Fate of a rare flowering event in an endangered population of *Acacia pendula* (Weeping Myall) from the Hunter Valley, New South Wales

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Abstract: A rare flowering event in a stand of *Acacia pendula* (Weeping Myall) (family Fabaceae, Mimosoideae) from the Hunter Valley of New South Wales is documented. This species flowers poorly in the region and (with the exception of horticultural specimens) has not been observed to fruit and develop viable seed for over a decade. One stand of this threatened Hunter Valley population of *Acacia pendula* was monitored over a seven month period (January to July 2018) to investigate this poor reproductive output. Despite copious bud production in January and February, the extent and condition of these, and all subsequent flowers rapidly declined, and none progressed to fruit.

Primary reasons for reproductive failure were postulated to be a combination of mass desiccation of capitula following extended dry conditions, infestation by native flower- and phyllode-galling midges and thrips (*Asphondylia* sp., *Dasineura glomerata, Kladothrips rugosus*), fungal galls (*Uromycladium* sp.), caterpillars (*Ochrogaster lunifer*), and mistletoe (*Amyema quandang*). Collectively, these stressors appear to be eliminating seed production from the study population; survival is maintained only by the copious root-suckering observed around most plants, particularly after the pressure from stock grazing (cattle, sheep) has been removed. The age of trees studied, based on measures of girth and comparison with growth rates reported for other semi-arid *Acacia*, was inferred to be between 50 and 150 years. The level of *Amyema quandang* (mistletoe) infestation on *Acacia* trees was independent of tree size, and there was no evidence to suggest that mistletoe density alone influenced flowering progress.

Consequences of these observations on future management of *Acacia pendula* in the Hunter Valley are briefly discussed.

Key words: *Acacia pendula*, Hunter Valley, endangered population, flowering fate, health

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Background

The tree *Acacia pendula* Cunn. ex Don (Weeping Myall) (family Fabaceae, Mimosoideae) in the New South Wales Hunter Valley region is a threatened species protected under three elements of legislation. Nationally, the *Environment Protection and Biodiversity Conservation Act 1999* includes *Acacia pendula* as a key species in the Critically Endangered *Hunter Valley Weeping Myall (*Acacia pendula*) Woodland*. Under the NSW *Biodiversity Conservation Act 2016* (BC Act), an Endangered Population of *Acacia pendula* is listed for the Hunter Valley, and the species also forms a key component of the Critically Endangered *Hunter Valley Weeping Myall Woodland in the Sydney Basin Bioregion*. For the highly modified Hunter region, Weeping Myall and its habitat is one of the most protected plant entities and subsequently presents a range of conservation management challenges wherever it occurs.

Recent debate in the literature over whether or not *Acacia pendula* populations in the Hunter Valley were present prior to European settlement is difficult to fully resolve without detailed cross-population genetic studies (Bell & Driscoll 2014, 2016; Tozer & Chalmers 2015, 2016). As a consequence, the NSW Threatened Species Scientific Committee resolved to retain *Acacia pendula* within its lists of threatened entities under the *Biodiversity Conservation Act 2016* until such clarifying evidence emerges. That being the case, continuing research into the ecology of Hunter Valley populations of *Acacia pendula* is desirable to better understand the taxon and to inform its management, so that government policies and conservation actions can be effectively implemented.

An opportunity arose to study one stand of the Hunter Valley population of *Acacia pendula* in detail following an observation of flower buds on plants in early 2018, a stage that few stands of the species in the region experience (Bell et al 2007). Importantly, successful fruiting and development of seed has never been observed in *Acacia pendula* in the Hunter Valley (critical for conclusive identification), promoting the hypothesis that plants here may be neotonous (retaining juvenile features in the adult phase) or may have lost the capacity for seed production (dispersing instead through vegetative suckers) in response to unfavourable habitat (Bell & Driscoll 2014). This paper documents the fate of a flowering event in *Acacia pendula* over a seven month period in this population, and examines the current age structure and health of individuals within the stand. Conclusions reached on the reproductive output and general health of these plants are considered in the context of future management.

Study Population

Location and habitat

The study population lies near Broke (32° 45' 0.4" S, 151° 6' 7" E) in the Hunter Valley of New South Wales (Fig. 1). This land has been established as part of the Weeping Myall Management Area (WMMA) by Glencore (Bulga Coal), with the central aim of conserving *Acacia pendula* and its habitat. A monitoring program has been established to inform the management of these plants to ensure that impacts associated with nearby coal mining activities do not denigrate the site. The 3.8 hectare WMMA was fenced and cattle removed in March 2015, and only resident macropods (mostly Grey Kangaroos, *Macropus giganteus*) have grazed the site since. At the time of fencing, twelve individuals of *Acacia pendula* were known from the WMMA.

Currently, ten live individuals of *Acacia pendula* remain within the WMMA (Fig. 2). Seven of the ten individuals are old, well established trees, two are of medium size, and one is represented only by young suckering plants. Most of the older trees have fallen (some comprising two or more trunks) but persist as living plants, their heavy limbs now supported by the ground (Fig. 3). Two of three senescing plants are represented only by vigorous suckering from rootstock following trunk collapse, the third has shown no such suckering and appears dead.

Fig. 1: Location of the Weeping Myall Management Area (WMMA) near Broke in the Hunter Valley, showing local relief (contour interval is 10 m) and extent of landscape clearing.

The WMMA lies in largely cleared, undulating country at a mid-slope position (110 m ASL), on Permian aged geology (Fig. 4). Wollombi Brook, a major feeder stream to the Hunter River, lies c. 2.5 km to the west and is separated by an elevated Jurassic-aged basalt ridgeline housing the historic Milbrodale trig station (c. 170 m ASL). Prior to European settlement, the original vegetation across the study site, as determined by a census of the larger remaining 'paddock' trees within a radius of 500 m, likely consisted of a grassy woodland of *Eucalyptus moluccana*, with occasional *Eucalyptus crebra*. There is conjecture as to the origins of the *Acacia pendula* individuals on this site (and elsewhere within the Hunter Valley region), given that their presence in a grassy eucalypt woodland such as this runs contrary to their occupied habitat elsewhere in inland eastern Australia (see Bell & Driscoll 2014).
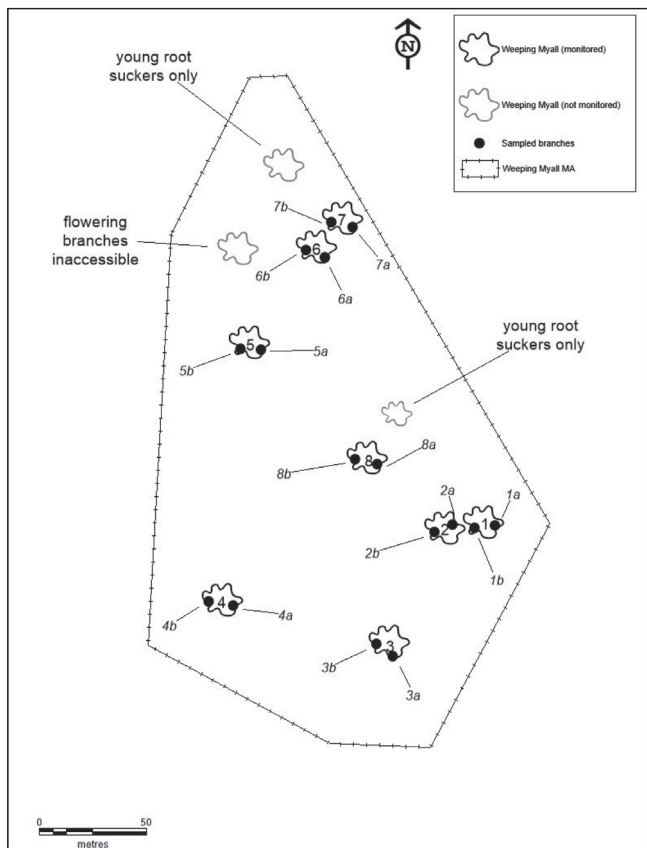
Fig. 2: The study population of *Acacia pendula* in the Weeping Myall Management Area, showing inspection locations on individual trees.

Fig. 3: Two fallen stems of a single individual of *Acacia pendula* (rooted in the centre at the position of observer), showing the canopy of each at extreme left and right.

Fig. 4: Landscape context of the Weeping Myall Management Area (fenced area in middle distance, below and within remnant *Eucalyptus moluccana* woodland).

Acacia pendula within the WMMA conform to morpho-type B of Bell and Driscoll (2014), represented by plants with green foliage, slightly pendulous branches on older specimens, flowering irregularly but rarely if ever proceeding to the fruiting stage, and commonly root-suckering. Monitoring of these plants following the exclusion of cattle grazing in March 2015 has shown an eruption of new shoots emanating from roots ('root-suckers', commonly mistaken by some observers as new recruits). Over the course of just two years, the number of stems of *Acacia pendula* rose from 12 in 2013 to 685 in 2015, a 57-fold increase following fencing of the WMMA (visible in Figs 3 and 16). In time, these root-suckers develop into a dense thicket of vegetation shading out a large proportion of native grasses and herbs, and is currently the subject of a separate study.

Land use history

Prior to establishment as a reserve for the protection of *Acacia pendula*, the area formed part of an extensively cleared and modified agricultural landscape. As early as 1821, cattle agistment was granted by land owner Benjamin Singleton for the wider Patrick Plains area, with grazing by cattle and sheep centred on the nearby township of Broke (7 km to the south-east). In the 1850s, subdivision of the land fronting Wollombi Brook began, with partial clearing to accommodate grazing and dairying enterprises (Umwelt 2012). These pursuits remained the sole use of the land for the next 150 years, whereupon properties were purchased for coal mining or biodiversity offsets.

Climatic conditions

Rainfall leading up to the flowering event in January 2018 was well below average for an extended period of time (Fig. 5). Apart from above average falls in the March and October of 2017, little rain fell for the thirteen months prior to flowering (December 2016 to December 2017). Over the course of monitoring (January to July 2018), rainfall remained below the long-term average.
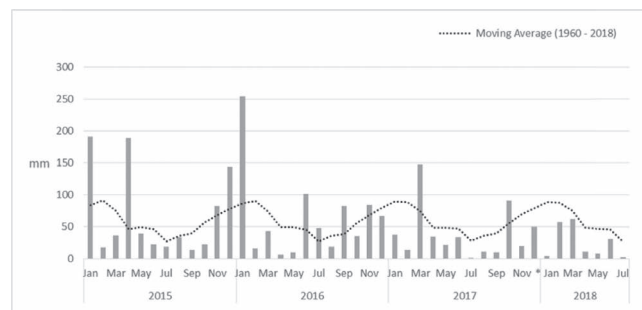
Fig. 5: Rainfall received at Bulga (3.5 km to the west) over the two years prior to flowering. Budding was first observed in January 2018 (* Jan.), following a prolonged dry period. Data source: Bureau of Meteorology (2018).

Methods

Flowering inspections

Eight individuals of *Acacia pendula* were selected for monitoring. For each monitored plant, two observation points were designated that were accessible and where most flower buds were evident at the commencement of the study. As far as possible, inspection points strived to include one receiving high sun exposure and a second receiving low sun exposure, but this was not always possible and was dictated by the extent of flowering on each individual (see Fig. 2). Inspections commenced in late February 2018 and continued monthly until the end of July 2018.

At each monthly inspection, general observations were made pertaining to the proportion and health of buds and flowers, and the presence or otherwise of developing pods. Tagging of specific inflorescences for more regimented monitoring was not undertaken as previous experience had shown high failure rates during flowering in this species, and observations of a more general nature were more likely to gather useful data. Additionally, notes were also made on the extent of flower and leaf galls, and activities of ants and other invertebrates. The presence of buds, flowers and fruits at each inspection point were assigned to one of four numerical categories: 0 (none present), 1 (few present, < 25 visible), 2 (many present, 25–100 visible), 3 (numerous present, >100 visible). Buds and flowers were considered viable and healthy if they were yellow and not dry and 'crispy', with no visible signs of galling or flower desiccation. Categorical data on bud and flower presence were averaged across the sixteen inspection points to graphically summarise the progress of flowering over the monitoring period.

Acacia age and health

In the absence of more definitive, non-destructive methods, the assessment of the age of individual *Acacia pendula* trees used stem diameter as a surrogate. The diameter-at-breast height was consequently measured on all *Acacia* plants within the study population (n=12, incorporating both live and dead individuals). In cases where more than one trunk was evident, all were measured but only the largest was used in analyses. For collapsed individuals that lay across the ground surface but remained alive, diameter was measured at approximately 1.7 m above the rooted point of the main trunk. Root suckers were too numerous to measure, and were ignored.

The presence of aerial mistletoe shrubs can impact on the general health and vigour of host species (Reid et al 1994; Watson 2011). In the case of *Acacia pendula*, the number of mistletoe clumps (*Amyema quandang*) was counted on each study plant to allow general observations on whether or not their presence appeared to influence the progress of flowering.

Results

Flowering phenology

Following initial observations of flower buds in early 2018 (Fig. 6), anthesis occurred from March (Fig. 7) but rapidly declined. There was a steady decline in both the number and health of inflorescences over the subsequent six months to July, where no active buds or flowers were evident (Fig. 8). In June, a small number of fresh buds were observed on some trees, suggesting that a second flush of flowering may occur but subsequent observations revealed otherwise. Flowering (open buds) peaked in March but then also underwent a decline to June, and none were present in July. No flowers were observed to progress to the fruiting stage, and no pods were recorded on any monitored tree. Rainfall during this six month period was below the long-term average, with April and May particularly well below average.

All monitored trees displayed at least some bud and flower development over the course of the study. Representative flowers sampled for microscopic examination appeared healthy and properly developed (Fig. 9), but over time these either senesced due to ongoing dry conditions (Figs. 10 & 11), or transitioned into galls. The majority of galls were found to be the result of infestation by the Common Flower Galler (*Dasineura glomerata*) (Fig. 12), and represents the first time *Acacia pendula* has been recorded as a host for this species (P. Kolesik pers. comm.). Previously documented host species include *Acacia deanei, Acacia elata, Acacia hakeoides, Acacia mearnsii, Acacia melanoxylon, Acacia pycnantha, Acacia retinoides* and *Acacia schinoides* (Kolesik et al 2005). Other galls present on inflorescences were attributable to bud galler (*Asphondylia* sp.) (Fig. 13), although these appeared less prevalent than *Dasineura*. On some flowers, woody, bulbous structures attributable to fungal gall (*Uromycladium* sp.) were also observed (Fig. 14). It is unknown if any individual flowers were successfully pollinated during this flowering event, but if so none proceeded to develop pods.

Fig. 6: Budding *Acacia pendula* (photographed 28 February 2018).

Fig. 7: Flowering *Acacia pendula*, approaching anthesis (photographed 27 March 2018).
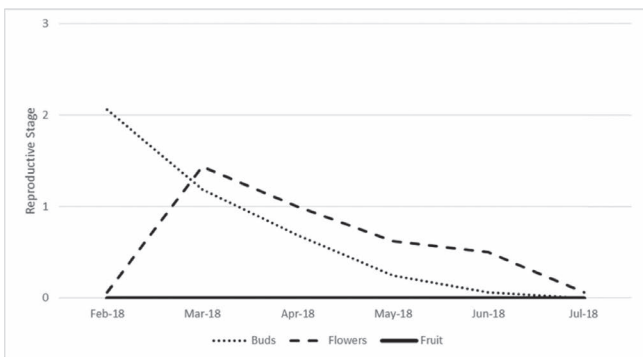
Fig. 8: Schematic summary of flowering fate of eight monitored trees over a six month period in 2018. No seed or fruit was produced. Reproductive Stage: 0 = none present, 1 = few present (< 25 visible), 2 = many present (25–100 visible), 3 = numerous present (>100 visible).

Fig. 9: Capitulum of *Acacia pendula* at anthesis, showing healthy stamens (photographed 28 February 2018).

Fig. 10: *Acacia pendula* inflorescence, showing desiccating capitula and partial dislodgement of stamens (upper capitulum) (photographed 31 May 2018).

Fig. 11: *Acacia pendula* inflorescence, showing complete dislodgement of stamens from each capitulum, and no development of pods (photographed 31 May 2018).

Fig. 12: *Acacia pendula* capitula freshly infected by galls of *Dasineura glomerata*, showing remnants of anthers and filaments between individual gall chambers (photographed 24 April 2018).

Fig. 13: *Acacia pendula* inflorescence, showing capitulum infected by bud galler (*Asphondylia* sp.) (upper left) and newer, healthy capitula (right) (photographed 31 May 2018).


Fig. 14: Fungal gall (*Uromycladium* sp.) on *Acacia pendula* capitulum, showing its woody texture (photographed 24 April 2018).

Acacia age and health

Across the study population, the average size of *Acacia pendula* trees was 50 cm DBH (diameter-at-breast height), with a standard deviation of 16.2 cm (n=12). The smallest tree was 23.2 cm DBH and the largest 82.8 cm DBH (Fig. 15). Three of the twelve individuals (including live and dead plants) possessed two trunks, while a further three had completely fallen trunks (two with copious root suckering) and lay across the ground (Fig. 16). One individual comprised a fallen trunk only with no root suckers and has presumably died, while another showed post-collapse development of roots from its trunk where it lay along the ground (Fig. 17). The large girth of trees within the study area is of some interest, as Boland et al (2006) described *Acacia pendula* with a diameter-at-breast height of "up to 30 cm", nearly one third of the size of the largest specimen measured here. The large size of *Acacia* stems within the study area may explain why many of them have fallen over but continue to grow while supported on the ground.

Based on reported growth rates of the related *Acacia salicina* elsewhere (Grigg & Mulligan 1999; Jeddi & Chaieb 2012), the estimated age of individual *Acacia pendula* trees is

likely to be between 50 and 150 years. The inferred age of individuals did not appear to influence the extent and success (albeit limited) of flowering, as buds and flowers were observed across all eight study trees ranging between 23 and 67 cm DBH.
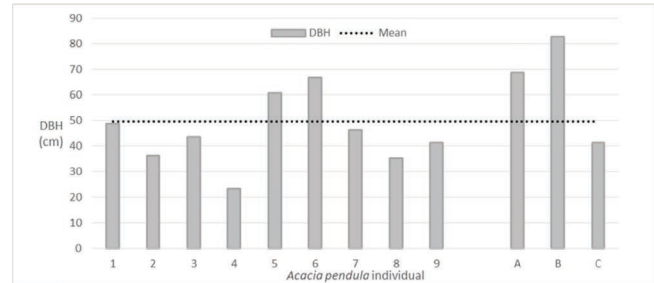
Fig. 15: Diameter-at-breast height (DBH) of *Acacia pendula* individuals within the study area. Only individuals 1–8 were the subject of flower monitoring; individual #9 supported an elevated canopy and was not monitored, while individuals A-C (also not monitored) were collapsed plants with vigorous (#A-B) or no (#C) root suckering.

Fig. 16: Aerial view of *Acacia pendula* (same individual as Fig. 3), showing fallen but still alive trunks (crowns at far left and far right), and copious root suckering in and around the centre.

Fig. 17: New root development mid-way along the collapsed trunk of *Acacia pendula*.

The extent of mistletoe (*Amyema quandang*) growth on *Acacia pendula* plants ranged from 2–38 clumps/tree with a high degree of variance (n=9, median of 5, mean of 10.8, SD of 11.7). There was no correlation between the size of *Acacia* trees and the number of mistletoe clumps supported on them. However, general observations suggest that those trees with higher densities of mistletoe appeared in poorer overall health than those with few mistletoes (Fig. 18).

Many trees also displayed evidence of attack by both Bag Shelter Moth (*Ochrogaster lunifer*; family Thaumetopoeidae) and galling-thrips (family Phlaeothripidae). Larvae of *Ochrogaster lunifer* feed on *Acacia* phyllodes and, in some cases, can completely defoliate a tree (Floater 1996). Large silk nests are formed in the canopy (Fig. 19), comprising *Acacia* phyllodes and silk produced by the larvae, and are used for resting during daylight hours. Galling-thrips also attack the phyllodes of *Acacia*, producing galls (Fig. 20) which extensively modify the shape and form of phyllodes (Crespi & Worobey 1998; Morris & Mound 2002). Galls present on *Acacia* within the study population appear attributable to *Kladothrips rugosus*, and although not extensive are present on most trees. All of these invertebrates are native Australian species and form part of the natural ecosystem in which *Acacia pendula* occurs.

Fig. 18: Mistletoe infested *Acacia pendula* showing signs of stress and death of limbs.

Fig. 19: Bag shelter produced by larvae of *Ochrogaster lunifer* in the branches of *Acacia pendula* (photographed 24 April 2018).

Fig. 20: Gall produced by *Kladothrips rugosus* on the phyllodes of *Acacia pendula* (photographed 27 March 2018).

Discussion

A rare flowering event in a population of *Acacia pendula* in the NSW Hunter Valley failed to progress to fruiting, suggesting that at least in the short-term persistence at this location is reliant on asexual reproduction. The 2018 flowering event was the first in that population since at least 2015 (when monitoring began), and such irregularity is reportedly a trait consistent with many other stands of the species in the region and throughout its range (Tame 1992; Boland et al 2006; Bell et al 2007). Fencing and the cessation of cattle grazing at the site in 2015 has been followed by copious emergence of root-suckers from nearly all individuals, yet evidence of successful seed production and subsequent new recruitment remains absent. As with other Hunter Valley stands of this species, long-term survival is likely to be contingent on the appropriate management of stock grazing pressures.

What events lead to the failure of fruit production in *Acacia pendula*? Within the study population during 2018 this appears primarily attributable to infestations of galling insects, accompanied by flower desiccation due to dry conditions. Gall-forming midges of the *Dasineura* and *Asphondylia* genera (family Cecidomyiidae) deposit eggs in the open flowers of *Acacia*, typically within the perianth tube near the ovary. On hatching, larvae then induce the ovary to evaginate and form a number of chambers, so that in some cases entire flower heads can transform into clusters of galls (Kolesik et al 2005; Kolesik 2015). This process results in the loss of flowering material, and hence reproduction in that inflorescence has effectively ceased. In other areas of New South Wales and South Australia, *Dasineura glauca* (Grey Fluted Galler) reportedly often occurs at such high densities that seed production is completely prevented in entire *Acacia pendula* trees (Kolesik et al 2005).

Dasineura glomerata (Common Flower Galler) is prevalent within the study population and appears likely to persist there permanently while ever the host plant remains. *Dasineura glomerata* has not been recorded infecting *Acacia pendula* previously, and represents a new host tree record for the species (P. Kolesik pers. comm.). Other known hosts for *Dasineura glomerata* included several *Acacia* species distributed mainly in coastal and near-coastal locations,

including *Acacia deanei, Acacia elata, Acacia hakeoides, Acacia mearnsii, Acacia melanoxylon, Acacia pycnantha, Acacia retinoides* and *Acacia schinoides*. None of these occur in the immediate locality of the study area, although *Acacia deanei* and *Acacia hakeoides* are present further west in the upper Hunter Valley (c. 60 to 90 km away from the study area), and *Acacia elata, Acacia melanoxylon* and *Acacia schinoides* occur in the adjacent mountainous districts. Only *Dasineura glauca* is known to infest *Acacia pendula* (Kolesik et al 2010), with other hosts for this species including the closely related *Acacia omalophylla*. A similar but undescribed gall-midge occurs on other semi-arid *Acacia* species, such as *Acacia aneura* and *Acacia ramulosa* (Kolesik et al 2005).

Individuals of *Acacia pendula* in the study population are also infected (to a lesser degree) by an undetermined species of a second gall-midge, *Asphondylia* sp., and a fungal gall, *Uromycladium* sp. (Pileolariaceae). In some *Acacia* populations, rust disease caused by *Uromycladium* poses a severe threat to the health and survival of infected individuals (e.g. McTaggart et al 2015), although at present this does not appear to be the case within the study population. Phyllodes are similarly attacked by the larvae of *Ochrogaster lunifer* (Thaumetopoeidae) and the galling-thrip *Kladothrips rugosus* (Phlaeothripidae). All of these invertebrates are native Australian species and form part of the natural ecosystem in which *Acacia pendula* occurs. When host plant species are under stress, such as brought about through habitat modification, infestations can severely impact normal growth and reproduction. Where Australian *Acacia* species have become invasive in other parts of the world, deliberate introduction of similar insects has been trialled as a biological control to limit spread (e.g. Impson et al 2008).

Flower desiccation due to dry conditions is a common reason for failure to reproduce in any one season (e.g. Anjum et al 2011). This phenomenon was also suspected to be occurring in the study population of *Acacia pendula* which was regularly under water stress with below average rainfall, despite reasonable falls in February, March and June. These falls did not, however, ensure the retention of flowering material on branches, and for those inflorescences not affected by galls the shedding of stamens to leave 'bald' capitulas soon followed. It was not possible to quantify the extent to which flower desiccation affected the overall potential for pollination and seed production, but this is suspected to be high. In a Western Australian study, Gaol and Fox (2002) noted that good winter rainfall was necessary to induce flowering in several *Acacia* species, but that further rain after flowering promoted pod development and seed production. For the *Acacia pendula* plants under study in the Hunter Valley, the abortion of flowering and the lack of pod production occurred despite rainfall in February, March and June.

Although plausible, an absence of pollinators is difficult to advance as a primary cause of flower failure. Most *Acacia* species are self-incompatible, and the transfer of pollen between individuals and populations via pollinating vectors is crucial for outcrossing and seed set (Stone et al 2003). For the bulk of *Acacia* species, this involves unspecialised, generalist insects (Tybirk 1997). Pollinators of *Acacia pendula* are thought to comprise small native flies, bees and wasps (Bernhardt 1987), all of which are likely to travel over considerable distances visiting multiple stands of flowering plants. Given that the landscape surrounding the study population has been heavily cleared of native vegetation for at least 150 years (now fitting the *fragmented* or *relictual* states of McIntyre & Hobbs 1999), it is possible that the necessary pollinating invertebrates have also declined or disappeared (Kearns et al 1998). Many co-occurring *Acacia* species flower simultaneously, and in such cases such an event serves to attract a number of pollinators which are shared between species. In heavily modified landscapes, co-occurring species are often absent leading to a lack of co-flowering between species, and the threshold needed to attract pollinators may therefore not be reached. Apart from a single individual of *Acacia salicina*, there are no co-occurring *Acacia* within the study population, nor in the immediate vicinity (although good stands of *Acacia filicifolia* do occur 1 km to the north). Stone et al (2003) noted that populations of *Acacia* reduced to relict populations may have already lost their pollinator networks, resulting in lower seed set and dependence on opportunist pollinators. This scenario could also be extended to the study population of *Acacia pendula*, but this requires further investigation.

Recruitment failure as a result of grazing pressure has been documented for other arid-zone *Acacia* species (e.g. Batty & Parsons 1992; Auld 1995), although for the study area *Acacia pendula* impacts from grazing have affected the regeneration of root-suckers. Where recruitment failure is ongoing due to an absence of seed production, there can be important implications for conservation and management. For *Acacia carneorum*, Roberts et al (2017) found this species to be almost entirely reliant on asexual reproduction for persistence in an area, and that relatively few genetically distinct individuals were present across its range despite the often many thousands of stems in a stand. In that case, land managers were encouraged to protect both vegetative root-suckers and true seedlings from threats, as well as to use the few stands that did produce viable seed to augment existing populations through translocations. The lack of seed-producing stands of *Acacia pendula* in the Hunter Valley suggest that a similar recommendation for propagation and translocation of local provenance material cannot be promulgated unless genets originating from outside the region are used. Such an action is not recommended given uncertainty over plant origin in the Hunter Valley (Bell & Driscoll 2014).

Forrest (2016) related flowering events and prolonged recruitment failure from grazing impacts to rainfall patterns for several arid-zone *Acacia*. He found successful reproduction occurred in at least one of the two consecutive years following a La Niña wet period for the arid zone species *Acacia melvillei, Acacia homalophylla* and *Acacia loderi*. However, although these wet periods initiated sexual reproduction in these species, other factors appeared to limit success. Gaol and Fox (2002) earlier suggested that a wet winter period was required to induce flowering in some *Acacia*, and that follow up falls were necessary to ensure

seed production. For the study population of *Acacia pendula*, the 2018 flowering event occurred two years after a very wet three-month period from November 2015 to January 2016. South-eastern Australia at this time was in the grip of an El Nino event, and this wet period contrasted strongly with the below average falls received at other times in 2015 and 2016 (refer Fig. 5). Flowering in 2018 was therefore potentially a response to the wet period two years earlier, although without additional data on flowering phenology prior to 2015 this remains conjecture. Apart from this event, examination of rainfall data in the period leading up to flowering shows no clear pattern or spike in rainfall that may have triggered the 2018 flowering event. Winter rainfall was below average in 2017 prior to the documented flowering event, but largely above average in 2016 where no flowering was observed.

High mistletoe density on some *Acacia pendula* within the study area is impacting on the health and vigour of these plants, but desiccation and gall-infestation of flowers was consistent across all study trees, irrespective of the number of mistletoe clumps. However, some trees appear to have suffered branch death as a result of high mistletoe densities. Modification to landscapes associated with agricultural activities are known to increase the density of mistletoes (e.g. Bowen et al 2009; Watson 2011), as the availability of perches for avian vectors becomes greatly reduced. In other studies, mistletoes have been implicated in rapid turnover and increased mortality of host trees (e.g. Reid et al 1994; Reid & Stafford Smith 2000), although susceptibility is not universal (e.g. MacRaild et al 2009).

The general poor health and flowering displayed by *Acacia pendula* within the study population and elsewhere in the Hunter Valley are perhaps symptomatic of wider implications following extensive landscape modification. The study population lies on land that has been largely cleared for grazing purposes for many decades. Henry Dangar's 1828 map of the Hunter River area shows the WMMA to be "*open forest country, deep loam soils occasionally intersected by scrubs & ill watered*" (Umwelt 2012), but by 1850 subdivision and clearing of the land for grazing purposes had begun. Pastoralism was the first industry established in this part of the Hunter Valley, and in the nineteenth century the Broke area was a centre of pastoral interests based on sheep and cattle grazing (Umwelt 2012). Progressive removal of canopy and shrub species would have occurred during this period to increase the carrying capacity of the land for agriculture and grazing. Such modification to landscapes, with the inherent fragmentation of habitats that ensues, often leads to extinction cascades when the loss of key species in an ecosystem triggers the loss of other species (Fischer & Lindenmayer 2007). It is possible that such removal of key structural and floristic components of the former *Eucalyptus moluccana* woodland over an extended period of time may have led to the poor health and reduced sexual reproduction currently evident in the *Acacia pendula* population at the WMMA.

In any case, *Acacia pendula* trees within the study population are evidently subject to a number of stressors which affect successful and ongoing recruitment. These include but are not limited to infection by various flower- and phyllode-galling midges and thrips (*Asphondylia* sp., *Dasineura glomerata, Kladothrips rugosus*), fungal galls (*Uromycladium* sp.), caterpillars (*Ochrogaster lunifer*), and mistletoe (*Amyema quandang*), together with stress brought about through drought and other climatic extremes. Pollinator absence or decline may also be imposing a different stress on the trees, but as of yet there is no data to confirm this. The absence of any old seed pods beneath all ten of the study trees suggests that these stressors have been operating on and limiting recruitment in them for many years, and that persistence in the area relies solely on asexual reproduction. Arguably, all of these stressors are a result of, or are exacerbated by, a highly modified and cleared landscape, and their collective impacts raise serious questions over how the species can remain viable in such a habitat into the future. Exclusion of stock grazing from *Acacia* populations may be feasible in the short-term at some locations, but management of grazing pressures for the benefit of *Acacia* is uncertain in the long-term, particularly during times of drought when all lands are subject to increased pressure to feed hungry stock.

Such a predicament for *Acacia pendula* has serious implications for conservation management, both here and in the wider Hunter Valley region if the patterns observed in the study population are repeated at other stands. This is particularly so in regard to conservation actions that require the augmentation of existing stands through translocation or supplementary planting. With no seed produced, augmentation planting can only rely on propagation from cutting material which re-distributes the existing poor genetic base. Alternatively, propagation using seed sourced from horticultural specimens (morpho-type A in Bell and Driscoll 2014) will introduce new genetic material into the region, a situation that is unfavourable given conjecture over the origin of existing plants. If *Acacia pendula* is ultimately shown through genetic studies to be a natural component of the contemporary Hunter Valley landscape, it remains unclear why such a disjunct population of the species occurs and persists in seemingly inhospitable habitat well east of its accepted geographical range. Hypotheses around its presence as a relict population from a previous drier climate regime (e.g. DEWHA 2009; OEH 2013), which may help explain the root-suckering habit, require further investigation.

Acknowledgements

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