Managing vegetation thickening in the Cape York Peninsula Bioregion:

Lessons from Artemis Station

A report to QLD Department of Environment Science and Innovation. NatureAssist Project NA905.

Front cover image: Habitat restoration on Artemis Station (site “17 Mile PDR 3”) 2022-2023.

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1. Introduction

The increasing density of native woody plants observed throughout Cape York Peninsula's savanna, known as woody thickening, is having profound impacts on biodiversity and production values. One species that seems to be especially badly affected is the Endangered Golden-shouldered Parrot (GSP; *Psephotellus chrysopterygius*). Existing research reveals a significant increase in tree stem density within many of this species' nesting and feeding habitats (Crowley and Garnett 1998; Crowley and Garnett 2000; Murphy *et al.* 2021). This phenomenon is likely the result of a complex interaction of cattle grazing and fire regimes, ultimately leading to a greater survival of woody plants. In turn, high stem densities increases the hunting success of some GSP predators that use ambush hunting tactics (e.g. Pied Butcherbirds *Cracticus nigrogularis* and Collared Sparrowhawks *Accipiter cirrocephalus*). It also leads to elevated populations of these and other predators (e.g. Black-backed Butcherbirds *C. mentalis* and small goannas *Varanus* spp.) that prefer thicker habitats (Murphy *et al.* 2021). The change in vegetation structure is also likely to be responsible for declines in other species, such as the Black-faced Woodswallow (*Artamus cinereus*), which act as sentinels for GSP alerting them to predators. Furthermore, declines in critical wet season foods such as Cockatoo Grass (*Alloteropsis semialata*) from intensive grazing by cattle and native herbivores (Crowley 2008) are likely contributing to the decline in GSP populations (Golden-shouldered Parrot Recovery Team 2021). In response to this issue, an extensive landscape-scale habitat restoration initiative was launched on Artemis Station in 2019. Artemis is one of the last strong-holds of the species and now sits at the northern-most limit of the its known range.

Despite the invasive nature of the trees involved in the restoration project, regulatory approval under the *QLD Vegetation Management Act* (1999) was necessary to legalise on-ground habitat recovery efforts. In collaboration with the QLD Herbarium in 2019-20 and again in 2023, we refined existing Regional Ecosystem (RE) mapping to show smaller habitat features that were more like the original structure and floristics as they appeared in 1950s aerial photos. This process, together with quantitative assessment of change (Murphy *et al.* 2021), underpinned the validity and urgency of native vegetation removal (known as thinning) to restore ecosystem function, which was embedded within an approved management plan and Voluntary Declaration Area. The management plan specifies where vegetation management is permitted and the optimal (ideal state) stem density targets for each RE.

The initial phase of habitat restoration employed methods developed under a previous project funded by the National Landcare Project facilitated by Cape York NRM as well as the Federal Government's Threatened Species Strategy Action Plan - Priority Species Grant (ERFIP000016). Work was extended in 2023-24 under the QLD Department of Environment, Science and Innovation's NatureAssist Project NA905 funding, associated with the significant expansion of the Nature Refuge on Artemis.

This report provides an overview of our approach to habitat restoration for GSP habitat on Artemis. We begin with a summary of areas treated in 2023 under NatureAssist Project NA905 funding. We then discuss the restoration methods that we have used since the inception of the project. It's important to note from the outset that we approach habitat restoration as a multi-staged process involving initial actions that remove and/kill stems ("primary treatment") and a series of follow-up actions that deal with subsequent re-sprouting and seedling establishment ("secondary treatment"). Without secondary treatment, regrowth would lead to rapid reversion to a dense woodland structure. The other major challenge is managing the fallen timber left after some primary treatment methods which is critical to maintain site access including for ongoing cattle management purposes such as mustering, and we have trialled several methods to deal with this. In the following pages, we detail the various primary and secondary treatments and debris management methods we have tried, and also include an assessment of the pros and cons of each, and our overall recommendation. Quantitative aspects of this assessment, and indeed the mapping of treated areas, was based on GPS track logs, which are positional data recorded automatically and frequently by handheld GPS units that were carried by all operators involved in the treatments.

2. NatureAssist Project NA905 clearing areas

In 2023 for NatureAssist Project NA905, we completed habitat restoration at 14 sites, amounting to 33.98 ha. This included primary treatment at three sites (12.83 ha) and secondary treatments at a further 11 sites (20.95 ha; Table 1 and Figure 1). One site *("Horse Paddock Shotlines")* received two secondary treatments of broad-leaf foliar spray; one using a tractor-mounted boomless nozzle and the other was spot-spraying on foot. The total amount of habitat treated on Artemis between 2021 and 2023 has been 69.62 hectares. Including secondary treatments, the cumulative treated habitat area is 90.54 hectares.

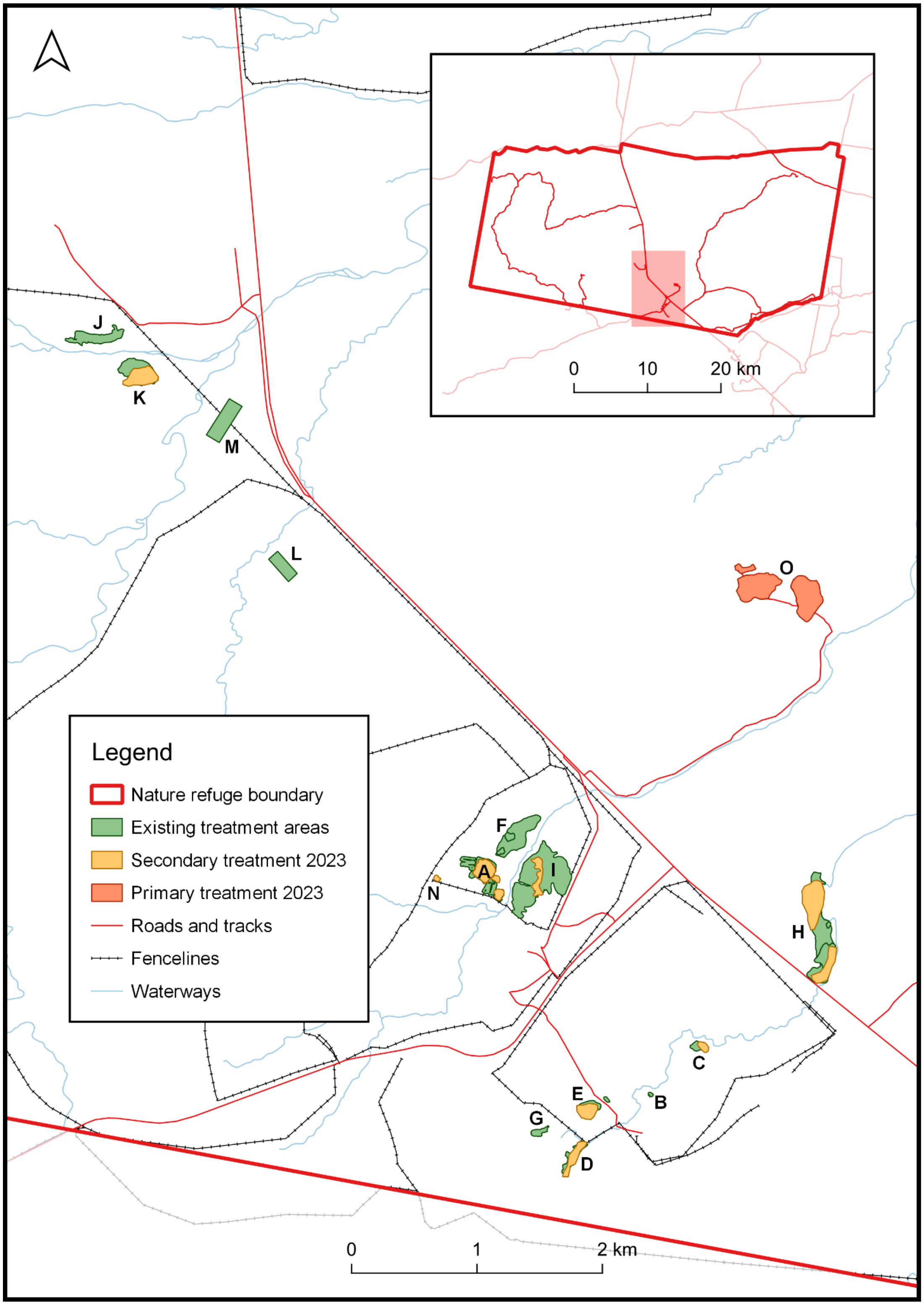

Figure 1. Primary and secondary treatment sites across Artemis Antbed Parrot Nature Refuge. Letters are explained in Table 2.

Table 1. Summary of primary and secondary treatment of habitat restoration areas on Artemis. Those in red bold occurred during the 2023 NatureAssist Project NA905 funding period.

Site name	Map label	Area of primary treatment (ha)	Primary treatment	Secondary treatment
Horse_Paddock_Graslan_Southeast	A	0.81	Graslan and blower	none
Horse_Paddock_Graslan_Northwest	A	0.96	Graslan and blower	none
Horse_Paddock_Middle_2	A	0.19	Cut stump thinning	**Knapsack spraying regrowth**
Horse_Paddock_Middle_1	A	0.22	Cut stump thinning	none
Horse_Paddock_Johnnos	A	0.64	Cut stump thinning	**Knapsack spraying regrowth**
Horse_Paddock_Shotlines	A	2.81	Cut stump thinning	**Strip clearing via wheel loader; boomless nozzle; knapsack spraying regrowth**
Horse_Paddock_North_3	A	4.81	Cut stump thinning	none
Turtle_Swamp_EnRoute	B	0.11	Cut stump thinning	none
Turtle_Swamp_Northeast	C	0.78	Cut stump thinning	**Knapsack spraying regrowth**
Steves_Ulcer	D	1.82	Cut stump thinning	**Knapsack spraying regrowth**
Turtle_Swamp_Flat	E	1.42	Cut stump thinning	**Knapsack spraying regrowth**
Turtle_Swamp_GrazonTest	E	0.13	Grazon Extra with pressure tank	none
Horse_Paddock_North_1	F	0.40	Cut stump thinning	none
Horse_Paddock_North_2	F	0.22	Cut stump thinning	none
Turtle_Swamp_Southwest	G	0.61	Cut stump thinning	none

17_Mile_PDR_1	H	0.12	Cut stump thinning	none
17_Mile_PDR_2	H	1.96	Cut stump thinning	**Knapsack spraying regrowth**
17_Mile_PDR_3	H	9.45	Cut stump thinning	**Knapsack spraying regrowth**
Molasses_Ramp	I	14.94	Cut stump thinning	**Knapsack spraying regrowth**
11_Mile_Long	J	3.30	Cut stump thinning	none
11_Mile_Butcherbird	K	4.41	Cut stump thinning	**Knapsack spraying regrowth**
12_Mile_Flat	L	4.16	Graslan and blower	none
13_Mile_Flat	M	2.31	Graslan and blower	none
Horse_Paddock_Porkys	N	0.20	**Clearing via wheel loader**	none
15_Mile_1	O	6.17	**Cut stump thinning and dragging**	none
15_Mile_2	O	5.96	**Cut stump thinning and dragging**	none
15_Mile_3	O	0.71	**Cut stump thinning and dragging**	none
	TOTAL	**69.62**		

Table 2. 2023 ONLY vegetation work on Artemis

Site name	Map label	Area (ha)	Treatment method	Treatment
Horse_Paddock_Johnnos	A	0.55	Knapsack spraying regrowth	secondary
Horse_Paddock_Middle_2	A	0.28	Knapsack spraying regrowth	secondary
Horse_Paddock_Shotlines	A	2.10	Strip clearing via wheel loader, boomless nozzle	secondary
Horse_Paddock_Shotlines	A	2.28	Knapsack spraying regrowth	secondary
Turtle_Swamp_Northeast	C	0.51	Knapsack spraying regrowth	secondary

Steves_Ulcer	D	1.69	Knapsack spraying regrowth	secondary
Turtle_Swamp_Flat	E	1.67	Knapsack spraying regrowth	secondary
17_Mile_PDR_2	H	2.33	Knapsack spraying regrowth	secondary
17_Mile_PDR_3	H	4.86	Knapsack spraying regrowth	secondary
Molasses_Ramp	I	1.59	Knapsack spraying regrowth	secondary
11_Mile_Butcherbird	K	3.10	Knapsack spraying regrowth	secondary
Horse_Paddock_Porkys	N	0.20	Clearing via wheel loader	primary
15_Mile_1	O	6.17	Cut stump thinning and dragging	primary
15_Mile_2	O	5.96	Cut stump thinning and dragging	primary
15_Mile_3	O	0.71	Cut stump thinning and dragging	primary
	Total	**33.98**		

3. Monitoring

Monitoring is an important component of vegetation restoration as it will enable refinement of primary treatment and guide the application of secondary treatment. We use, and recommend, photo monitoring points in each treatment area, marked with a star-picket. Qualitative site visits to assess the level of post-treatment regrowth is also required. Monitoring should constitute a regular component of restoration activities, we recommend as a minimum monitoring treatments sites every six months in the first two years.

Aside from initial pre-treatment photographs, monitoring of primary treatments is not required until following the first wet season post treatment. This will give the herbicides sufficient time to work and will enable re-sprouting plants sufficient time to recover as well as seedlings to develop so that they are detectable. We recommend monitoring the effectiveness of primary treatment during May to June, when grasses have started to cure, this enables a greater detection and therefore assessment of primary treatment effectiveness. It is important to determine what type of regrowth is most apparent, whether it is suckering from cut stems or recruitment of seedlings. If there is a high proportion of suckering cut stems (>30%), then it is likely primary treatment has been ineffective and therefore methods must be assessed to determine the cause. High levels of recruitment from existing saplings and seedlings can be expected. Monitoring should also asses weed species present and their extent of occurrence. Weed control may need to be factored into secondary treatments. This may include widespread application of broad-leaf herbicides for woody weeds, and/or burning in the early wet season for annuals (including invasive grasses).

4. Primary treatments

4.1. Cut-stump

4.1.1. Method

The main primary treatment we used was 'cut-stump', where selected trees are razed to ground level and the stump immediately treated with herbicide. A combination of chainsaws (Stihl® MS261) and clearing saws (Stihl® FS 560 and FS 561C) were used. Tungsten-tipped chains (Stihl® Duro) and clearing saw blades (Stihl® WoodCut carbide-tipped) were used. We found clearing saws were effective at removing stems up to 120mm diameter, which represented the majority of stems to be thinned. Some softer timber species such as *Grevillea* spp. and *Melaleuca* spp. could be taken as larger stems by the clearing saws. Larger stems of other species were removed with chainsaws. It was most effective to make an initial pass with the clearing saws, removing the majority of smaller stems and then a second pass with the chainsaws removing the larger stems.

Stems should ideally be cut to ground level or within 25mm. Any higher and they present hazards to vehicles. Taller stems also reduce herbicide uptake efficacy. Cutting stems this low inevitably leads to contact of cutting machinery with abrasive soil. To overcome this we used only tungsten chainsaw chains and tungsten tipped clearing saw blades. These are significantly more resilient to abrasion, though still required regular changing. A sharpened clearing saw blade would last 1-2 hours of operation and a chain would last 4-5 hrs of operation depending on conditions. Some species such as Quinine (*Petalostigma* spp.) were very hard on machinery and often had termites and hence sand inside the timber. Dull chains and blades will readily burn the timber as it cuts; this is evident as blackened cut stems. This greatly reduces the uptake of chemical and should be avoided. Operators changed chains/blades when burning was observed.

The optimal herbicide for cut-stump was 100mL of 240 g/L triclopyr and 120 g/L picloram (Access®) in 6L diesel, applied from a 1L hand-carried spray bottle. Initial trials involving spraying with 200 g/L triclopyr, 100 g/L picloram, 25 g/L aminopyralid in water (Tordon Regrowth Master®), resulted in higher rates of resprouting compared to Access® and diesel. This difference may relate to the time window from cutting to herbicide application, which must be as short as possible to maximise uptake. The extra penetrating quality of diesel may mean that this application window is longer compared to herbicides in water.

4.1.2. Assessment

From a GSP management perspective, the primary benefit of this method is that the landscape is immediately returned to an open state. Further it has almost zero impact on groundcover vegetation and when performed by competent operators there is very little risk to damaging fragile termite mounds. In this manner thickened vegetation can be precisely removed from around active GSP nests without damage.

The first significant drawback of this method is that it is labour intensive, (including equipment maintenance time), especially compared to other methods (such as tebuthiuron, see below). GPS track logs at a 2.3 ha grassland RE site (i.e. allowed zero stem retention) was 36 person hours, which equated to 15 hours per ha. Broad-leafed Ti-tree was the dominant encroaching species at this location, and we note that sites with higher prevalence of harder species, such as Quinine, take longer.

The second significant drawback of cut-stump is the timber (debris) left on the ground after felling (Figure 2). This becomes an issue primarily in accessing the treatment areas. Access was required for follow up treatment of regrowth as well as parrot nest monitoring and cattle mustering. The amount of debris made access even on two and four wheeled bikes very difficult and dangerous. Initially, debris was left where it fell with the intention being that a subsequent fire would remove it effectively. We trialled both hot dry season fires and cooler wet season fires but surprisingly neither resulted in a significant reduction in fallen debris (see Section 5.3).

Figure 2. Persistent woody debris after primary treatment.

Following the failure of fire alone to remove debris, during the NatureAssist Project NA905 period, we trialled using a front-end loader to push access lines through the treatment areas (Figure 3). This enabled access for a tractor and 800l spray unit with boomless nozzle for the application of herbicide for secondary treatment of regrowth (see Section 5.2). There are inherent risks associated with using such machinery such as potential damage to termite mounds (GSP nests), soil disturbance leading to erosion and weed invasion, as well as the associated costs. This method was effective in giving access for regrowth management but access was limited to the pushed tracks. See Section 5.2 for more details about secondary treatment using boomless nozzle.

Figure 3. A loader pushing access tracks through debris.

In 2023 we also trialled manually dragging the woody debris into heaped piles as soon as it was felled (Figure 4). The most efficient method we determined was to have one person dragging for every person cutting. The method has the benefit of giving immediate access to the treatment area and the risk of damage to termite mounds and erosion is negligible when compared to pushing access tracks with machinery. The obvious downside of dragging is that it's very labour intensive, practically doubling the time taken to clear an area. Further if left in the treatment areas these piles could provide suitable habitat for feral cats (*Felis catus*) and goannas (*Varanus* spp.) which are GSP predators. To mitigate this risk and to remove the heaped debris from the treatment areas, we burnt piles in the early wet season (January 2024) which was very effective. However, one negative outcome was poor grass growth (perennial reshoot and seedling establishment) under the burnt pile, which we attribute to high fire intensity. Despite the additional labour required to heap and later burn the woody debris, we found this was the most effective method to remove the debris from the treatment areas.

Figure 4. Woody debris piles to allow access post- primary treatment.

4.2. Tebuthiuron

4.2.1. Method

Several REs within the project area are mapped as natural grasslands, with a “BioCondition Benchmark” of zero stems in all tree strata, meaning we had regulatory approval for a zero stem retention target in the understory. At five of these sites we trialled tebuthiuron (Graslan®), which is a pelletised, residual herbicide, specific to broad-leaf (non-grass) plants. Elsewhere, the application of tebuthiuron has proven to be a highly effective and rapid method for controlling woody plant species. This chemical is active in the soil for an extended period, ensuring continued control of woody plants for several years without impacting grass species when applied at the correct rate. This method cannot be used in areas where there is an intention to maintain canopy trees and close to watercourses.

We used a Stihl® mist-blower to apply tebuthiuron pellets at a rate of 7.5 to 10 kg/ha. Calibration of the equipment is critical to kill woody vegetation without damaging the grass layer. Broadly, calibration involved determining the throttle position and hopper delivery aperture that delivered the required rate, given an operator’s walking pace and the spread of pellets. We found calibrating both the machine and operator took considerable time and effort, and even then was prone to error, potentially lead to an incorrect application rate. Even when initially calibrated correctly, we also found that pellet flow rate dropped significantly when there was a large volume of pellets in the hopper. Clumping of pellets due to moisture may have also contributed to this. To overcome these issues, we ensured the machinery and operator were accurately calibrated immediately prior to each application.

4.2.2. Assessment

We observed excellent control of encroaching woody species at our five tebuthiuron sites. During initial trials we used a 10kg/ha application rate, which although within the range specified on the product label, caused some damage to the grass layer (Figure 5). This may have been due to inconsistent application, with patches of higher pellet concentration potentially associated with the operator's walking pathway being semi-obstructed by vegetation. Subsequent trials used 7.5kg/ha, and this seemed to reduce grass damage considerably. At one site treated in 2022, incorrect calibration resulted in significant over application and damage to the grass layer over approximately 50 x 20 m area. The worst scalding occurred in the first wet season, when the chemical is leached into the soil profile and becomes active. We saw significant improvements in grassy cover in subsequent wet seasons as the active is leached through the soil profile and out of reach of germinating grasses.

In terms of pros and cons, in addition to the calibration issue discussed above, one significant drawback of tebuthiuron (in the context of GSPs) is it takes several years to completely restructure the vegetation to an open state. Tebuthiuron uptake by the plant relies on rainfall (~> 50mm) and episodes of plant growth, during which the active is transported through the plant. Consequently, tree mortality can be delayed and even when dead, the trees may stand for decades. From a GSP perspective, this probably does not reduce predation pressure as effectively as complete stem removal. While foliage removal probably reduces the effectiveness of ambush attacks, there are still ample perches for sit-and-wait predators and small tree goannas. Another potential problem is the negative impacts on termites, which would be especially acute in the context of GSPs given they are completely reliant on mounds for nesting. For this reason, our trial sites avoided areas with high numbers of suitable nesting mounds, and so we are limited in how much we can say about this potential impact.

This method is not recommended to be used within grassland REs that include other subdominant non-grassland REs that must be retained. Larger trees are most susceptible to mortality due to their large root system. The label suggests that pellets shouldn't be applied within twice the height of any tree that needs to be retained. For the same reason, tebuthiuron should be used with caution along fence lines where live mature trees are used as posts or are situated within say 10 metres of the fence line.

The main advantage of tebuthiuron is that it's very quick to apply, taking only 1 hour per hectare (although calibration can take up to 2 hours). The second benefit is that the chemical controls broad-leaved plants for several years, and therefore requires little secondary treatment.

Figure 5. Scalding of grasses from unintentional tebuthiuron over-application.

4.3. Tordon Axe

4.3.1. Method

Stem injection using Tordon Regrowth Master® (200 g/L triclopyr + 100 g/L picloram + 25 g/L aminopyralid, mixed as a rate of 1L in 4Lwater) is known to be an effective method of controlling tree species. We undertook limited trials on Artemis, always in association with other primary treatments (which is why this method doesn't appear in Table 1). The method involved using a hatchet to make small (20-30mm deep) incisions in standing trees where herbicide could be applied. Incisions should be 10-15cm apart from the centre of the cut and should be staggered to prevent the tree from weakening and snapping (which would prevent transport of the active up and down the stem). We used a backpack reservoir and stem injection gun to apply 1 ml to each cut. Stems must be at least 30 mm in diameter for this method, smaller stems can be treated with the same chemical using cut-stump application.

4.3.2. Assessment

Stem injection was effective at controlling tree species where we used it. It was quick to apply and was performed with less physical excursion than other methods. It was also very selective and its impacts are much easier to control than tebuthiuron. Similar to tebuthiuron, stem injection may take several months or longer to kill the plant, and also results in dead standing timber.

4.4. Summary of primary treatment recommendations

- If instant removal of stems is required, use cut-stump with chainsaws/clearing saws, with immediate application of Access® and diesel as per product label.
- Fire is not effective at removing debris within 1-3 year time-frames (possibly longer), which will significantly impede access through most sites. The most effective way to clear resultant debris is dragging into piles at the time stems are cut. However this is labour intensive and can result in small areas of poor grass growth due to high fire intensity.
- Tebuthiuron pellets are effective at killing trees without impacts to grasses, when applied consistently at 7.5kg/ha. This can only be done in Regional Ecosystems officially mapped as homogenous native grasslands. Regular calibration of equipment is recommended and can be challenging. Dead trees may remain standing for decades.
- Stem injection is a viable, comparatively low effort option to thin trees where a high level of control over tree mortality is required. Dead trees may remain standing for decades.

5. Secondary treatments

The cut-stump primary treatment method is not completely effective, with a proportion (10-30%) of stumps likely to reshoot, which must be controlled. Many factors contribute to the likelihood of plant recovery following treatment such as species, the presence of a lignotuber, whether the plant was actively growing, herbicide type and coverage, time between cut and herbicide application, whether the stump was cut too high, and if the cambium was burnt during cutting. Another issue is that disturbance from treatment activities and the reduction in competition from removed plants (i.e. increased sunlight), which can result in greater recruitment of seedlings. If left unmanaged, the outcome is a rapid reversion to a thick vegetation structure following primary treatment. Some species such as Golden Grevillea (*Grevillea pteridifolia*) and Broad-leafed Ti-tree may reach three to four meters in as little as two years post treatment (Figure 6).

Figure 6. Rapid regrowth 17 months after primary treatment with no secondary treatment.

5.1. Spot spraying

5.1.1. Method

On Artemis, regrowth of woody plant species and seedlings have been treated with broad-leaf specific herbicide applied with an 18L electric back-pack sprayer (Solo® 18L battery operated back-pack sprayer). We used a high concentration: low volume application of triclopyr/picloram (e.g. Conquerer® or Grazon® at 5ml/1L, plus 5mL of spray oil (582 g/L paraffinic oil and 240 g/l alkoxylated alcohol non-ionic surfactants; e.g. Uptake®) and 10-15ml liquid marking dye (EnviroDye Red®). Operators aimed for complete coverage of foliage to the point of runoff. We also trialled spot spraying with a spray wand and 200l tank fitted to the back of a utility task vehicle or side-by-side work buggy (UTV) .

5.1.2. Assessment

The UTV was not sufficiently agile to traverse treatment areas, and the woody debris and cut stumps greatly limited access. This method of spot spraying was determined to be ineffective for secondary treatments at sites on Artemis. It may be useful at other sites where the final target stem density is low and debris is effectively removed.

In contrast, the back-pack spot spraying method is done on foot, and was not so seriously impeded by the woody debris resulting from primary treatment. However, we note that tripping is a potential hazard, and debris may hinder the use of other spray equipment that uses long hoses (eg QuikSpray®).

Spot spraying has the benefit of being selective, in that herbicide is only applied to specific plants. There is therefore less impact on desirable (from a cattle perspective) native broad-leaf pasture species (e.g. legumes), which would be removed through non–selective applications. Results are visually apparent within two weeks, though some species such as *Austromyrtus* spp. may only show yellowing after four weeks. Due to the rapid indication of die off, if needed, follow-up treatments can be undertaken at this stage. The major drawback of this method is that it is labour intensive. At one site ("Horse Paddock Johnnos") that did not receive secondary treatment the year following primary treatment (and therefore had significant regrowth), it took approximately 12 hours to treat the 0.55 ha area (21.8 hrs/ha). In contrast, another site ("Turtle Swamp Flat"), that was also left untreated in the year following primary treatment, was burnt prior to a secondary treatment. The secondary treatment for this 1.67 ha area only took approximately 6 hours to complete (3.6 hrs/ha).

We found spot spraying using a back pack sprayer to be effective if done following one wet season of growth since primary treatment. Leaving this period ensures that any suckering and germination have occurred, and have reached sufficient size to be detected and treated. It was found to be most effective from July when the grasses had cured and green woody vegetation would contrast strongly making them visually apparent. The marking dye also prevented missed plants and double-ups. Spraying would cease in September/October when plants were less active due to dry conditions, which would limit herbicide uptake.

Spot spraying becomes increasingly difficult and impractical if sites are untreated for more than one wet season because of the sheer biomass of regrowing vegetation (which can reach >2m after two wet seasons). At one site where this occurred we trialled early dry season fire to remove extensive above-ground re-growth and promote low re-suckering (Figure 7). This was successful and significantly reduced the herbicide required for effective treatment (which was done ~ 4 weeks post fire; see Section 5.3).

Figure 7. Extensive untreated regrowth following fire.

5.2. Boomless Nozzle Application

5.2.1. Method

As described in Section 4.1.2, in April 2023 using a front-end loader, we pushed a series of access lines through one area ('Horse 22 South') that received primary treatment in 2022. The paths were spaced approximately 8m apart such that the use of a boomless nozzle with > 16m swath width would have complete coverage (see Figure 3). A "Field Link 800" (Rapid Spray®) with boomless nozzle attachment was used to spray regrowth along the access lines using the "opposite pass method" for increased spray coverage. We used standard volume application rates of triclopyr/picloram at 5 L/ha, plus 500mL/ha of spray oil (582 g/L paraffinic oil and 240 g/l alkoxylated alcohol non-ionic surfactants; e.g. Uptake®). This method was restricted to this treatment site as debris prevented this method elsewhere.

5.2.2. Assessment

Our boomless nozzle application from loader lines trial was effective at controlling regrowth, although we did encounter problems. Its main advantage was that it was less labour intensive and faster compared to our other secondary treatments. It also has the additional benefit of controlling broad-leaf weed species. The main disadvantages relate to the initial requirement for a loader to push access line through the debris. There are risks associated with soil erosion risk and weed seed spread. In the context of GSP habitat management, we also note the need to be very cautious of not damaging termite mounds. During our trial, avoiding mounds meant that the lines were often not parallel, which increased the inter-spray width, meaning that some regrowth missed herbicide application. We also note that our effective spray width was sometimes only about 10 m (nominal was 16 m), perhaps due to the uneven surface of the access tracks (which may have tilted the nozzle) and/or minor wind drift. This meant that some foot-based spot spraying was required for complete treatment of the site. Our overall assessment was that the risk of damage to termite mounds, uneven application and need for follow-up spot spraying on foot anyway, meant that this method is not worthwhile.

5.3. Fire

5.3.1. Method and assessment

Fire was used for two purposes during secondary treatment method: (1) to remove woody debris and (2) to kill or suppress regrowth and seedlings.

We anticipated that a hot fire that occurred at least one wet season after primary treatment would be sufficient to remove woody debris, however we discovered this was not the case. Almost all stems lying on the ground at one site ("17 Mile PDR 3") remained more or less unchanged despite an intense October fire in 2022. This was unexpected, due to (a) the relatively small diametre of stems (most < 15cm) (b) the intensity of the fire (c) the relatively large accumulated fuel load and (d) that the fuels we're well cured and > 12 months since they we cut. This finding lead us to develop the practice of dragging debris into piles at the time of primary treatment (Section 4.1.2).

In contrast, the use of fire to kill or suppress regrowth was effective. The effect is two-fold. First, it reduces the amount of above-ground biomass that needs to be targeted with foliar herbicides (Figure 8). This is especially important for sites that have advanced regrowth following primary treatment. For example, an early dry season fire was used at 'Turtle Swamp First Clearing Area' in May 2022 to reduce two years of untreated regrowth back to a more manageable level (see Figure 7). Indeed, secondary treatment with spot spraying was roughly seven times faster after the fire than a similar area that was not burnt (see Section 5.1). In all cases, it's important to allow some post-fire recovery of vegetation to ensure adequate uptake of herbicides. **Second, fire itself is important in suppressing regrowth, and overtime, we expect that the maintenance of open vegetation structure will be achieved solely by the strategic application of fire, with ever-decreasing reliance on herbicides.**

One issue we have experienced is the lack of fuel resulting in a fire that is not sufficiently hot enough to kill or suppress woody plants. This is largely due to grazing pressure from cattle, Feral Pigs (*Sus scrofa*) and Agile Wallabies (*Notamacropus agilis*). Grazing pressure removes accumulated fuel and may also selectively reduce the density of tall and high volume perennial grasses such as Giant Spear Grass (*Heteropogon triticeus*) and Plumed Sarga (*Sarga plumosum*). In areas where these perennial grasses are absent due to grazing pressure, spelling may not be adequate to accumulate sufficient fuel. We are currently trialling reintroduction of these perennial grasses. It is anticipated this will greatly increase fuel load leading to more effective burns.

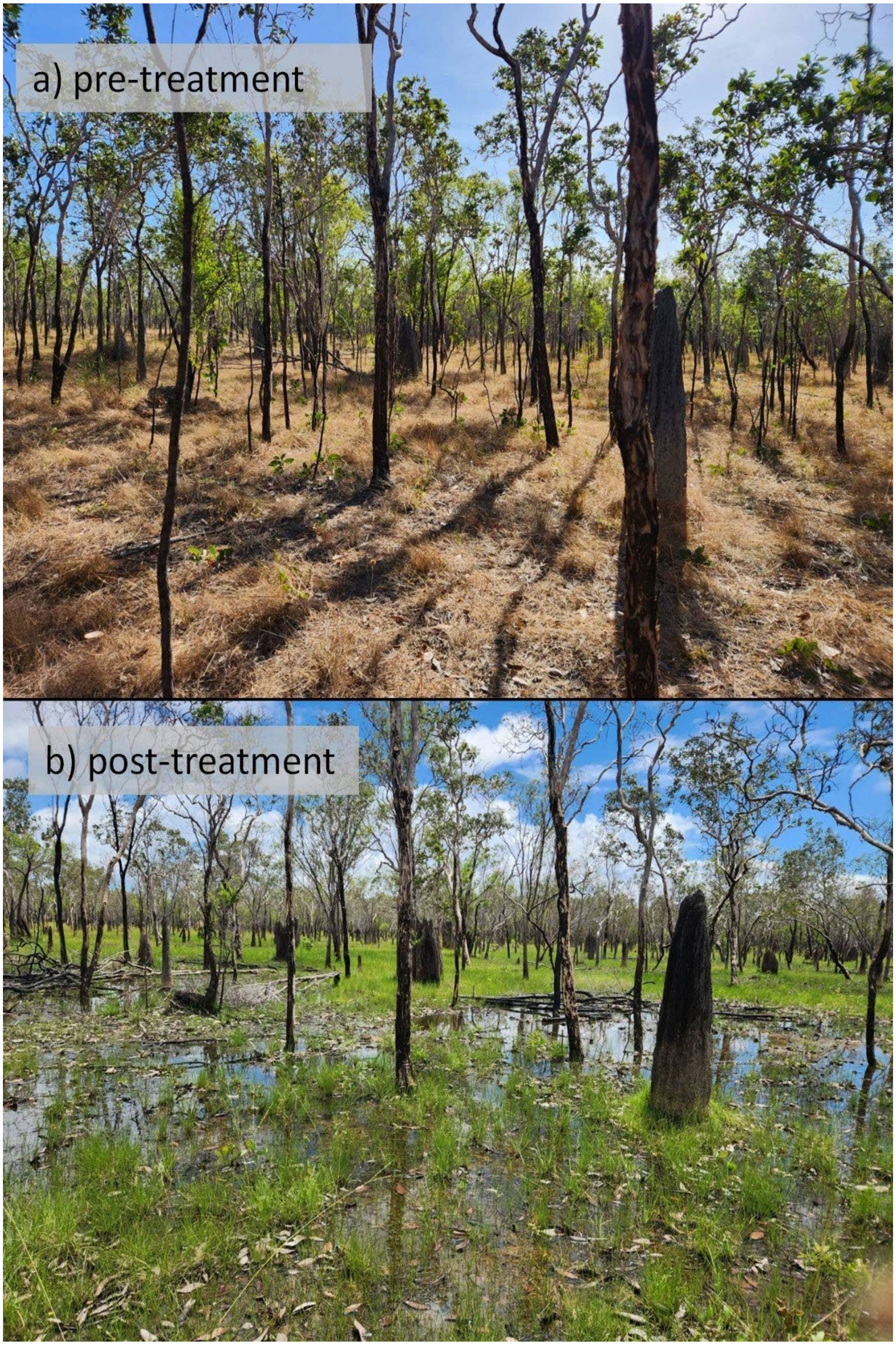

Figure 8. Before and after primary treatment and wet season burn.

5.4. Secondary treatment recommendations

The ideal secondary treatment management regime is:

- Areas should be spelled for one wet season after primary treatment to promote fuel accumulation.
- Sites should be burnt early the following year when soil moisture is high. Some seedlings and regrowth may be killed, but it will also promote suckering.
- Once suckering is sufficiently high (0.5-2m), a high concentration-low volume broad-leaf, foliar application (e.g. Conquerer® or Grazon®) using a back-pack is effective across sites up to 5 ha. Use of broad-leaf herbicides will minimise impacts to grasses. Liquid dye reduces missed plants and double ups.
- Regrowth > 2m requires significantly more labour and herbicide, and so burning to promote suckering is required for effective and efficient control.
- We recommend site assessment after three to four weeks to check for missed plants; reapplication may be required.
- Some herbicides should not be burnt within six months of application because the chemical may still be active.
- Reintroduction of perennial grasses may be required in areas where intensive grazing pressure has resulted in the loss of these species.
- Photo point monitoring will provide feedback about the best strategies for regrowth control. This will vary from only a grazing-burning regime to regimes that also require additional herbicide application. Over time, all sites should be able to be maintained by grazing-fire only management regimes.

6. References

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