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XII INTERNATIONAL RANGELAND CONGRESS AUSTRALIA 2025

Mulga populations at risk: 50% drought mortality outside reserve areas and low recruitment everywhere

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Key words: grazing; demography; semi-arid; tree mortality; seedling survival

Abstract

Mulga (*Acacia aneura* and related species) is a drought-tolerant tree that dominates large parts of Australia's arid and semi-arid zone. Following a severe drought in 2017-2019, mass mortality was reported across the distribution of mulga. In 2021-2022, there was substantial rainfall in some regions that was expected to stimulate a mulga recruitment pulse. In this study, we quantify mortality and recruitment following these events in two land uses that differ in their grazing pressure. We surveyed inside and outside the Arid Recovery Reserve, Roxby Downs, SA. Inside the conservation reserve, small native mammals are present—bettongs, bandicoots, and bilbies. Outside the reserve, the land is managed for pastoralism, with livestock, native kangaroos, and feral rabbits. During 2023-2024, we surveyed ten 0.5 ha plots in each land use. In each plot, we counted alive and recently dead mulga plants to quantify mortality and mulga seedlings to assess recruitment. We found that adult drought mortality was 1.8 times higher outside the reserve (50%) than inside (28%). Recruitment after the rainfall was insufficient to offset the drought mortality in either land use type. Inside the reserve, plots had 0.01 seedlings per dead adult and outside the reserve, there were no seedlings. Our results reveal high drought-induced mortality in mulga is exacerbated outside reserves, where livestock and feral animals are present. Low subsequent recruitment indicates that these mulga populations may be at risk. It is imperative to predict mulga population trajectories to conserve the vegetation and functioning of Australia's arid and semi-arid ecosystems.

Introduction

Mulga (*Acacia aneura* F. Muell. Ex Benth and nine related species; Miller et al., 2002) are dominant or co-dominant trees throughout much of Australia's large arid and semi-arid zone. Droughts and high temperatures are common in the Australian arid/semi-arid zone. Mulga has several adaptations, such as phyllodes, to cope with these stressful conditions. However, during the 2017-2019 drought, large dieback events in mulga were reported anecdotally across its distribution. During this period, rainfall was approximately half the long-term average (Bureau of Meteorology, 2023a). Additionally, many regions experienced their highest temperatures on record, especially during the dry months. Dieback events in mulga have occurred in the past (Evans, 1903; Godfree et al., 2019). However, with ongoing climate change, hot and dry conditions are predicted to increase in frequency and intensity (Jenkins and Warren, 2015).

Previous research indicates that mulga mortality is a function of rainfall deficit (Fensham et al., 2019) and other factors such as soil depth which determines water availability (Fensham, et al., 2012). Additionally, heavy grazing pressure can intensify mortality rates (Evans, 1903; Godfree et al., 2019) by reducing water availability due to reduced water infiltration and retention capacities (Witt et al., 2011), and by reducing nutrient availability due to lower diversity and cover of soil crusts (Williams et al., 2008). To predict the likely trajectory of mulga populations in the future, it is essential to quantify mortality and its dependence on climate and other factors. Additionally, an important question is whether recruitment will be sufficient to maintain the population despite severe dieback. Previous research suggests recruitment in mulga is particularly contingent on the timing and intensity of rainfall (Preece, 1971a and b) and is also strongly affected by grazing pressure (Hall et al., 1964; Munro et al., 2009). In 2021-2022, following the drought, significant rainfall occurred in some regions: annual rainfall totals in parts of central South Australia were 100-200% higher than the long-term averages (Bureau of Meteorology, 2023b). The rainfall may have stimulated a recruitment pulse.

Here, we quantify the 2017-2019 drought mortality and 2021-2022 rainfall-induced recruitment in mulga to assess if recruitment offsets mortality, under two land use types that differ in their grazing communities. We surveyed plots inside a conservation reserve (Arid Recovery Reserve), which has small native herbivores, and outside the reserve, on pastoral stations, which have livestock, native kangaroos, and feral rabbits. We compare i) drought-induced mortality and ii) recruitment between the two land use types. We hypothesise that mortality rates will be higher in the pastoral regions because mortality increases with grazing pressure, which we assume to be higher where livestock and feral grazers are present. We also hypothesise that seedling recruitment will be higher inside the reserve where livestock and feral grazers are excluded.

Methods

The study was conducted in and around the Arid Recovery Reserve (-30.33943 N,136.89982 E), near Roxby Downs, South Australia (Fig. 1). This fenced conservation reserve (123 km^2) was established in 1997 (Moseby and Read, 2006). In the part of the reserve where we conducted the study, all herbivores were removed in 1998 and native small herbivores were reintroduced over time, including western barred bandicoots, burrowing bettongs, and greater bilbies (Munro et al. 2009). Outside the reserve, on the adjoining pastoral stations, the chief herbivores are cattle, native kangaroos, and feral rabbits. The different grazing communities inside and outside the reserve represent the two land use types in this study. During 2017-2019, hot-dry conditions prevailed in the study area. The long-term average annual rainfall in the area is 182 mm (at Andamooka Station, Bureau of Meteorology 2023c). During the three years of the 2017-2019 drought, the mean annual rainfall was 86 mm, causing a cumulative rainfall deficit of 288 mm over the period. The long-term average daily maximum temperature of the driest quarter (January to March) is 34.8°C. During the drought, the average was 1 – 1.2°C higher, with some days hitting the highest on record at 48.1°C. However, above-average rainfall followed in 2021-2022. In these two years, the average rainfall was 231 mm, ~50 mm more than the average, and the average dry-quarter maximum temperatures dropped to 33.7°C.

In each land use type, we surveyed ten plots. Each plot was a circle of 40 m radius (0.5 ha) centred on an adult mulga tree. In each plot, we counted alive and recently dead adult mulga plants, and seedlings. Plants were classified as '*alive*' if green leaves were present. Plants were classified as '*recently dead'* if green leaves were absent, but fine twigs were present, and bark was intact; indicating that these plants died following the recent drought. Plants ≥2 m in height were classified as adults which have a recruitment potential, as most of these had flowers or pods. Plants ≤0.3 m in height were classified as seedlings and assumed to have recruited following the 2021-2022 rainfall events. We tested the effect of land use type on mortality and recruitment using a generalised linear model (Dobson 1990). For comparing mortality and recruitment percentages, the response variable was the ratio of the counts to the total with binomial family and logit link (i.e., the response variable for mortality was the number of recently dead tree counts divided by the total number of alive and recently dead trees and, total as weights). All analysis was done in R v.4.2.1 (R Core Team, 2022). The study area map was made using QGIS v.3.30.3 (QGIS.org, 2023).

Results

The average adult (alive and recently dead) density of mulga was 78 trees ha^{-1} inside the reserve and 59 trees ha^{-1} outside the reserve. The 2017-2019 drought caused an average mortality of 39% in mulga adults. Plots outside the reserve recorded higher adult mortality (50% outside and 28% inside, $p<0.01$) (Fig. 2). Despite the above-average rainfall in 2021-2022, a recruitment pulse was not observed. Only one plot inside the reserve had any evidence of recruitment, with one seedling present. Outside the reserve, no plots had seedlings. The recruitment did not offset the observed mortality. There was only one seedling for 288 dead adults.

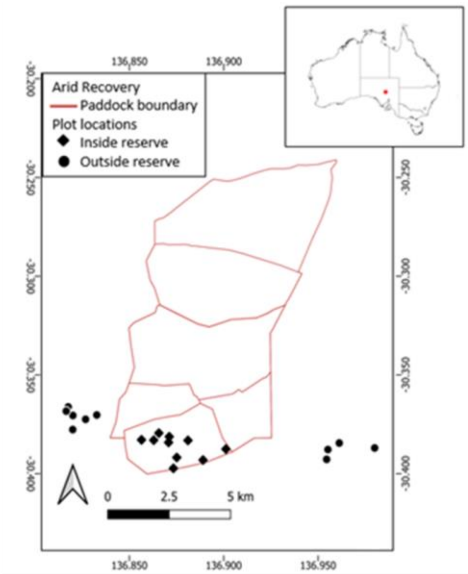

Fig. 1: Plot locations inside and outside the Arid Recovery Reserve. The map inset shows the location of the Arid Recovery Reserve within Australia, in a red star.

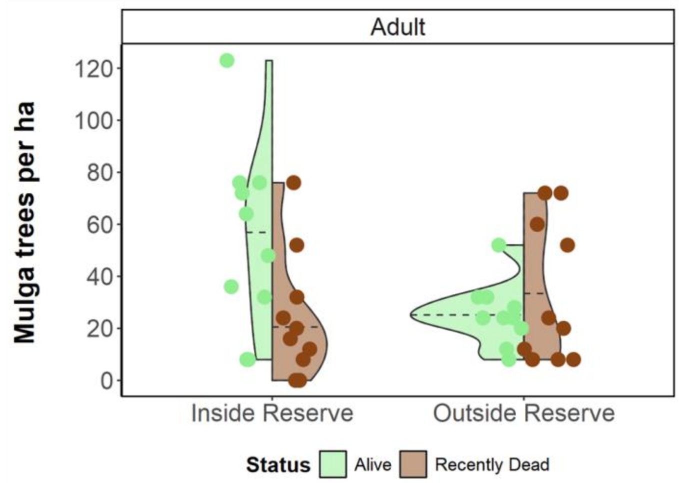

Fig. 2: Number of alive and recently dead mulga adults (≥2 m height) in plots inside and outside the Arid Recovery Reserve. The dashed lines indicate the respective medians.

Discussion

Many regions of Australia received less than half their average rainfall during 2017-2019, along with record-high temperatures. In the study area, this 3-year rainfall deficit and high temperatures caused significant mortality in mulga (39% of all adult plants). Moreover, despite above-average rainfall during 2021-2022, a recruitment pulse has not occurred (only one seedling was observed across all plots). The high mortality and low recruitment indicate that subsequent recruitment was insufficient to offset the occurred drought-induced mortality. The high mortality rate, coupled with poor subsequent recruitment rates, could lead to a local population decline in mulga. Drought-induced population declines are not restricted to our current study area; surveys during 2021 at Uluṟu-Kata Tjuṯa National Park also reported a 42% drought mortality in mulga (Wright et al., 2023). While drought-induced mortality has occurred in the past (Fensham et al., 2019), the lack of recruitment despite the subsequent above-average rainfall highlights the need to assess the population trajectory of mulga under a changing climate.

To understand population trajectories, it is vital to examine the drivers of mortality and recruitment. From our study and others (Fensham et al., 2019; Wright et al., 2023), it is evident that a rainfall deficit of less than half of total rainfall that lasts more than one year causes considerable dieback in mulga. This threshold can vary with soil depth (Fensham, et al., 2012), but this was not tested in this study.

Our study indicates that increased grazing pressure exacerbates drought-induced mortality. We found that the grazed areas outside the reserve had 1.8 times higher mortality than inside, supporting our hypothesis that mortality rates are higher where livestock and feral grazers are present. Anecdotal reports from the 1900s (Evans, 1903 in Fensham et al., 2019; Godfree et al., 2019) indicate high mortality in mulga occurred in overgrazed areas, but few studies have systematically studied the interaction between drought and grazing in determining mortality. Fensham et al., (2012) assessed mulga mortality as a function of a grazing intensity index (distance to watering points) but did not find a consistent relationship between grazing intensity and mortality rates. However, heavy grazing pressure reduces water availability and nutrient availability (Witt et al., 2011; Williams et al., 2008), indicating mechanisms by which grazing could increase drought-induced mortality.

Mulga seedlings were too rare in either land use to draw conclusions on the drivers of recruitment. However, recruitment clearly has not offset the drought-induced mortality.

The preliminary analysis presented here demonstrates an important effect of grazing on drought-induced mortality. Reducing grazing pressure may be important for maintaining mulga populations under future climate conditions. In future work, we will analyse the relationship of recruitment and mortality rates to more detailed drivers, including impacts of different grazer types and other factors such as soil and topography.

Acknowledgements
This study is a part of the PhD work of AS. This work is funded by the 2019 Australian Research Council Laureate Fellowship FL190100003, the Arid Recovery Reserve and Bush Heritage Australia. We acknowledge the people of Kokatha and the neighbouring Kuyani and Arabana, where Arid Recovery lies. We acknowledge the Darug people, where the Hawkesbury Campus of the Western Sydney University lies. AS is thankful to James Lowe, Narelle Pickering, Robert Heathwood, Caitlin Rutherford, and Charlotte Hogan for assisting with the fieldwork.

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