ECOLOGICAL RESPONSES BY BULLICH (*Eucalyptus megacarpa*) AND JARRAH (*Eucalyptus marginata*) TO MULTI-DECADAL PERIODS OF WATERLOGGING AND DROUGHT IN SOUTH-WEST OF WESTERN AUSTRALIA (SWWA)

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Abstract

In the past 120 years, a period of above average rainfall that lasted for about 60 years (1910-1970) was followed by a similar length of time with below average rain. Jarrah grows best on deeper soils on well-drained slopes and crests and is susceptible to waterlogging, whereas bullich is found on the margins of water gaining swamp systems. Pluvials and droughts that occur over such long periods of time should lead to substantial changes in hydrology and ecological responses.

Between 1910 and 1970 the water table rose and resulted in extensive deaths of jarrah in gully-heads due to a combination of waterlogging and Phytophthora disease. Moisture-loving tree species such as bullich began to invade the areas formerly occupied by jarrah. Bullich trees between 50 and 100 years old can be found growing among very large jarrah stumps.

The current dry period from 1970 has also resulted in change. In March 2011 crown scorch and some deaths of jarrah were associated with shallow soils adjacent to exposed rock. A bullich stand of about one hectare in a gully-head site was also affected. The invasion by

bullich into drier habitats during periods of higher rainfall exposes the trees to drought and bushfire. Most of the larger bullich trees were killed and replaced with coppice stems and seedlings. This new stand will now be much more susceptible to fire damage.

Since 1910, the northern jarrah forest ecosystem has been subjected to cycles of increasing and then decreasing rainfall. The ecological changes we have described, initially favouring bullich and now again favouring jarrah have taken many decades to be fully expressed. We propose that the current drier phase is likely to be the more "natural" condition for this ecosystem.

1 Introduction

The jarrah (*E. marginata*) forest covers two million hectares located in the extreme south-west of Western Australia (SWWA). It has a "Mediterranean type" climate with hot, dry summers and cooler, wetter winters. The canopy can reach a height of 30 meters, the forest has high biomass (up to 600 m3/h) but low increment (<2 m3/ha), and grows on an ancient, infertile lateritic soil. Individual trees may grow for 350 years, have a thick, rough bark and are resistant to moderate bushfire. Jarrah is a beautiful red-coloured timber which is highly versatile in use and resistant to termites. Timber production commenced soon after settlement by Europeans in 1829 and large quantities were harvested for local use and export, especially between 1880 and 1970. Commercial timber harvesting ceased in 2023, with the Government claiming concerns about Climate Change as the reason.

Jarrah is the dominant species and grows in association with marri (*Corymbia calophylla*) on slightly more fertile soils, and bullich (*E. megacarpa*) and blackbutt (*E. patens*) on water-gaining sites. Bullich is smooth-barked, making it more susceptible to bushfire. Since 1970 rainfall in SWWA has fallen about 20%, water-tables by over 10 meters and inflow into the metropolitan water supply dams by 80 %.

Such a large change in hydrology is likely to result in ecological responses.

The winter of 2010 was exceptionally dry and was followed by a long, hot summer. By March 2011 extensive crown scorch and some deaths of native vegetation occurred in the western, higher rainfall parts of the northern jarrah forest. The Water Corporation funded an aerial survey by helicopter over the Wungong research catchment and we estimated that about five percent of the jarrah forest on this catchment had been affected. It was obvious that most tree deaths were associated with shallow soils adjacent to exposed rock. A number of patch deaths were also observed in areas previously mined for bauxite which had been rehabilitated.

One notable exception was an area of bullich on a streamline, near White gum road. The aerial survey was then followed up with field visits to eleven sites, five located in native forest, five on rehabilitated minesites and the bullich site.

All of the academic research effort to date has targeted the deaths on shallow soil near rock surfaces, as these were the more obvious and extensive (Matusick *et al* 2013). As the impacts on jarrah on upland sites with shallow soil have previously been reported (Batini 2025), we shall concentrate on the response by bullich on a water-gaining site.

2 SOILS

An excellent soils map was produced for the Wungong catchment by CSIRO soil scientist (Churchward and Batini 1975). Slopes were classified into four classes (gentle to very steep), rock surfaces into five classes (also gentle to very steep) and valley floors into five classes based on drainage and soil type. The soils on the crests and gentle slopes are gravelly sands over laterite, while on steeper slopes earths and podsolics are common. Crests and slopes were the dominant units covering 78% of the area (Havel site-vegetation types S and P); Rock surfaces with shallow earths and gravelly earths occupy 5%, (Havel site-type R); Swamps on wet, silty-loam alluviums, 6.% (Havel site-type C) and Gully Heads , with slightly better-drained, sand or sandy-gravel alluviums at variable depth to clay, 10% (Havel site-types D,W, Havel 1975). Depending on depth to clay, these gully heads are the sites most likely to experience either waterlogging or drought.

3 Observations 2011 to 2025

3.1 June 2011 The bullich site where scorch and collapse was observed is located within the Wungong catchment, in Chandler Block, adjacent to White gum road. The team included Dr E Davison (plant pathologist), Mr P Shedley and F Batini (foresters). It is a water-gaining gully-head site with a dense stand of bullich, growing on a lateritic loam of depth 80 cm, Havel site type D. Most trees were scorched some had died but the understorey species were unaffected.

Dead stags indicated that occasional tree deaths had occurred previously and the area affected was estimated at one hectare. Basal area at a single site was measured as 26 m2/ha, stems per hectare as 300 and the girth of the largest tree as 1.60 meters. The area had not been burnt for at least ten years.

There was no indication that tree deaths were associated with any pathogenic organisms. Drought was considered as the most likely cause (Davison 2011). It was expected that at least some trees would recover by producing epicormic or coppice shoots.

Downstream, in a more clearly defined streamzone (Havel type C), the individual bullich trees were much larger in size and unaffected by drought.

3.2 June 2020 The site was re-visited and measurements were made. The trees that were killed in 2011 had not produced epicormic shoots on the trunk or branches, but many had coppiced from the collar region and this coppice was now several meters tall. In addition there were many smaller stems that had germinated from seed. The area has not been burnt since 2011.

Two parallel transects each 10 m wide and 125 m long was established within the bullich stand moving upstream into the gully head and estimates of basal area (factor 2 prism), stem numbers and crown health (by 10 cm size class increments) were made for all stems > 10 cm in diameter at breast height. The site is approximately one hectare (150m x 60m) in size. A total of 138 stems were assessed, of which 74 were alive and 64 dead. Basal areas and stems/ha recorded were 9 and 296 (alive trees) and 7.5 and 256 (dead trees). Most of the living stems (92%) were <30 cm at breast height, mainly coppice stems from trees which had died in 2011. Only 20% of the original mature trees (>30cm in 2011) within the plots were alive. The ratio of very healthy to very poor crowns was 1.5:1. More recent deaths of some younger stems were noted, probably as the result of a drier winter in 2019.

3.3 April 2024 and June 2025 Severe scorch and some tree deaths were again observed in April 2024. By January 2025 some of the affected stems had recovered (Figure 1)

3.4 Comment

The pattern of collapse, partial recovery, collapse and recovery between 2011 and 2025 confirms that drought was the most probable cause of the original deaths. The effects have been substantial, killing most of the larger trees and replacing these with much younger coppice stems and seedlings. This new stand will now be much more susceptible to fire damage since the crowns are lower, the bark is thinner and there is much less seed in the young crowns. The site has not been burnt for at least 25 years and there is a lot of accumulated ground fuel. Even a cooler prescribed burn is likely to do considerable damage.

The bullich stand located immediately downslope of these dead trees (Havel site -type C) was able to survive the 2011 and 2024 droughts and is still healthy, as are other bullich stands growing along streamlines within the Wungong catchment. These are key areas for the protection of a number of threatened species of bird and mammal.

Monitoring of vegetation in the adjacent 31 Mile Brook over five decades (1973-2012) has shown only a slight xeric shift in species composition, near exposed rock and in gully-head sites (Mattiske 2012). A few moisture-loving species such as blackbutt , bullich and small shrubs such as *Hypocalymna* have died and retreated to slightly wetter sites.

Drought death of trees which grow on shallow soils near rock outcrops are not unusual, however drought induced mortality of trees growing on water-gaining sites may be more difficult to explain. We shall attempt to do so by referring to soils, rainfall and groundwater.

4 Ecological drivers and responses

4.1 Rainfall The key environmental driver is rainfall and we are fortunate to have a rainfall record from Jarrahdale, a mill town located about 6kms SSW of the bullich site, from 1882 to 2024 (Figure 3). Between 1910 and 1970 the rainfall at Jarrahdale increased substantially, water table rose and resulted in extensive deaths of jarrah in gully-heads due to a combination of waterlogging and Phytophthora disease (Batini 1973, Figure 2). One-quarter of the

Wungong catchment was affected. This was an unusually wet period, probably the wettest in six centuries (O'Donnell *et al* 2021).

Moisture-loving tree species such as bullich and blackbutt and understorey species such as *Hypocalymna* began to invade the areas formerly occupied by jarrah Examples of this invasion can be readily seen along Chandler and White Gum roads, where pole and pile sized bullich trees, estimated to between 50 and 100 years old, are now growing among very large jarrah stumps. These high-quality jarrah sites were first harvested for timber between 1895 and 1920.

Since 1970, following several decades with lower rainfall, these species are now showing drought symptoms on shallower soils and are retreating back to their more favoured, wetter sites. Despite a number of alarmist comments in the media, the ecosystem, especially the understorey, has shown resilience to the climatic shifts. This is the "*good news*", since the streamside vegetation supports many species of bird and mammal (Dundas *et al* 2011) that depend on plants for food, shelter and cover.

4.2 Groundwater There is anecdotal evidence (Dr J J Havel) that foresters planting *Pinus pinaster* in the 1950's, in a gully-head site previously devastated by Phytophthora disease, worked calf-deep in slushy soil. Unfortunately there are no empirical data on how much the groundwater in the jarrah forest would have risen as a result of the unusually high rainfall from 1910 to 1970.

Modelled depth to groundwater in a catchment adjacent to Wungong shows significant change (Croton *et al* 2011). In the early 1970's extensive areas of the valley floor, especially in gully-heads, had positive heads above the soil surface, but by 2010 the groundwater contact with the surface was limited. Bore data from Cobiac, a sub-catchment of Wungong show a decline of six meters between 1992 and 2012 (Reed *et al* 2012). Presumably water tables would have risen substantially after decades of above-average rainfall.

5 Discussion

The invasion by bullich into drier habitats during periods of higher rainfall exposes the species to the effects of drought and bushfire during an extended drought. The pattern of scorch, some deaths and then partial recovery of this stand from 2011 to 2025 confirms that drought is the most probable cause. The effects have been substantial, killing most of the larger trees and replacing these with much younger coppice stems and seedlings. This new stand will now be much more susceptible to fire damage, especially as the fuels are now over 25 years old. Even a milder prescribed burn is likely to do significant damage.

The vegetation adjacent to streams supports many species of bird and mammal, some of which are classified as threatened. Protection from bushfire is essential and this can best be achieved by prescribed burning of the adjacent jarrah forest on a rotation of eight to ten years. Small burns of varying intensity within the stream-zone will also be necessary at longer intervals so as to regenerate senescent understorey species and provide feeding areas. Predator control will be desirable.

It is not clear why the older bullich stand located immediately downslope was able to survive in 2011 and is still healthy. Probably the site is wetter or the soil deeper above the clay layer. The other extensive bullich stands growing along streamlines within the Chandler catchment are also healthy (Figure 4).

Since 1880, the northern jarrah forest ecosystem has been subjected to cycles of increasing and then decreasing rainfall. An ecosystem is never static and the ecological changes we have described, initially favouring bullich and now again favouring jarrah have taken many decades to be fully expressed. Comparing the damage done to the ecosystem, we would argue that the negative effects associated with waterlogging and Phytophthora disease have been far greater than the more recent effects of drought.

The community, Academics, water-supply Engineers and some forest managers had become accustomed to decades of above-average rainfall and were concerned when rainfall reduced, groundwater dropped, streamflow decreased, aquatic biodiversity changed and some trees on shallow soils died. However we would argue that the current drier phase is not atypical, but that it is likely to be the more "natural" condition for this ecosystem.

Figure 1 Bullich in gully head, White gum road. Collapse in 2011, recovery in 2020, scorch in April 2024 with some recovery by January 2025.6426000/415000

Figure 2 Stands of jarrah affected by waterlogging and *Phytophthora* disease on water-gaining sites with healthy forest in the background.

Figure 3 Rainfall Jarrahdale 1882-2020 (M J Freeman)

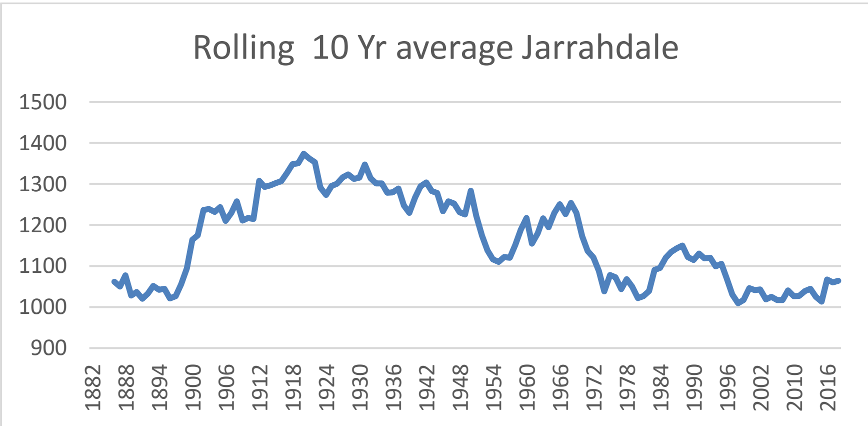

Figure 4. Healthy stands of bullich with dense understorey and water point for fighting bushfire.

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MJ Freeman for rainfall graph

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References

Batini F (1973) Jarrah dieback – a disaese of the jarrah forest in Western Australia. Bulletin 84 Forests Department of Western Australia

Batini F (2025.) Is the jarrah (*Eucalyptus marginata*) forest under threat from a changing climate? Australian Forestry, Volume 88, pp 50-56.

Churchward H M and F E Batini (1975) Soil patterns and land utilization in the Wungong Brook catchment, Western Australia, CSIRO Land Management Series No 1.

Croton J T, K A Green and J A Dalton (2011) WEC-C modelling of the 31 mile brook research catchment. Report to the bauxite hydrology Committee.

Davison E (2011) tree deaths in native forest and rehabilitated minesites in the Wungong catchment. Report to Water Corporation 1 70443 720 9.

Dundas S, F Batini, G Hardy and T Fleming (2011) Implications of climate change, reductions in streamflow and falling water tables on biodiversity in the northern jarrah forest from Armadale to the Murray river. Report to the bauxite hydrology Committee

Havel J (1975b) Site-vegetation mapping in the northern jarrah forest (Darling Range) 2 Location and mapping of site-vegetation types. Bulletin 87 Forests Department of Western Australia.

Mattiske Consulting (2012) Comparison of vegetation values in the 31 mile brook catchment area from 1975 to 2012. Report to Forest Products Commission 1201/72/2012

Matusick G, K Ruthrof, N Browers, B Dell and G St J Hardy (2013) Sudden forest canopy collapse corresponding with extreme drought and heat in a Mediterranean-type eucalypt forest in southwest Australia. European Journal Forest Research 1612-4667.

O'Donnell AJ, Lachlan McCaw W, Cook ER, Grierson PF. 2021. Megadroughts and pluvials in south-western Australia, 1350 CE - 2017 CE. Climate dynamics. 57:1817–1831.

Reed A, K L Barrett and J T Croton (2012) Future streamflows from the northern jarrah forest. Learnings from the Wungong catchment trial. Water Corporation 1 74043 797 7