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The Wollemi Pine—16 years on

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Introduction

The year 2010 marks the sixteenth anniversary of the discovery of the Wollemi pine. This paper gives a brief overview of literature relating to its discovery, the potential threats to its existence, the efforts that have been made to ensure its survival, and some of the wealth of anatomical and physiological information that we now know about this newly-discovered tree species.

Wollemi National Park

Wollemi National Park in the Australian state of New South Wales (NSW) (see map Figure 1-G) is an area of sandstone which is criss-crossed with hundreds of canyons, some of which are only a few metres across but can be hundreds of metres deep (Hill 1996). Not surprisingly, we are told that the name 'Wollemi' is derived from the aboriginal word 'wollumii' meaning 'watch your step' or 'look around you' (Jones et al. 1995). The very rugged terrain and poor soil of the park has discouraged exploitation so that the area has remained a wilderness. Since it now has World Heritage Listing, the area is likely to remain as wilderness in the future.

Internet publicity for bushwalking describes the unique isolation and remoteness of Wollemi National Park as follows:

> At over 487,000 hectares, Wollemi National Park is the second largest park in the state behind Kosciuszko. Lying around 150 km north-west of Sydney, it forms part of an amazing belt of green that surrounds the city. It contains the largest remaining area of wilderness in NSW. It is also part of the Greater Blue Mountains World Heritage Area. As an area for adventuring it is almost without peer. Few people venture more than a handful of kilometres from the boundaries of the park, and as a result there is an intense feeling of remoteness once you head into the interior. Weeks can be spent bushwalking, canyoning, liloing and climbing in various areas of Wollemi.

The infertile soil of the park supports a 'tall eucalypt woodland' and a 'dry open woodland' vegetation, but sometimes on the floors of wide and deep canyons a different 'microclimate' can occur 'supporting warm temperate rain-forest species dominated by coachwood (*Ceratopetalum apetalum*) and sassafras (*Doryphora sassafras*)' (Hill 1996).

The Discovery

The story of the discovery of the Wollemi Pine is fully covered in James Woodford's book (Woodford 2000). Briefly, the finding was made on 10 September 1994 by David Noble, a NSW National Parks and Wildlife Service field officer. Noble was canyoning with two companions in Wollemi National Park. When he abseiled down into a deep gorge bounded by sandstone cliffs he found tall, strange-looking trees which had bubbly bark (which he later described as looking like the breakfast cereal Coco-Pops) and peculiar branches that resembled the fronds of a fern. Noble tucked a piece of foliage into his bag and went on his way. When he later showed the sample to a colleague it was recognised as being 'unusual' (Jones et al. 1995) and it was agreed that it would be worth a second trip to collect more material for identification. A female-cone brought back from the site demonstrated that the unknown was a conifer of the family Araucariaceae which at that time was known to consist of two genera, *Araucaria* and *Agathis*. The samples from Wollemi National Park had characteristics common to both of these genera. It was a new taxon, which was appropriately named *Wollemia* *nobilis* in honour of the park in which it was found and of David Noble the person who had found it, and was fully described for the first time by Jones et al. (1995).

In the weeks that followed, the pollen of *W. nobilis* was studied. It was found that its pollen matched perfectly with fossil pollen which had been formally named *Dilwynites granulatus* 30 years previously. This fossil pollen had been found over a wide area of southern Australia during oil exploration drillings and had been dated from 91 million years ago for the oldest, and two million years ago for the youngest (Hill 1996). The *Dilwynites* fossil pollen was identical to pollen of *W. nobilis*, giving very strong indication that *Wollemia* had been in existence since the Cretaceous (about 90 million years ago) and in fact was much more common in the time of the dinosaurs than it is now. A research paper describing this finding was produced by Macphail et al. (1995). Further indication of the ancient lineage of *W. nobilis* came from Carrick Chambers et al. (1998) who compared leaves, cone scales, seeds, and pollen of *W. nobilis* with Cretaceous fossils and found that the result was a more meaningful reassessment of a range of fossils which were recognised as Araucarian, but could not be assigned with confidence to either of the (then)-recognised genera *Agathis* and *Araucaria*. Some of these fossils could now be fitted into *Wollemia*. Thus *W. nobilis* was described as a 'living fossil', a term used to describe a very rare organism with a good fossil record but which at some time in the distant past disappeared from the fossil record but then reappeared, alive, in some little-explored place (Woodford 2000). *W. nobilis* is the third 'living fossil' discovered in recent times, the first being the coelacanth, a fish caught off Madagascar in 1930, and the second a tree, *Metasequoia*, found in China in the 1940s (Woodford 2000).

In December 1994, three months after David Noble had found it, the discovery was announced to the world's media. It created sensational news. The Director of the Royal Botanic Gardens in Sydney, Professor Carrick Chambers, said that 'This is the equivalent of finding a small dinosaur alive on Earth' (Anon 2009). This newly-discovered conifer was a population of tall, majestic trees, so rare that they survived undiscovered for centuries of European occupation, in a mountain gorge situated just 150 km from Sydney, the biggest city in Australia, and with lineage dating back for 90 million years. No wonder it attracted so much public and media attention and made front-page news around the world. In addition, the discovery of *W. nobilis* was made soon after the release of the Spielberg movie 'Jurassic Park' and the 'dinosaur' connection greatly improved the importance of the discovery in the public's eye (Meagher and Offord 2002). *W. nobilis* became popularly known as 'Wollemi pine' although it is not a true pine (genus *Pinus*) and is not even in the family Pinaceae. However, this is in common with the naming of many other Australian species such as cypress pine (which is actually in the Cupressaceae), bunya pine (which is in the Araucariaceae) and huon pine (in the Podocarpaceae). Timber traders use the term 'pine' for just about any conifer tree and *W. nobilis* was immediately called Wollemi pine, although as Tudge (2000) says, 'in modern times we should have known better'.

The Problem and the Solution

Unfortunately, the discovery of Wollemi pine, and the media attention it received, created a problem. It was quickly realised that allowing unlimited access to the site within the park would cause risks to the survival of the trees. The risks include: (1) uncontrolled seed and plant collecting at the site; (2) increased fire frequency; (3) seedling damage and soil compaction by trampling; (4) introduction of pathogens and weeds by visitors; and (5) changes in the hydrology and climate of the site (NSW Department of Environment and Conservation 2006). It was obvious that, without some sort of control of these risks, Wollemi pine, which had existed for millennia, would probably become extinct.

The initial response to this problem was to keep the site location in the park a secret, to restrict visitation to the site to only a few scientists and park rangers, and to prohibit access to the site with prosecution of offenders. Later a full recovery plan was devised. The Wollemi Pine Recovery Plan (NSW Department of Environment and Conservation 2006) that is now in place, attempts to provide for the future recovery of Wollemi pine and advocates a program that (1) protects and maintains the known stands and their habitat from threatening processes in the long term; (2) provides a greater understanding of the biology of the species and associated species; (3) maintains and utilises representative off-site populations in botanic gardens; (4) continues the implementation of an education and awareness program; and (5) supports the commercial release of Wollemi pines (NSW Department of Environment and Conservation 2006). The cost of the recovery plan (over a five-year period) was estimated to be approximately $1.3 million and the funding was to be provided by the commercial release of Wollemi pines (NSW Department of Environment and Conservation 2006).

Wollemi Pine—Understanding its Biology

One of the prime tenets of the Wollemi Pine Recovery Plan (NSW Department of Environment and Conservation 2006) is recovery objective 2: to 'understand the biology of Wollemi Pine and associated species in its natural habitat to inform conservation of the species and its habitat'. This action is 'to promote research that will assist with the management and conservation of the species and its associated habitat' (NSW Department of Environment and Conservation 2006). Briggs (2000) says that scientists have responded to this with enthusiasm 'offering research collaboration to its many aspects' and 'including evolutionary relationships, palaeontology, ecology, genetics, plant pathology, mycology, and plant propagation'. Hill (1996) says that aspects of Wollemi pine's morphology, anatomy and chemistry have also been actively studied. Some of this research is outlined as follows:

General

Wollemi pine trees are monoecious (they have both male and female reproductive units (cones) on the same tree) (Jones et al. 1995). Trunks are up to 40 metres in height and up to 1.2 metres in diameter and there is frequent coppicing (the trees produce new shoots from their base or below ground level which can eventually grow into new stems). Thus old trees can have multiple stems of various ages. Hill (1996) describes this as a mechanism ensuring survival in case of major damage to the tree such as that caused by fire or a violent storm. Some on-site Wollemi pine trees are said to have up to sixty separate trunks of various ages developed in this way and the original trunk no longer exists (Hill 1996). Thus, most specimens appear as clumps of trunks.

Wood

Banks (2000) used dendrochronology to estimate the age of trees at the site. Sections of a trunk cut by the National Parks and Wildlife Service from a dead and fallen tree were used in the study. First, scanning electron microscopy (SEM) was used to confirm that the tree rings were distinct and annual (Figure 1-E). Banks (2000) then counted 384 rings in the heartwood of the tree (the sapwood had previously rotted away). He concluded that trees on site could be 400–450 years old. The reason why the tree died was also deduced by Banks (2000). He found that a cross-section of the bole of the tree contained a major wind-shake (a shear-stress flaw) which he attributed to a major windstorm. The storm had bent the tree over, past the maximum elasticity of the xylem of the trunk, causing a large semi-circular crack extending for several metres along the trunk. He concluded, therefore, that turbulent windstorms sometimes occur within the gorge which can, on occasions, destroy older (larger) individual trees.

Heady et al. (2002) used a small piece of the wood from the same dead tree used by Banks (2000) to examine the wood anatomy of Wollemi pine. First, it was found that the wood consisted of tracheids and rays; there were no vessels or fibres present, indicating that the wood of *W. nobilis* is 'softwood', as would be expected from a conifer. It is possible to separate the Araucariaceae from all other conifer families on the basis of its wood anatomy. The Araucariaceae is the only family with bordered pits set in double and triple rows that are arranged in

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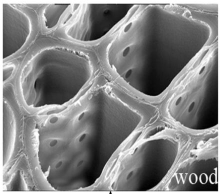
Figure 1 (opposite): Various aspects of Wollemi pine as depicted by a poem, scanning electron micrographs, and photographs. The images are described as follows: (A) Wood of Wollemi pine showing tracheids in transverse section, the insides of which are pitted in an 'alternate biseriate' manner. (B) A Wollemi pine pollen grain, approximately 75 µm (0.075 mm) in diameter. The granulated surface and laminated endexine layer can be seen. (C) A sunken stomata on the underside of a juvenile leaf. (D) Cross-section through a juvenile leaf of Wollemi pine with upper surface showing palisade cells, spongy mesophyll and veins. (E) Transverse section of a wood block of Wollemi pine showing three complete and two partial growth rings. (F) A block of Wollemi pine wood with transverse section in the upper half of the image and alternate-biseriate pitting in the lower half. (G) Map of NSW showing the position of Wollemi National Park. (H) The 'John Banks' Wollemi pine growing in the grounds outside the Fenner School of Environment and Society at the ANU. (I) A 5-year-old Wollemi pine growing in a pot. Coppicing can be seen—a further stem rising from ground level. (J) A Wollemi pine female cone.



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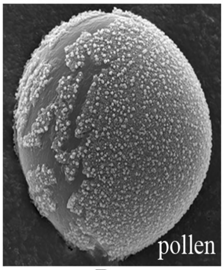

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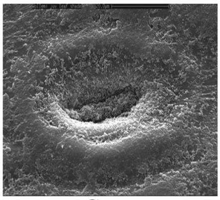
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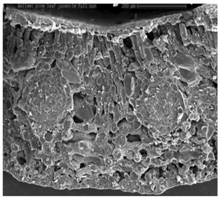
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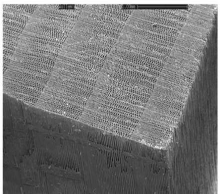
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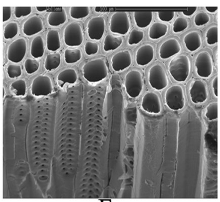
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Wollemi survivor

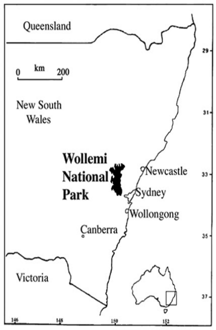
The fossil record gives indication
of your once widespread population.
In the Cretaceous you stood tall
surviving even the dinosaur's fall.
But then your habitat became cold and dank,
reduced, and in the ice-age shrank
to almost nothing. Your numbers depleted
and to a Wollemi gully you retreated.

There in a misty haven, deep in Wollemi
veiled, cloistered, unseen to eye
you skulked. Unwilling to cede
your Eden, and with a need
to stay unchanged, consistent
you endured, invariable and persistent.
For millennia, danger you eluded
Methuselah in a paradise secluded.

But an end came to your seclusion
When a bushwalker's chance intrusion
Brought publicity and instant fame
Wollemi pine became a household name.
Press headlines declared you to be
the tree find of the century.
The sole species in a genus new
Forty living specimens - so few.

But in their need to see the "dinosaur tree"
An admiring public's curiosity
Would bring chaos to your fragile realm
And your habitat, ecosystem, overwhelm
Trampled seedlings, compacted soil
And vandalism your home would spoil
And introduce pathogens not previously seen
To your secluded quarantine.

So your destiny must now be controlled
by Man. A well-meaning and bold
plan to plant and propagate
seedlings and clones to populate
a million gardens. To spread your flora
through a human-controlled diaspora.
To assist you - a benevolent plan
to survive your ultimate nemesis - Man.



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H


I


J

'alternate' fashion. Heady et al. (2002) showed that the bordered pits were 'alternate' in *W. nobilis* (Figure 1-F) thus 'strongly supporting its classification as a member of the Araucariaceae'. Phillips (1948), however, says that it is notoriously difficult to separate individual species within Araucariaceae on the basis of their woods and *W. nobilis* proved to be no exception. Thus Heady et al. (2002) reported 'on the basis of its wood anatomy, it is not possible to state whether *W. nobilis* is more closely related to *Agathis* or to *Araucaria*'.

Leaves

Wollemi pine leaves are arranged in two opposite ranks, and are twisted so that the adaxial (upper) surfaces face the sky (Jones et al. 1995). The juvenile and adult leaves of Wollemi pine are strikingly different (Hill 1996). Adult leaves are stiff in texture, yellowish-green on both surfaces and are distinctively arranged in four rows along the upper surfaces of the branches. Juvenile leaves are soft in texture and dark green above with white waxy undersurfaces, and are arranged in two rows along the branches. Some dimorphism between adult and juvenile stages of a plant is known in other Araucariaceae but not to the same extent as Wollemi pine (Hill 1996).

Burrows and Bullock (1999) reported that adult Wollemi pine leaves possess a thick cuticle, sunken stomata (Figure 1-C), a fibrous hypodermis (a layer of cells just under the epidermis), a distinct palisade, and spongy mesophyll layers with most palisade development on the adaxial (upper) side (Figure 1-D). Burrows and Bullock (1999) say that these features represent a survival characteristic which helps the tree to reduce water loss. Stomata are present on both sides of the Wollemi pine leaf. Since *Agathis* species have stomata only on the lower surface, while most *Araucaria* species have stomata on both surfaces, it was concluded that *W. nobilis* has a leaf anatomy which has greater similarity to *Araucaria* than to *Agathis* (Burrows and Bullock 1999).

Hill (1996) pointed out that *Wollemia* shares with the (closely-related) genus *Araucaria*, a very unusual feature in that the broad-based leaves have no mechanism for being shed from the tree when the leaves become senescent, as occurs in the other closely-related genus *Agathis* and, indeed, in most flowering plants. The leaves of Wollemi pine do not possess a petiole (Meagher and Offord 2002). When leaves become senescent in *Wollemia* the whole branch is shed with the leaves still attached (Hill 1996; Burrows et al. 2007). Heady and Burrows (2008) investigated the self-pruning of branches in response to leaf senescence in juvenile Wollemi pine. Using six-year-old trees, grown off-site, they showed that a zone of stranded xylem at the base of each branch, in which the cross-sectional area of the xylem was reduced, had a profusion of bordered pits and ray parenchyma cells, many times more than occur further up the branch. They suggested that this zone represented a weakness which facilitated branch abscission. The prevalence of bordered pits in the same region was said to promote water flow and thus alleviate the restrictive effects of the reduced cross-sectional area of xylem in this region.

Pollen and seeds

Wollemi pine is a conifer, its pollen and seeds being produced in male and female cones, borne on lateral branches on the same tree. Hill (1996) says that features of the male and female cones place Wollemi pine in the family Araucariaceae, most closely related to Agathis, although more resembling Araucaria superficially.

Wollemi pine pollen is transported by wind (NSW Department of Environment and Conservation 2006). The pollen (Figure 1-B) is characterised by its spheroidal shape, its surfaces ornamented with granules, a granulate ectexine and a laminate endexine (Lobreau-Callen and Meagher 2004).

Seeds of Wollemi pine are borne within the female cones (Figure 1-J), which disintegrate once mature and seeds fall to the ground (Offord et al. 1999). Seeds are circumferentially winged and are shed separately from the cone scale (Jones et al. 1995). They are also light in weight so that wind has a major role in dispersing them. Seeds are probably also dispersed by running water of the creek into which they may fall (Offord et al. 1999). Off-site research on seed germination by Offord and Meagher (2001) showed that temperature (optimally 24–30 °C) is the prime mechanism for promoting germination of seed, and that light has only a secondary or negligible role.

Roots

Root wood (xylem) of five-year-old Wollemi pine trees was examined by Heady et al. (2002). It was found that root wood was similar to stem wood in having latewood-earlywood interface differentiation (i.e. tree rings could be distinguished) and the bordered pitting was 'alternate', identical to that of stem wood.

McGee et al. (1999) found two distinct types of *Mycorrhizae* (the symbiotic associations that form between fungi and the roots of most plants) in roots of Wollemi pines growing in the wild. These were identified as *Arbuscular mycorrhizae* and *Ectendomycorrhizae*. *Ectendomycorrhizae* has not previously been reported in the Araucariaceae. Friends of the Royal Botanic Gardens, Sydney (2002) reported that Wollemi Pines grown in cultivation from seedlings and cuttings do not have *Mycorrhizae*, even at three years of age, whereas a seedling of similar age, transplanted from the wild, does have *Mycorrhizae*. McGee et al. (1999) points out that the appropriate mycorrhizal association may need to be pre-colonised to ensure the survival of Wollemi pine trees when they are transplanted (horticulturally).

Genetics

Peakall et al. (2003) conducted a genetic study of Wollemi pine and found that the genetic diversity was exceptionally low. This was attributed to a combination of small population effects (inbreeding), clonality, and the below-average genetic variation that is inherent in the Araucariaceae. Peakall et al. (2003) reminds us that low genetic diversity in a species means that there is a greater risk of disease epidemics, and that efforts are made in agriculture and forestry to combat the risk of disease by broadening the genetic base of crops and trees. However, since there is a possibility that the species as a whole is a single genotype, and considering the long generation time of Wollemi pine, it seems unlikely that mutation-conferring resistance will occur to protect the species. The clonal nature of the trees makes it imperative that the site within Wollemi National Park is protected because 'any introduced disease that killed one tree would probably kill them all' (da Silva 1997). Nevertheless, the species appears to be resistant to pathogens both in the wild and in cultivation (Peakall et al. 2003).

Horticulture

Commercial propagation of Wollemi pine has been carried out by Wollemi Australia, a partnership between the Queensland Department of Primary Industry and the Birkdale Nursery near Gympie. There is also on-going communication between the NSW Department of Environment and Conservation and Wollemi Australia (NSW Department of Environment and Conservation 2006). Commercially-grown trees are now readily available for sale at $55 for a 40 cm tree and $95 for a 60 cm tree (Figure 1-I).

In the wild, *W. nobilis* lives in an environment that is different from the surrounding dry Eucalypt woodland of Wollemi National Park. The original site is in a deep gorge bounded by sandstone cliffs with a constant water supply (from a stream) in temperatures that are made more equable by the surrounding walls, but most importantly, as pointed out by Briggs (2000), by being protected from wildfire. Soil at the Wollemi site is acidic, with a pH of 3.5–4.0 (Meagher and Offord 2002). Since on-site trees grow in deep steep-sided canyons, even the emergent crowns are shaded for much of the day and seedlings may receive less than 10 per cent of full sunlight for less than an hour a day, so may persist in a dormant state for many years (Meagher and Offord 2002).

Wollemi pine is now a common inclusion in home gardens around Australia and overseas, growing in a range of microenvironments and apparently adapting to some conditions that are quite different from those of its natural environment. However, as might be expected considering on site conditions, full sun is detrimental to seedlings and this has been reported by Meagher and Offord (2002). The preferred low light conditions make young trees suitable for growing in a pot, and as an indoor or patio plant. Anon. (2009) recommends that pots be watered, to saturation, only when the potting mix becomes dry in the top 5 cm of the pot and then not watered again for a fortnight. Wollemi pine is apparently intolerant to over-watering.

Anon. (2009) says that Wollemi pine can grow in temperatures from -5 °C to 45 °C. During winter in cold climates, the Wollemi pine becomes dormant and its growing buds sometimes develop a white waxy coating (commonly called ‘polar caps’). The wax is said to protect the growing tips against frost. When spring comes the caps disappear and new growth bursts through (Anon 2009).

Meagher and Offord (2002) report that cuttings taken from the lateral branches of juvenile trees form plants with prostrate (ground cover) shoots. When these plants are tip-pruned, a dense spreading plant is formed that can be used for ground cover or for other horticultural possibilities.

Bark

On older Wollemi pine trunks, the bark becomes densely covered with soft, spongy nodules, ten millimetres in diameter (Jones et al. 1995). The outer surface of the bark sheds in thin, papery scales (Jones et al. 1995). The unusual bark of adult Wollemi pine trees was a feature that caught the eye of David Noble when he first saw the trees in 1994. Woodford (2000) records that Noble described the bark as looking like bubbling chocolate, or the breakfast cereal 'Coco-pops'. Hill (1996) says that this is another unique feature of Wollemi pine that is quite different to the barks of related trees of the same family.

Discussion

Since the discovery of the Wollemi pine site by David Noble, two further sites have been found, both not far distant from the original site. Nevertheless, fewer than a hundred adult trees are presently known to exist in the wild (NSW Department of Environment and Conservation 2006).

The discovery of Wollemi pine increased the Araucariaceae family from two genera to three (*Araucaria, Agathis* and *Wollemia*). However, the question as to whether *Wollemia* is more closely related to *Araucaria* or to *Agathis* is still not clearly decided. Studies of the leaf anatomy of *Wollemia* by Burrows and Bullock (1999) and also by Carrick Chambers et al. (1998) indicate closer ties to *Araucaria*, whereas studies of the structure of pollen by Lobreau-Callen and Meagher (2004) and genetic research by Gilmore and Hill (1997) indicate more similarity with *Agathis*.

Carrick Chambers et al. (1998) say that examination of Wollemi pine pollen and leaves has resulted in a reassessment of fossil material that was previously identified as belonging to the Araucariaceae but could not be recognised as either *Araucaria* or *Agathis* (which were the only two genera then known). The studies also show that Wollemi pine was once much more widespread than it is now in that fossil pollen grains that were formerly known as *Dilwynites granulatus*, but now known to be *W. nobilis* have been recovered from sediments in Antarctica and New Zealand (Dettmann and Jarzen 2000; Lobreau-Callen and Meagher 2004).

Several researchers (Hill 1996; Briggs 2000) have commented on the enormous amount of scientific interest and enthusiasm that *W. nobilis* has created. In a paper entitled 'What is significant—the Wollemi pine or the Southern Rushes', Briggs (2000) compares the unprecedented public, media, and scientific interest created by the discovery of the single new genus/species (Wollemi pine) with the relatively unpublicised findings of some 60 new species, many new genera, and two new plant families made, in Australia, in virtually the same period of time, on the Southern Rushes (Restionaceae). While she proposes that both examples are significant, she points out that in both Wollemi pine and the Southern Rushes 'the significance of the discoveries was only fully realised in the context of knowledge of organisms and their evolution that has been established in many fields'. Wollemi pine, by its attractiveness as a tall, magnificent tree, in effect serves as a 'flagship species' in relation to public awareness of vital environmental and conservation issues.

In an article in *The Australian* newspaper dated 14 April 2007, the environment writer Matthew Warren, under the headline 'Biologist takes axe to the "myth" of Wollemi', reported that claims that Wollemi pine was a living fossil were disputed by biologist Allen Greer. Warren (2007) reported that the dispute centred on claims that Wollemi pine existed in the time of the dinosaurs, and that the story was 'fuelled by a media race to earn accolades and publicity'. Allen Greer had suggested that a more modest interpretation would not have captured the public's imagination.

Research by Bullock et al. (2000) has indicated that Wollemi pine is susceptible to certain types of fungal infection. Juvenile trees, grown off-site from cuttings, were inoculated with five different fungi, two of which (*Phytopthora cinnamomi* and *Botryosphaeria* sp.) were found to be pathogenic, causing plant death over a period of up to five weeks. In 2005, *Phytopthora cinnamomi* was found to be causing dieback of foliage in some trees at one of the sites (NSW Department of Environment and Conservation 2006).

Conclusions

Many changes have occurred in the past 16 years in relation to the survival of Wollemi pine. The objective 'to protect and maintain wild stands and their habitat from threatening processes in the long term' has been acted upon in several ways. Whereas Jones et al. (1995) reported *W. nobilis* as being 'endangered and inadequately conserved', it is now (16 years later) protected by the New South Wales *Threatened Species Conservation Act* of 1995. It is also listed as endangered at a national level by the *Environmental Protection and Biodiversity Conservation Act* of 1999, and is on the Directory of Rare or Threatened Australian Plants (RoTAP). Also, the Wollemi National Park, where the sites are located, was, in December 2000, added to the World Heritage list (as part of The Greater Blue Mountains Area). In addition to these legislative safeguards, the Wollemi Pine Recovery Plan (NSW Department of Environment and Conservation 2006) works to protect the wild population and ensure the ongoing survival of the species. This plan specifically maintains the secrecy of sites, monitors them against illegal visits, and controls an on-going program that cultivates and commercially markets Wollemi pine trees worldwide. Sales of commercially-grown Wollemi pine trees have more than adequately provided the funding necessary for the Recovery Plan, and have resulted in an off-site population of Wollemi pine trees growing in thousands of Australian home gardens under a range of climatic conditions (Figure 1-H).

Our understanding of the biology of Wollemi pine, which is necessary information in order to properly carry out conservation of the species, has greatly increased in the past 16 years. Wollemi pine trees now exists in a number of botanic gardens, in particular the one at Mount Annan near Sydney, enabling research to be carried out using trees grown off-site. Many studies have been conducted on these off-site populations that have added to the understanding of the species.

Since Wollemi pine has survived in relative solitude as a very small population for a very long period of time and shows no detectable genetic diversity, it gives an excellent insight into the proper management of a rare plant species. This has helped to explain to the general public the value of biological research and habitat conservation in conserving biodiversity. It has also demonstrated the function that 'flagship species' such as the Wollemi pine can provide in making the public aware of conservation and environmental issues.

Perhaps Wollemi pine, which outlived the dinosaurs and endured the Ice Ages, will survive the impact of mankind. Let us hope so.

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