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RESTORING PIG DAMAGED PEAT ECOSYSTEMS IN THE WALPOLE WILDERNESS WESTERN AUSTRALIA

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SUMMARY

The Walpole Wilderness is an important component of an internationally recognised biodiversity hotspot in southwest Australia. The Wilderness contains numerous peatlands, many of which are wetlands of national significance and contain critical habitat for a rich diversity of threatened, endemic and relictual taxa. Despite significant control efforts, feral pigs have damaged large areas of peat following fire. Their activities aerate the peat, resulting in accelerated decomposition, acidification and the rapid mobilisation of toxic heavy metals. This project investigates the effectiveness of field techniques available for the stabilisation and recovery of peatlands damaged by feral pigs. The practicalities of attempting to reduce aerobic decomposition of the disturbed peat and to restore vegetation for habitat and peat deposition processes were investigated. With extensive community involvement, a range of remedial techniques were trialled. Fencing was effective at excluding feral pigs, but oxidation and decomposition processes continued well after the removal of pigs. Mulching and planting techniques were the most effective at stabilising the peat substrate, reducing oxidation rates and re-establishing vegetation. A natural mulch layer of <30mm was sufficient to reduce surface aeration, strengthen the peat substrate and provide micro-niches for natural plant growth. Outcomes from this project have potential application for the recovery of peat ecosystems following disturbance from aerating processes such as feral pigs and fire.

Keywords: *oxidation, decomposition, mulching, re-vegetation*

INTRODUCTION

Feral pigs have damaged large areas of peat in the Walpole Wilderness. In many instances, fire is the main predisposing factor that allows the pigs ingress into the peat system. The damages consist of deep and widespread digging, extensive disruption and mixing of soil profiles, complete loss of vegetation and in some cases little sign of vegetation recovery after 15 years. Without active intervention, there is a high likelihood that these peatlands will collapse and species that have persisted for millions of years will become extinct as their mesic refuges disappear. This paper reports on the outcomes of field rehabilitation trials to determine whether:

1. Further damage from feral pigs can be effectively prevented within affected peatlands
2. Rehabilitation efforts can reduce aerobic decomposition processes to levels that are comparable with nearby unaffected peatlands, and
3. Vegetation can be restored in damaged peatlands for habitat and peat deposition processes.

STUDY AREA AND METHODS

The study area comprises two peatlands located in the Walpole Wilderness, Western Australia (Figure 1). The study sites are known to be important habitat for 14 species of conservation significance, a threatened ecological community and 12 Gondwanan relictual taxa. The area of the peatlands is 38 ha and 22 ha respectively, but these relatively small areas are connected with other peatlands in a patchy and extensive system. The peatlands are naturally ephemeral but have experienced below average rainfall for the past seven years resulting in significantly lowered groundwater levels. These conditions, along with fire damage, have contributed to the severity of damage caused by increased feral pig activity.

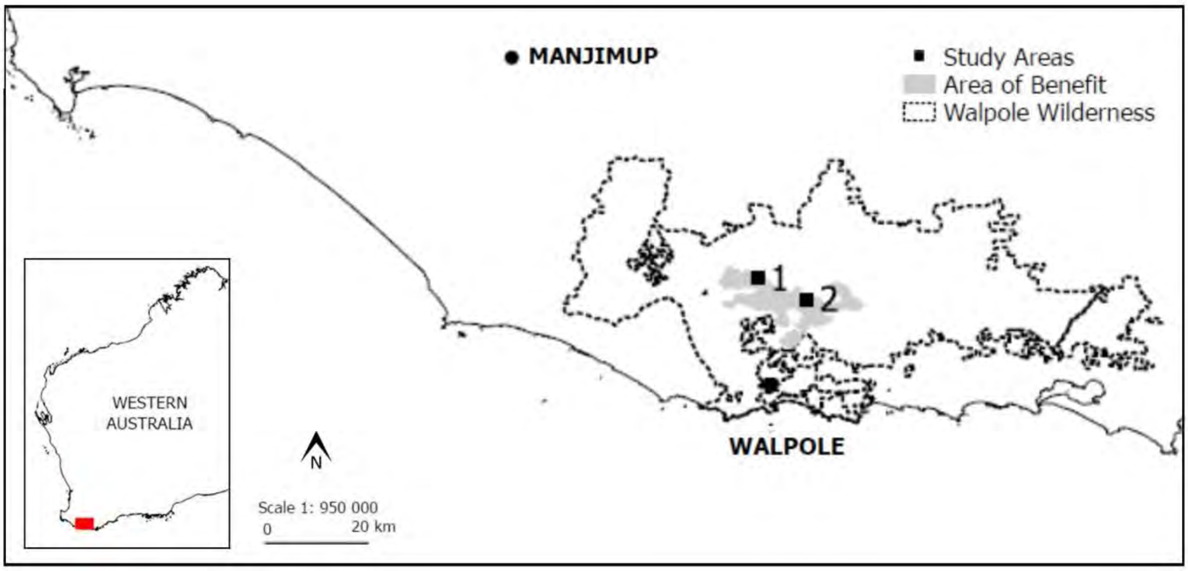

Figure 1: Map showing location of trial sites and an estimation of broader areas of peat and riparian vegetation that will benefit from the project.

Fencing of disturbed areas to exclude feral pigs was undertaken to prevent further damage, allow natural revegetation of areas and prevent disruption of the treatment plots. Fencing in Study Area 1 began in 2001 (0.7 ha), 2010 (0.6 ha) and in March 2015 (4.4 ha) - giving a total fenced area of 5.7 ha. A proportion of Study Area 2 was also fenced in 2012 (3.0 ha).

A total of five remedial treatments (mulching, planting, mulching and planting, disturbed control and undisturbed control) were trialled based on existing techniques for acid sulfate soil remediation (Rosicky *et al.* 2002, Schuman and Joosten 2008, Fraser *et al*. 2012). For each of the treatments, 12 replicates were allocated throughout the two study areas. Surface disturbance techniques were not trialled due to a drought conditions during the trial period.

For each treatment site, sediment and water samples were collected monthly for four months prior to and for 12 months following application of the treatments. Sediment samples at the surface and at 20 cm depth were tested in the field for pH and conductivity. Groundwater samples were collected from piezometers installed within each of the treatment sites and measured for water level, temperature, pH and conductivity. Every three months additional sediment and groundwater samples were sent for laboratory analysis (Table 2). Vegetation plots, photo points and erosion pins were established to record seedling recruitment and survival, percentage vegetation cover and soil loss.

Two threatened species were used as indicators that the peatlands were still providing functional habitat: 1. *Reedia spathaceae* was mapped and the number of seedlings, mature plants and their relative health recorded at the beginning and end of the project; 2. Calling males of *Spicospina flammocaerulea* were surveyed as an indicator of a breeding population.

Community members were actively involved throughout the study with a total of 2425 volunteer hours committed by a broad range of volunteers, local business, government organisations and school groups. The total cost of labour alone in the recovery efforts implemented in this study is estimated at approximately $90,500 (AUD).

Table 2: Physical and biotic factors and analyses used to assess the condition of peatlands being targeted for rehabilitation treatments.

Factor	Analyses undertaken
Soil	Electrical Conductivity at 25°C, Total Soluble Salts, pH KCl, Titratable Actual Acidity, sulfidic - Titratable Actual Acidity, Chromium Reducible Sulfur, Net Acid Soluble Sulfur, acidity - Net Acid Soluble Sulfur, Sulfidic - Net Acid Soluble Sulfur, KCl Extractable Sulfur, HCl Extractable Sulfur, ANC Fineness Factor, Net Acidity (sulfur units), Net Acidity (acidity units), Liming Rate
Water	Electrical conductivity at 25°C, Total Dissolved Solids at 180°C, Acidity as CaCO3, Aluminium, Arsenic and Iron
Vegetation	Digital cover estimation techniques for percentage cover of vegetation, plot based counts of the number of seedlings (alive and dead), number of mature plants (alive and dead), number of different species present and number of invasive species present.
Erosion	Temporal change in substrate surface level as measured from erosion pins.
Threatened species	Persistence and recorded reproduction for *Reedia spathaceae* and *Spicospina flammocaerulea*

RESULTS AND DISCUSSION

Prevention of further damage through fencing

The use of fencing to exclude feral pigs was effective at preventing additional damage to the peat systems as evidenced by a lack of new pig activity within the fenced areas. This resulted in modified chemistry of the groundwater associated with disturbed sites. In particular, sites that had been historically damaged by feral pigs and were subsequently fenced had a significantly lower conductivity, acidity from CaCO3 and concentration of aluminium than sites that were outside of the fence and still being exposed to feral pig activity (p=0.001, p=0.02 and p=0.000; Figure 2). This suggests that there were lower levels of total dissolved solids, acid discharge and oxidation reactions in the sites where pigs had been physically excluded.

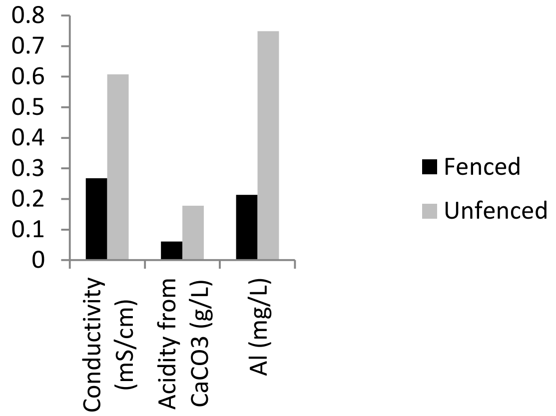

Figure 2: Groundwater parameters sampled in sites disturbed by feral pigs that were found to be significantly different between fenced and unfenced areas.

Reduction in aerobic decomposition through remedial treatments

Although many of the treatments used introduced alkalinity, none were effective in readjusting the pH of the sediments into a range that was completely comparable with the undisturbed sites. Treatments involving mulching came closest, with a significant increase in alkalinity recorded in the top 10 cm of the sediments. This resulted in the field pH of the treatments becoming more similar to those recorded in the undisturbed sites and this was a sustained trend (Figure 3). As the mulch layer continues to decay, the Titratable Actual Acidity (TAA) and pH of the treated sites are likely to reach levels that are more and more comparable with the undisturbed sites over time.

Interestingly, the addition of mulch to treatment sites resulted in a significant increase in the concentration of Aluminium in the groundwater for the first three months following treatment. During these months, an initial decrease in soil pH was also recorded (Figure 3). The short-term decrease in soil pH is likely to have been a result of acids and salts trapped beneath the mulch layer. When soil pH drops, aluminium becomes soluble and a small decrease in pH can result in a large increase in soluble aluminium (Baldwin and Fraser 2009), as seen here.

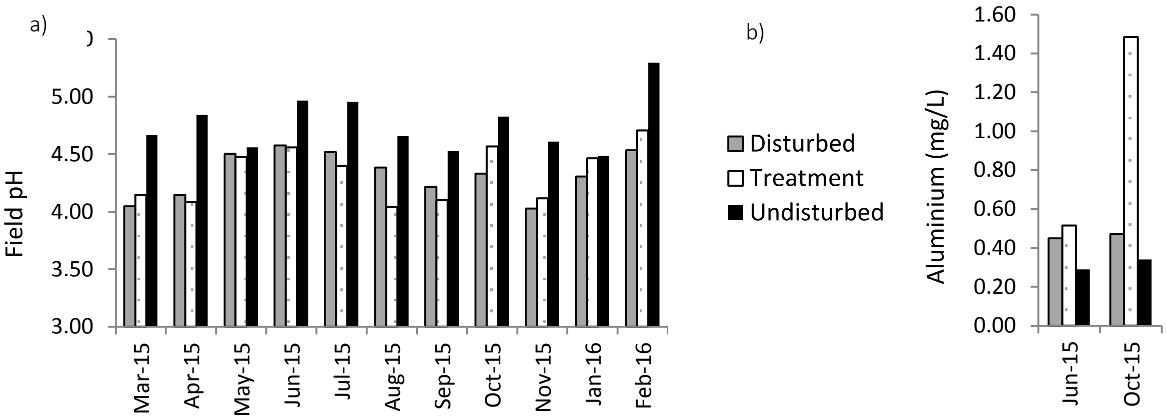

Figure 3: Effects of treatment on a) the field pH of surface soil (p=0.006) and on b) the concentration of Aluminium in the groundwater (p=0.021).

In addition to reducing acidity, the mulch formed a physical barrier between the exposed sediment and the air, which reduced availability of oxygen for oxidation processes. This physical barrier also provided a stable surface for the sediment that prevented further collapse of the substrate as a result of erosion, native fauna movement and human activity (Figure 5). There were observably higher levels of moisture in the sediment below the mulched areas and these treated sites provided a micro-niche for establishing seedlings that was moist, cool and shaded.

While the planting of seedlings didn‘t result in an effective readjustment of the pH within the duration of this project, the plant material, and particularly the sedge material, is expected to contribute to long-term organic matter accumulation within these peatlands. Over time, the dead and dying plant rhizomes and roots will also serve as a source of carbon for the deposition processes within the peatlands.

There was also a significant effect of time that was independent of treatment on conductivity (p=0.033), titratable actual acidity (p=0.000) and KCl extractable sulfur (p=0.002), which is not surprising given the natural drying and wetting processes that these peatlands are subject to on an annual basis and the associated oxidation processes. To completely avoid these fluctuations and keep the peatlands in a state of deposition, it would be necessary to keep the sediments perpetually inundated. However, these systems are naturally ephemeral and it is not our desire to modify the natural balance of deposition and decomposition, only to return balance where this has been disrupted by feral pigs.

Restoration of vegetation

The expectation that seedling survival would be linked to acidity has not been demonstrated by the results of this study. Acidity levels initially increased in areas where active treatments were undertaken, however seedlings still survived in these sites, which suggests that acid is not the limiting factor for plant establishment in areas that have been affected by feral pigs. Pig activity disturbs the substrate profile, accelerates desiccation processes and contributes to large exposed areas of black soil. The effect of these processes on soil moisture and temperature were not explored in this study, but are worthy of future consideration. This study did demonstrate that the survival of seedlings can be enhanced through the use of mulch and the protection of regenerating areas from further feral pig activity. In all cases, the survival rate for planted and naturally recruiting seedlings outside of the fenced areas was nil due to the pigs returning to areas they had previously disturbed and working outwards from these areas.

Persistence of threatened species

The extent of *Reedia spathacea* did not change during the project however plants within the fenced area remained healthy whilst many plants outside the fence died as a result of sustained pig activity. Plants outside of the fence also showed marked signs of chlorosis as a result of stress or desiccation processes associated with pig activity. A survey undertaken of *S. flammocaerulea* within the breeding period located five calling males in a single pool on the edge of the peatland. This study confirmed the persistence of these species in areas that have been fenced to exclude feral pigs, and within the fence their populations appear to be healthy and breeding, despite drying climatic conditions and other potential stressors such as fire. Outside of the fenced areas however, the feral pig activity has contributed to significant loss of habitat and an associated significant decline in the abundance and condition of individuals. This highlights the effect that unmanaged feral pig activity can have on threatened species, particularly those that have restricted distributions, limited dispersal capacity and specific mesic habitat requirements.

CONCLUSION

There are number of options available for rehabilitating peatlands where the decomposition processes have been unnaturally accelerated. The efficacy of the various approaches will depend on the nature of peatland, the extent of the problem and the resources available to tackle the issue. This project has highlighted some of the practical difficulties faced in the management of peatlands in the Walpole Wilderness. The only effective remedial option here appears to be the combination of fencing, mulching and planting, all of which are expensive and labour intensive processes. Preventing the damage in the first instance is of utmost importance. Proactive management of the interactive threats of fire and feral pigs is critical to the long-term conservation of the peatlands and the huge diversity of unique species and communities that depend upon them.

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