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Threatened plant translocation case study:

Wollemia nobilis (Wollemi Pine), Araucariaceae

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The species

The Wollemi Pine is a Critically Endangered conifer that is endemic to a single catchment in Wollemi National Park, NSW. Fewer than 100 mature Wollemi Pines remain in the wild. The Wollemi Pine is a high profile species since its discovery in 1994 by David Noble. It has attracted international media interest, and was dubbed a 'living fossil' because of its similarity to previously described fossil records (Chambers *et al.* 1998). The Wollemi Pine was the subject of the State of New South Wales' first Recovery Plan for a threatened species, which included *in situ* management and *ex situ* conservation actions. Another action was a campaign of 'cultivation for conservation' by the Royal Botanic Gardens and Domain Trust, with the first plants available for sale in 2005.

Biology and ecology

The trees occur in deep gullies within warm temperate rainforest. The tallest recorded Wollemi Pine is 42 m. Wollemi Pines are multi-stemmed and show little genetic variation among individuals (Greenfield *et al.* 2017), and recruitment from seed appears to be rare. Seed viability is typically around 10% (Offord *et al.* 1999) and the survival of germinants in the wild is around 35% (Zimmer *et al.* 2014a). Once seedlings establish, survival rates are higher, but growth rates remain low (Zimmer *et al.* 2014a). There are around 200 seedlings and juvenile Wollemi Pines in the wild. It is likely that the creation of canopy gaps would increase Wollemi Pine recruitment, as many rainforest trees.

Threatening processes

The most significant threat to the Wollemi Pine is its limited geographic distribution. The risk of a single catastrophic event affecting all individuals is very likely.

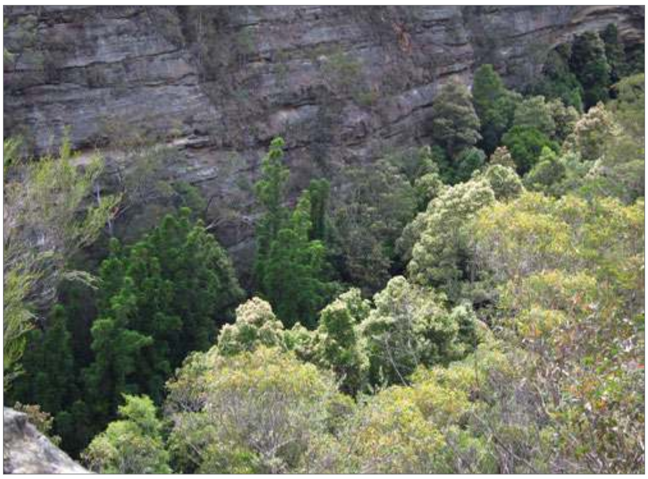

Photo 1. Wollemi Pines in the wild. Photo: Heidi Zimmer

Fire is common within the surrounding landscape; however, Wollemi Pines are one of the few conifers with the capacity to resprout after fire (Zimmer *et al.* 2014b). Wollemi Pines are also affected by *Phytophthora* spp., which can cause mortality in seedlings (Bullock *et al.* 2000, Puno *et al.* 2015). Climate change also poses a further threat to Wollemi Pine due to its intolerance of high temperatures (Offord 2011) and drought (Zimmer *et al.* 2015). Wollemi Pines are also threatened by human-mediated disturbances, such as trampling, damaging trees, illegal collection and spreading *Phytophthtora* spp. It is for these reasons that the location of the wild Wollemi Pine population is kept secret.

Deciding to translocate

The Wollemi Pine Recovery Team discussed the need to translocate for several years, and the development of guidelines for Wollemi Pine translocation was recommended as part of the Wollemi Pine Recovery Plan (2007). Establishing new populations using translocation may reduce the risk of losing the entire wild population. However, the first requirement was to ensure that the species had adequate *ex situ* representation that could subsequently be used to produce material for translocations.

Aim of the translocation

The initial Wollemi Pine translocation had the broad aim of informing future translocations. There were several questions associated with the first translocation, including: (1) how does growth and survival of translocated Wollemi Pines vary along a light gradient? (2) how does light affect Wollemi Pine growth and survival, and does this vary with plant size? (Zimmer *et al.* 2016), and; (3) how do soil properties and soil microbial communities influence translocation success? (Rigg *et al.* 2017). We focused on the influence of light because of known positive effects on seedlings in the wild (Zimmer *et al.* 2014a) and in greenhouse experiments (Offord *et al.* 2014). We investigated the influence of plant size (stem length) as it is often positively correlated with growth and survival in translocation and because the available seedlings varied in size. Another potential benefit of the experimental translocation was, if successful, that it would become a viable *ex situ* population and reduce the risk of extinction of Wollemi Pines in the wild.

Translocation working group and key stakeholders

The translocation was a collaborative effort overseen by the Wollemi Pine Recovery Team, which includes members from the NSW Office of Environment and Heritage, Royal Botanic Gardens and Domain Trust, and the NSW National Parks and Wildlife Service. The translocation experiments were led by PhD students from the University of Melbourne and Western Sydney University.

Photo 2. Potted Wollemi pine clone at the Australian Botanic Garden Mount Annan. Photo: Heidi Zimmer

Photo 3. Translocated Wollemi Pine at recipient site. Photo: Heidi Zimmer

Site selection

The recipient site was selected to be similar to the wild site, in terms of soil (low pH), vegetation community (warm temperate rainforest), and climate. We selected an area of warm temperate rainforest on land managed by the Blue Mountains Botanic Garden Mount Tomah that provided long-term land tenure security, as well as ease of access for planting and monitoring, and the ability to limit public access.

Translocation proposal

A translocation proposal was developed following Vallee *et al.* (2004).

Pre-translocation preparation, design, implementation and ongoing maintenance

Prior to translocation, we conducted soil testing (focusing on *Phytophthora* spp. and soil pH), marked and georeferenced individual planting sites, and measured their light availability. We flagged 30 planting sites from the creek line (moister, darker) to the (drier, lighter) rainforest-woodland ecotone. We obtained 191 plants grown from cuttings from the Australian Botanic Garden Mont Annan (ABGMA) and a commercial supplier.

Planting was conducted in August 2012, which was before the Wollemi Pine's growing season (spring) and maximised volunteer and staff availability. All equipment was sterilised using 70% methylated spirits to minimise the potential for *Phytophthora* spp. infection. Wollemi Pines of varying sizes were planted in groups of 6 or 7 (in areas approximately 4 m x 4 m). Each plant was watered (around 5 L) and plant guards were placed around translocants in order to minimise Lyrebird disturbance. Initial stem length was measured. The plants were re-watered one month post-planting.

The translocated Wollemi Pine population was monitored intensively for the first 6 months after planting (four visits) and less intensively over the next 18 months (four visits). The plants have been subsequently monitored annually in February. Measures of survival, stem length, and number of branches were recorded. Additional notes on plant health and the presence of reproductive structures are also made.

Subsequent actions

Following on from the results of the experimental translocation, the Wollemi Pine Recovery Team is considering the potential to establish additional translocation sites in Wollemi National Park.

Outcomes

Around 82% of plants have survived since planting in 2012. In summer 2018, some of the larger plants (sourced from the ABGMA) developed male and female cones.

Our original aim was to determine the effect of light availability and plant size on translocated Wollemi Pine growth and survival. We found greater survival in sites with more light. This was largely due to high mortality in deeply shaded sites during the first winter post-translocation, associated with infection by the native pathogen *Botryosphaeria* sp. – an opportunistic fungus that attacks stressed plants. Growth and survival have been highly variable, with most of the variation attributed to the two plant suppliers, and differing plant condition at the time of planting. The effect of plant size has been difficult to disentangle. Of the ABGMA plants, larger individuals had high survival rates and grew fast, whereas small plants from the commercial supplier had high survival rates, but grew very little (Zimmer *et al.* 2016). In addition, we found that Wollemi Pines developed their own species-specific microbial communities after two years, and this unique community was linked to plant health and condition (Rigg *et al.* 2017).

What we learned

- Wollemi Pines can survive and grow at light levels much higher than at the wild site.
- Plant condition is key to survival. Acclimatise your plants before translocation in conditions as close as possible to that of the recipient site.
- Collaboration is the foundation of success. This work would not have been possible without the exceptional input from a diverse group of horticulturists, ecologists, soil scientists, land managers and science communicators.
- Unexpected things can happen – the mortality due to *Botryosphaeria* sp. in dark sites was unexpected.

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