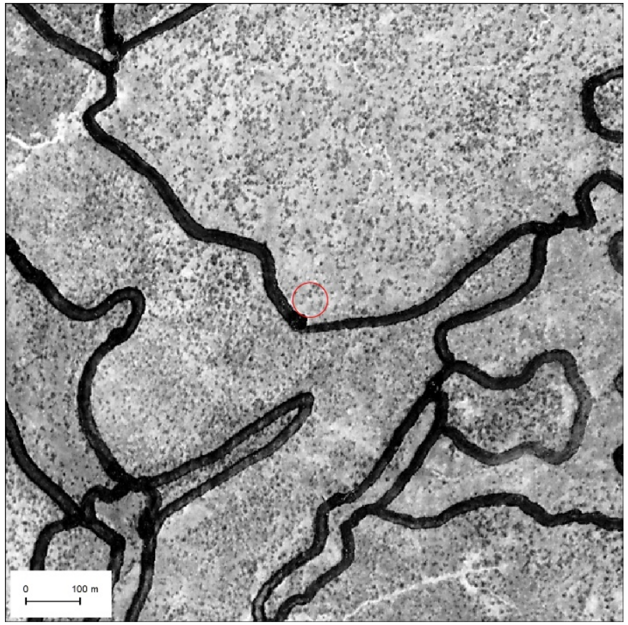
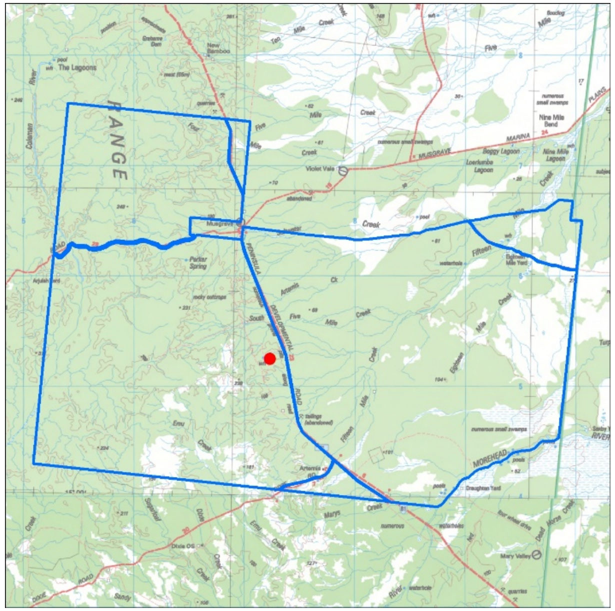


1955

AR14

-14.889
143.531

2021



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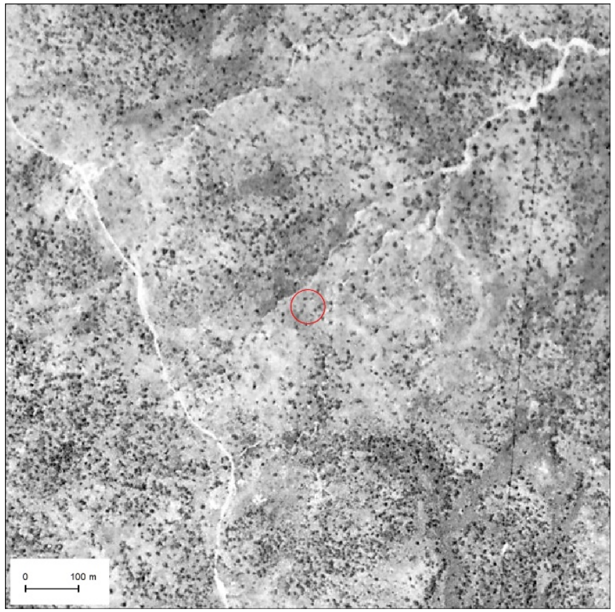
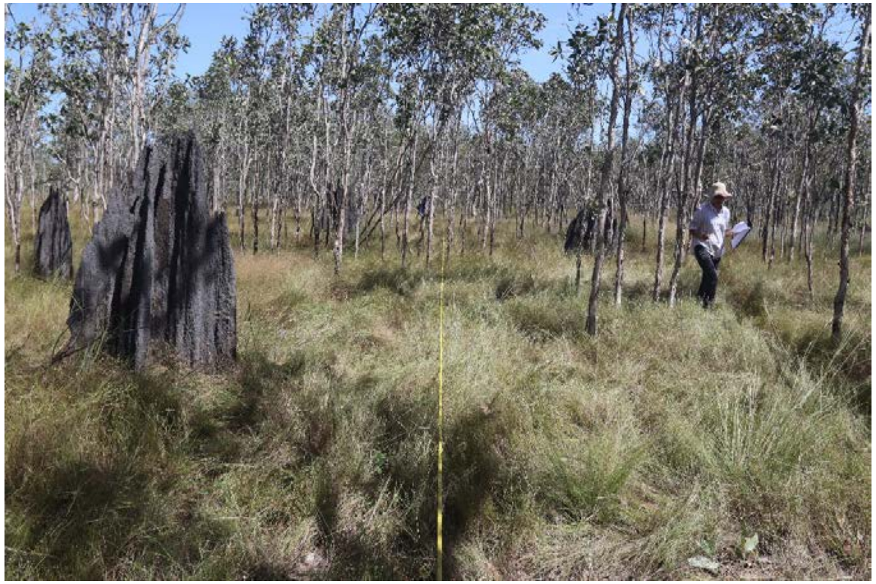


1955

AR26

-14.911
143.561



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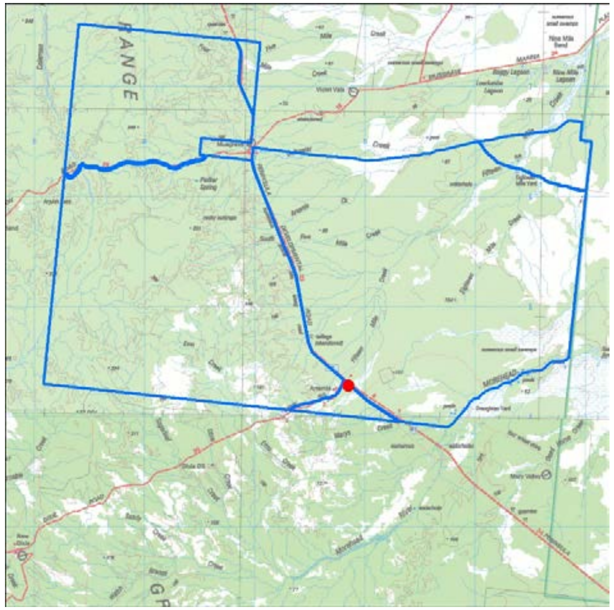

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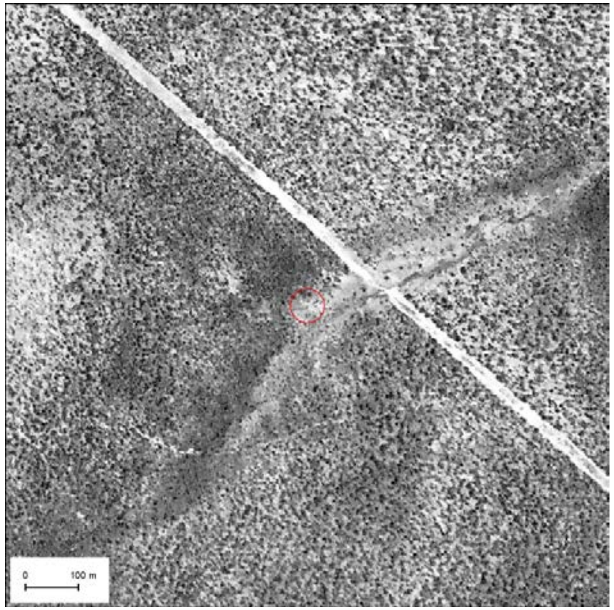
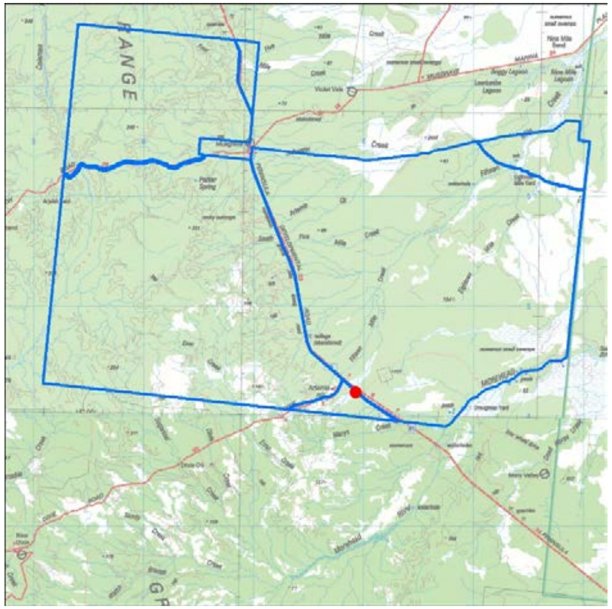


1955

AR27

-14.981
143.597

2021



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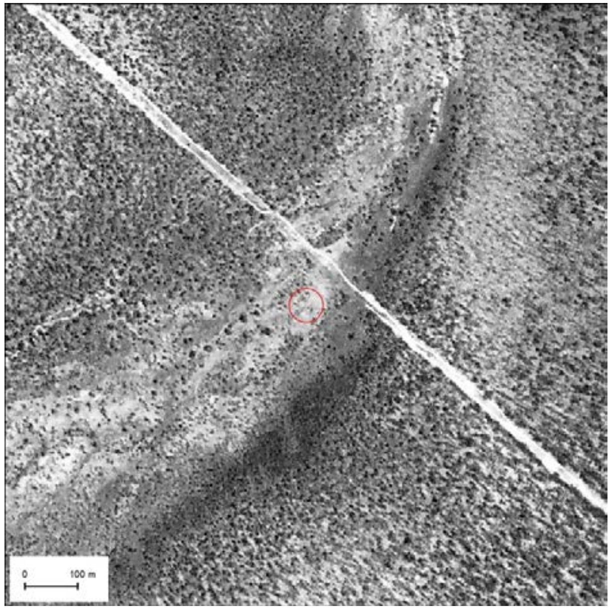
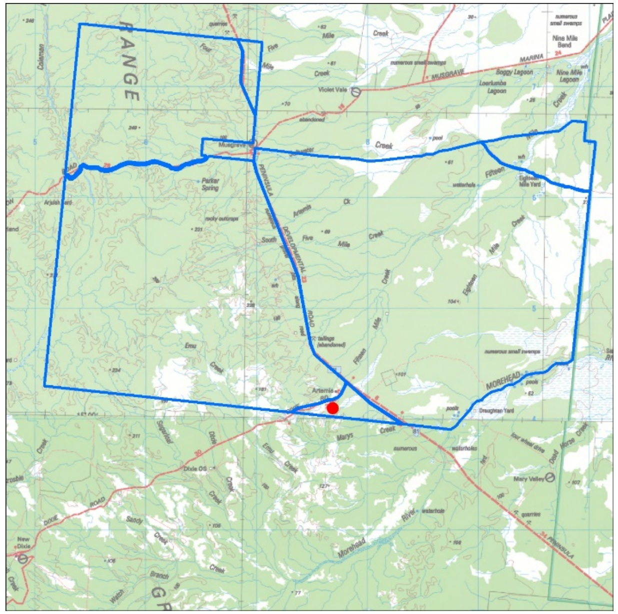


1955

AR28

-14.992
143.575

2021



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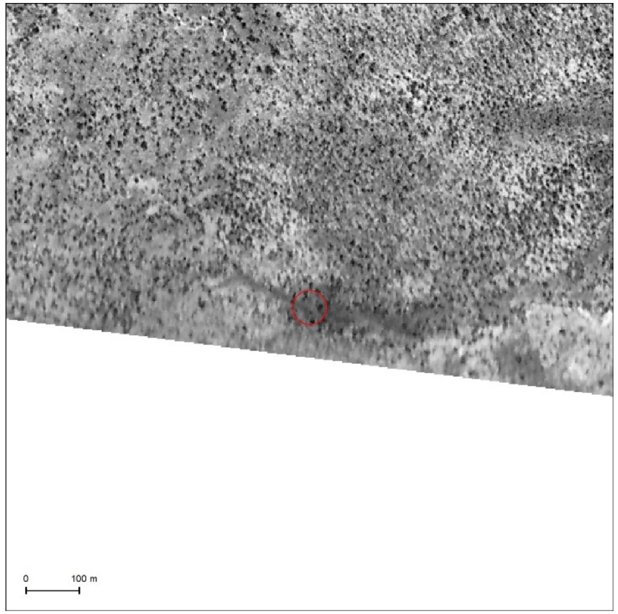
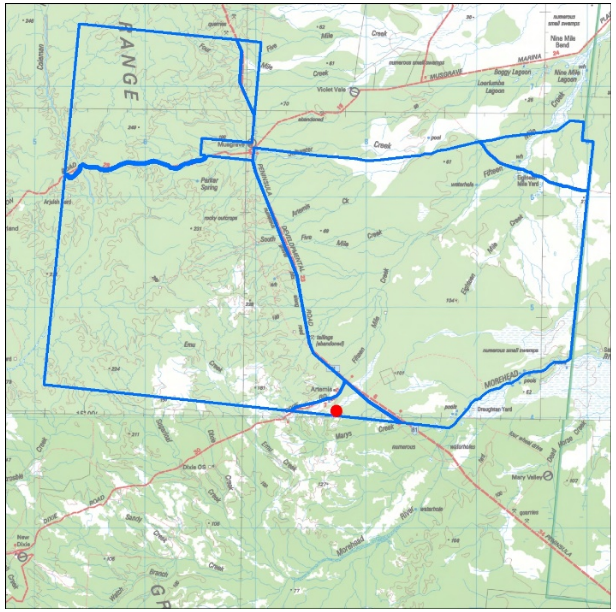


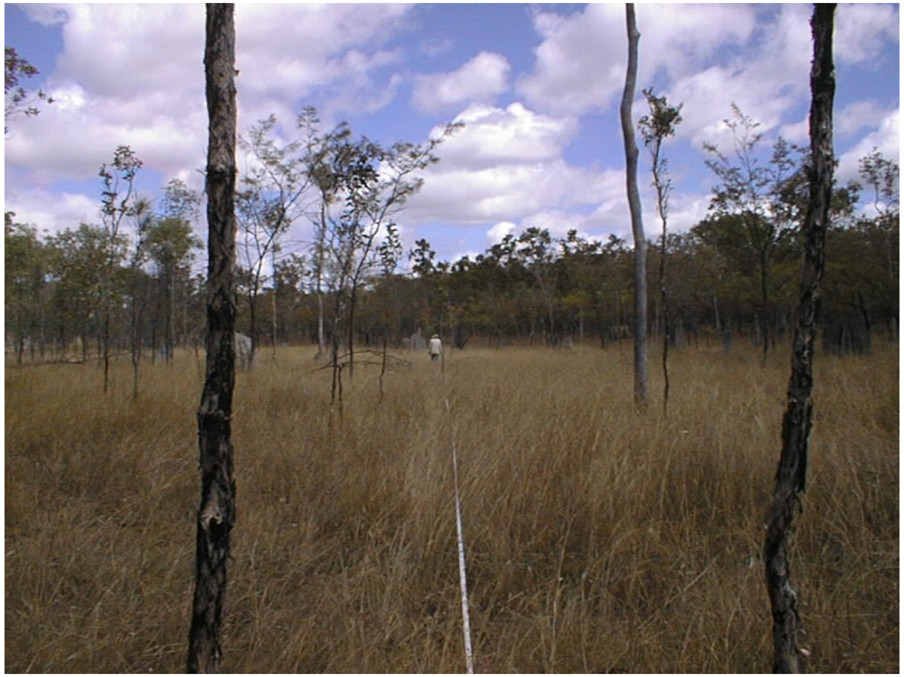
1955

AR29

-14.995
143.579

2021





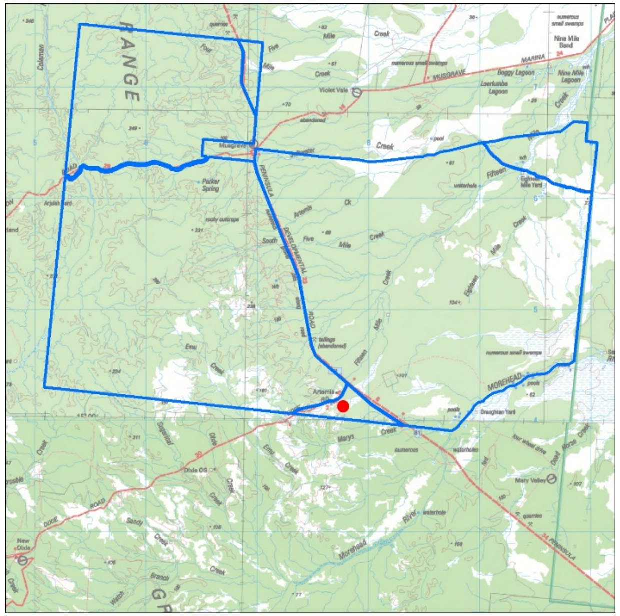
2001

NOT AVAILABLE

AR30

-14.989
143.583

2021



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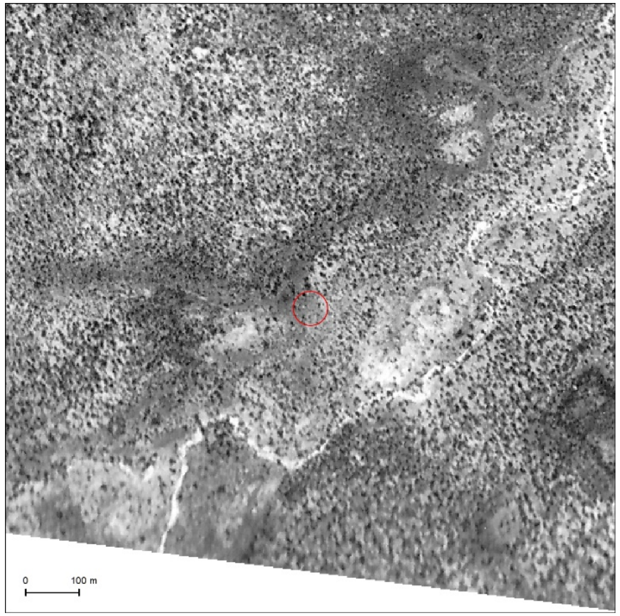
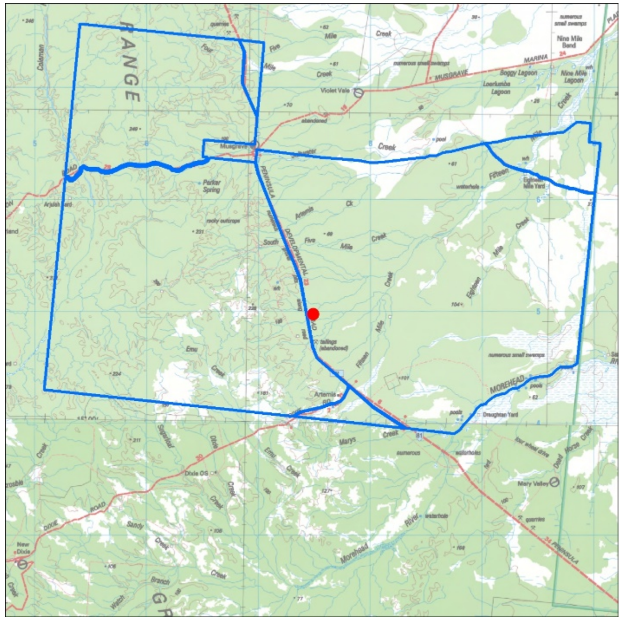


1955

AR32

-14.913
143.555

2021



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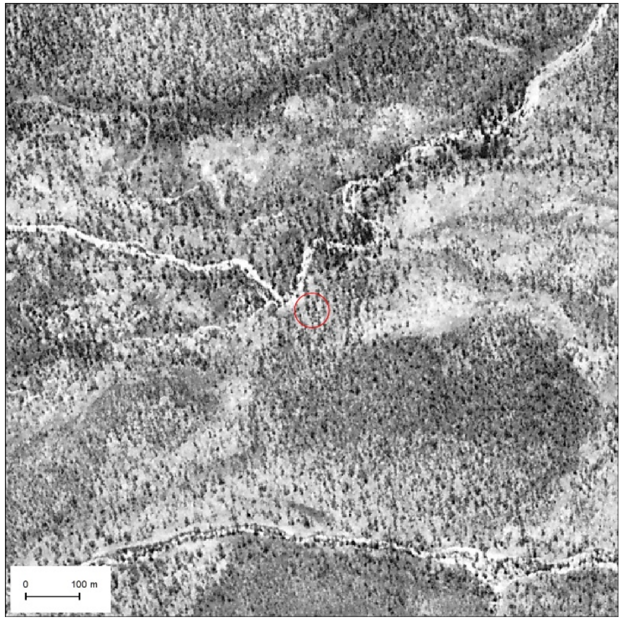

1955

8. Appendix 2: Ground cover species and trends

Species	Trend	Historical mean frequency	Contemporary mean frequency	W statistic	p-value
Allopterigeron filifolius	1	13.75	15	3.5	1
Alloteropsis semialata	-1	13.52	8.57	118	0.3
Alphitonia pomaderroides	-1	5	0	1	1
Aristida sp.	-1	28.55	23	99	0.33
Arundinella setosa	1	5	7.5	1	0.62
Asteromyrtus symphyocarpa	-1	7.5	5	1.5	1
Bothriochloa sp.	-1	5	0	1	1
Buchnera sp.	1	5	10	0	1
Cartonema spicatum	1	0	5	0	1
Cassytha filiformis	1	0	5	0	1
Chloris inflata	-1	16.67	0	3	0.37
Corymbia dallachiana	-1	5	0	1	1
Cyperaceae	-1	15	10	17.5	0.76
Cyperus squarrosus	1	0	10	0	0.54
Dapsilanthus spathaceus	1	49.44	63.33	8	0.35
Desmodium sp.	1	0	5	0	1
Dimeria acinaciformis	-1	16.67	0	12	0.14
Drosera lunata/serpens	1	0	5	0	0.48
Drosera petiolaris	-1	5	0	1	1
Ectrosia leporina	-1	5	0	2	0.48
Ectrosia nervilemma	-1	10	8.75	2.5	1
Ectrosia sp.	1	21.74	23.19	121	0.478
Eragrostis sp.	-1	18.64	14.17	68.5	0.91
Eremochloa bimaculata	-1	16.48	6.67	54	0.36
Eriachne burkittii	-1	18	0	10	0.15
Eriachne mucronata	-1	20	17.5	1	1
Eriachne sp.	1	12.15	16.67	40	0.9
Eriachne stipacea	-1	67.83	47	209.5	0.07
Eriocaulon sp.	1	8.75	18	7.5	0.61
Evolvulus alsinoides var. decumbens	1	0	5	0	0.48
Fabaceae	-1	10	0	3	0.35
Fimbristylis recta	1	0	20	0	0.19
Fimbristylis sp.	-1	27.18	15.77	320	0.16
Galactia tenuiflora	1	0	5	0	1
Goodenia sp.	0	5	5	0.5	NaN
Grewia savannicola	0	5	5	0.5	NaN
Heterachne gulliveri	1	0	5	0	1
Heteropogon contortus	-1	13.33	0	3	0.35
Heteropogon sp.	-1	5	0	1	1

Species	Trend	Historical mean frequency	Contemporary mean frequency	W statistic	p-value
Heteropogon triticeus	-1	13.85	5	20	0.22
Indigofera sp.	-1	5	0	1	1
Ischaemum decumbens	1	11.67	32.5	4.5	0.72
Ischaemum fragile	-1	28.68	19.06	192	0.18
Lepidosperma sp.	-1	5	0	1	1
Lomandra sp.	1	0	5	0	0.48
Ludwigia hyssopifolia	1	0	5	0	1
Melaleuca viridiflora	-1	8.53	6.67	30	0.63
Mesosphaerum suaveolens	1	5	10	2	0.12
Mitracarpus hirtus	1	0	5	0	1
Pandanus cookii	-1	5	0	1	1
Panicum sp.	-1	21.25	5	28	0.04
Panicum trichoides	1	0	5	0	1
Paspalum scrobiculatum	-1	12.5	0	2	0.54
Paspalum sp.	-1	25	0	1	1
Perotis rara	-1	12.5	0	2	0.54
Phyllanthus carpentariae	0	10	10	1	1
Phyllanthus virgatus	1	0	6.67	0	0.35
Pigea enneaspermus	1	0	5	0	1
Pseudopogonatherum irritans	1	20.83	49	19	0.02
Red knee	1	0	7.5	0	0.54
Rhamphicarpa australiensis	1	0	35	0	1
Rhynchospora pterochaeta	-1	27.98	24.67	363	0.39
Sacciolepis indica	1	0	10	0	0.54
Schizachyrium spp.	-1	61.14	49.17	490	0.14
Scleria rugosa	1	37.60	57.5	257.5	0.01
Scleria sp.	-1	15.5	10	17	0.79
Sehima nervosum	-1	5	0	1	1
Setaria surgens	-1	7	0	5	0.20
Sorghum angustum	1	6.67	7.5	5	0.84
Sorghum plumosum	-1	22.90	5	16	0.28
Spermacoce sp.	-1	20	7.5	7	0.55
Tephrosia turpinii	1	0	5	0	1
Thaumastochloa rariflora	1	23.53	23.57	58	0.95
Themeda arguens	1	0	5	0	1
Themeda triandra	-1	5	0	6	0.04
Utricularia sp.	-1	10	5	1	1
Xyris complanata	-1	25	0	1	1

Further information:

http://www.nespthreatenedspecies.edu.au

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Threatened Species Recovery Hub

National Environmental Science Programme