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SHORT COMMUNICATION



Avifaunal use of an artificial waterpoint in the Strzelecki Desert during an extended dry period

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ABSTRACT

Dryland ecosystems have limited and patchily distributed water – a vital resource for species in these landscapes. Degradation of these ecosystems is increasing due to climate change and understanding species' responses to this drying is critical for effective ecosystem management. During an extended dry period, we surveyed drinking visits of an avian community at an artificial waterpoint in semi-arid Australia. Opportunistically, a small rainfall event punctuated the survey, enabling comparisons of avian visitations, before and after the event, as a proxy for increased water availability in the landscape. Visitations of drinking birds to the waterpoint before the rainfall event (17 species) were significantly higher than after (3 species). Permanent waterpoints, such as the single site surveyed in this study, can sustain avifauna during extended dry periods in drylands, affecting spatio-temporal and potentially functional avian community dynamics. Periodic reliance of dryland birds on permanent water may increase with prolonged droughts under climate change, and this reliance must be considered alongside the negative ecological consequences of permanent waterpoints in the management of these ecosystems.

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Introduction

Drylands are water-limited, affecting resources for species and communities. Globally, these ecosystems are degrading, but will undergo a projected 50% expansion in global land area by 2100 due to climate change (Huang *et al.* 2016). Duration, frequency, and severity of rainfall-deficient periods in some drylands is also increasing under climate change (BOM and CSIRO 2018), necessitating improved understanding of their ecology. To inhabit these ecosystems, birds must effectively exploit limited water resources to persist, which is commonly achieved through specialised adaptations, which enable them to maximise water intake through their food and by drinking (Williams and Tieleman 2005; Morton *et al.* 2011). These adaptations are diverse, and can be both behavioural (e.g. Dean *et al.* 2009; Kingsford *et al.* 2010) and physiological (Williams and Tieleman 2005).

In Australia, 70% of the continent is dryland, with many birds exhibiting nomadic and opportunistic life-histories associated with accessing variable and unpredictable resources (Morton *et al.* 2011). For example, irregular large rainfall events attract nomadic waterbirds over long distances, offering a pulse of abundant food and water, enabling breeding events (Kingsford *et al.* 2010). Zebra Finch *Taeniopygia guttata* opportunistically breed

when grass seeds become available after rainfall (Griffith and Buchanan, 2010), while Spiny-cheeked Honeyeaters *Acanthagenys rufogularis* are both sedentary and nomadic, capitalising on variable dryland resources (Rawsthorne 2016). However, with the expansion of artificial waterpoints (e.g. dams, tanks, troughs, and bore water overflows) across Australia's drylands, largely for pastoralism, available surface water has become less unpredictable where these structures are present, with consequences for the avian community.

These community shifts can be attributed to the behaviour of the birds in these communities, but also to the shifts in other animals, which have also responded to these more reliable sources of water. Artificial waterpoints enable nomadic species to persist where they otherwise would not (Fisher *et al.* 1972). Growing numbers of artificial waterpoints have also increased and concentrated water-dependent grazing mammal and predator activity, linked to long-term avian declines and altered community composition (Davies *et al.* 2010). While these broad-scale effects are known, the way avian communities use or rely on these features during extended dry periods which are increasing under climate change (BOM and CSIRO 2018), and how resource pulses may affect these patterns, are seldom known, but it is important to understand in order

to manage these communities and ecosystems sustainably. As such, we aimed to determine how bird drinking activity (abundance, timing, and community composition) changed at an artificial waterpoint before and after a small resource pulse, during an extended dry period in semi-arid Australia.

Methods

In the semi-arid far-eastern Strzelecki Desert of Australia, we surveyed the avian community drinking at a greywater outflow at Wild Deserts Field Station, Fort Grey, Sturt National Park (29°05'20.5" S 141°12'13.2" E) in April and May 2019. The site has highly variable, predominantly summer rainfall (Morton *et al.* 2011; Pedler *et al.* 2018), but experienced an extended and severe dry period during which 136.5 mm fell in the 24 months before surveys and only 35.3 mm fell in the prior 12 months – the driest 2-year period on record and across vast areas of eastern and inland Australia (rainfall records from BOM 2019a; missing records from, BOM 2019b). Between surveys in April and May 2019, there was a resource pulse with 20.8 mm of rainfall (BOM 2019c), providing an opportunity to compare avian behaviour before and after this resource pulse.

The waterpoint was about 30 m from the Wild Deserts Field Station at Fort Grey, in a sparsely vegetated clay swale between sand dunes, where a greywater outflow trickled into a narrow ditch (Appendix A Figure A1). Two other waterpoints (homestead bird bath and a small trough in the chook yard; see Appendix A Figure A1) were not surveyed systematically but visited by Greater Bluebonnet *Northiella haematogaster*, Magpie-lark *Grallina cyano-leuca*, and White-breasted Woodswallow *Artamus leucor-ynchus*, together the three waterpoints offered the only permanent water within a 30-km radius (2830 km² area) during the study period. These artificial water sources have probably been available since establishment of the homestead in the early 1950s. A single observer surveyed birds from a vehicle to reduce disturbance (20 m away) at three periods during the day (3 hours each): morning (starting 30 minutes before first light), midday (starting 1.5 hours before the middle of each day), and evening (starting 2.5 hours before last light, see Appendix B Table B1). Binoculars and an infrared camera (for low light conditions) were used to identify and count bird visits. A visit was counted when a bird arrived and drank, and not recounted unless the bird moved away more than approximately 50 m from the water point before returning. We conducted five surveys before rainfall over two days, and eight surveys after rainfall over five days, in the morning (before $n = 1$; after $n = 1$), midday (before $n = 2$; after $n = 2$), and evening periods (before $n = 2$; after $n = 5$).

We applied a Generalised Linear Mixed Modelling (GLMM) approach using the 'glmmTMB' package in R (Brooks *et al.* 2017; R Core Team 2020, assumed Poisson distribution for visitation) to compare avian visitation (summed across all species) in response to the rainfall event (before and after), survey period (morning, midday, evening), and mean ambient temperature (midpoint of maximum and minimum temperatures of a survey from half-hourly readings from a meteorological station 10 km west). We assigned random factors to survey date and a unique identifier for each survey:

$$\text{Abundance} \sim f\text{Rainfall} + f\text{Mean Temperature} \\ + f\text{Period} + r\text{Date} + r\text{Survey}$$

Model assumptions and fit were assessed using the 'DHARMA' diagnostics package in R (Hartig 2018; R Core Team 2020).

Multivariate community visitation and species-specific responses to rainfall, temperature, and survey period were also analysed using the *manyglm* function from 'mvabund' package in R (Wang *et al.* 2012):

$$\text{Abundance} \sim \text{Rainfall} + \text{Mean Temperature} \\ + \text{Period}$$

The *manyglm* function fitted a Generalised Linear Model (GLM) separately for each species' visitation data (adjusting p-values for multiple hypothesis testing), using a negative binomial distribution to account for the zero-inflated distribution of the data. This GLM-based approach was preferable to mixed modelling approaches for multivariate analysis with our dataset, due to issues with convergence and fit, likely derived from low sample sizes when counts were analysed per species. However, we compromised by not accounting for survey date. Bootstrap resampling was completed among surveys to account for inter-survey variation (block resampling per survey), with residual fit appropriately tested.

Results

We recorded 1524 visitations from 17 species over a total of 39 survey hours (13 surveys, Appendix B Table B1). Over the period April–May 2019, 57 species were observed incidentally in the broader area (within 25-km radius), with 42 species recorded before the rainfall event, of which 17 species (40%) were recorded drinking, and 54 species recorded after the rainfall event, of which 3 species (5.6%) were recorded drinking (Appendix B Table B2). More than half the visitations (54.6%, $n = 832$) occurred during the morning, which constituted only 15.4% of total survey hours;

113 visitations (7.4%) occurred during the middle of the day, representing 30.8% of total survey hours; and 579 visitations (38.0%) occurred during the evening, representing 53.8% of total survey hours (see Appendix B Table B3). This pattern was similar before and after the rainfall event, in that overall visitations were greater in the morning and evening than at midday when drinking activity reduced (Figure 1(a); Appendix B Table B3). Species-specific responses (from the nine species which drank at the waterpoint on three or more surveys) showed a similar pattern, with greater drinking activity in the mornings and evenings, particularly in

Bourke's Parrot, Crested Pigeon, White-breasted Woodswallow, and Willie Wagtail which never drank during the midday period (Appendix B Figure B1).

Drinking visits were significantly higher before rainfall, when 17 species were recorded, than after, when only 3 species were recorded ($Z = 2.46$, $p = 0.01$; Figure 1b; Appendix B Table B1). Of these, 14 species recorded only before the rainfall (see Figure 1(b)), with six of these recorded on three or more surveys: Australian Raven, Crested Pigeon, Galah, Little Crow, White-breasted Woodswallow, and Willie Wagtail (Appendix B Table B1). There was no statistically

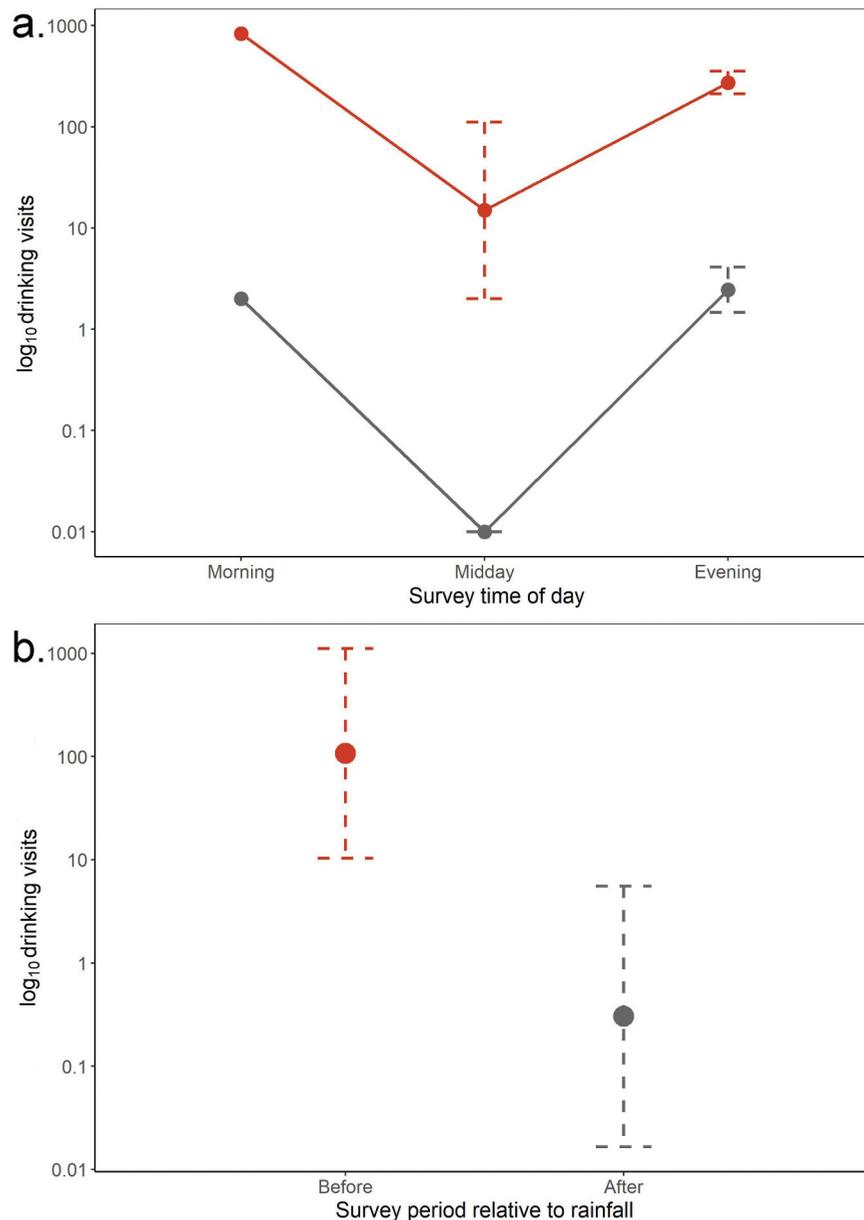


Figure 1. Comparison of mean (\pm s.d.) drinking visits/3 hr survey ($\log_{10}(y + 0.01)$ scale), at an artificial waterpoint in semi-arid Sturt National Park before (orange) and after (grey) rainfall: (a) visitation counts for before the rainfall event in the morning ($n = 1$), midday ($n = 2$) and evening ($n = 2$), and after the rainfall event in the morning ($n = 1$), midday ($n = 2$), and evening ($n = 5$); and (b) visitation counts for surveys before and after the rainfall.

significant effect of mean survey temperature on visits ($Z = 1.08$, $p > 0.05$), however drinking visits were significantly lower at midday than during other survey periods ($Z = -3.466$, $p < 0.001$). Analysis of multivariate abundance (visitations) showed distinct avian communities between before and after rainfall counts ($Deviance = 100.99$, $p < 0.01$), with no statistical support for an effect of temperature ($Deviance = 33.87$, $p = 0.14$; Appendix C Table C1 - 2). However there was a statistically significant effect of survey period ($Deviance = 106.5$, $p = 0.002$), which was driven by the response of Crested Pigeon ($Deviance = 25.224$, $p = 0.014$; Appendix C Table C1 - 2). There were eight species with significantly higher numbers of drinking visits before compared to after the rainfall event (Figure 2; see Appendix C Table C2 for all species' outputs): Australian Raven ($Deviance = 11.45$, $p < 0.01$), Crested Pigeon ($Deviance = 8.24$, $p = 0.03$), Galah ($Deviance = 14.56$, $p < 0.01$), Little Crow ($Deviance = 7.23$, $p = 0.05$), Spiny-cheeked Honeyeater ($Deviance = 6.685$, $p = 0.05$), White-breasted Woodswallow ($Deviance = 8.48$, $p = 0.03$), White-

plumed Honeyeater ($Deviance = 14.36$, $p < 0.01$), and Willie Wagtail ($Deviance = 7.31$, $p = 0.04$). The remaining nine species did not differ statistically before and after rainfall (Figure 2), and none of the 17 species' visitations showed a statistically significant association with temperature ($p > 0.05$; Appendix C Table C2).

Discussion

Greater visitation and diversity of the avian community using the artificial waterpoint was found before the rainfall event than after, with no detectable effect of ambient temperature, indicating that most of the birds observed drinking were reliant on the waterpoint for their persistence in the region during the extended dry period. Species which ceased visiting the waterpoint after rainfall are assumed to have exploited highly variable water resources elsewhere in the landscape in response to the small resource pulse, highlighting how dryland avian communities can exploit permanent water during an extended dry period, and how this varies with water resource availability.

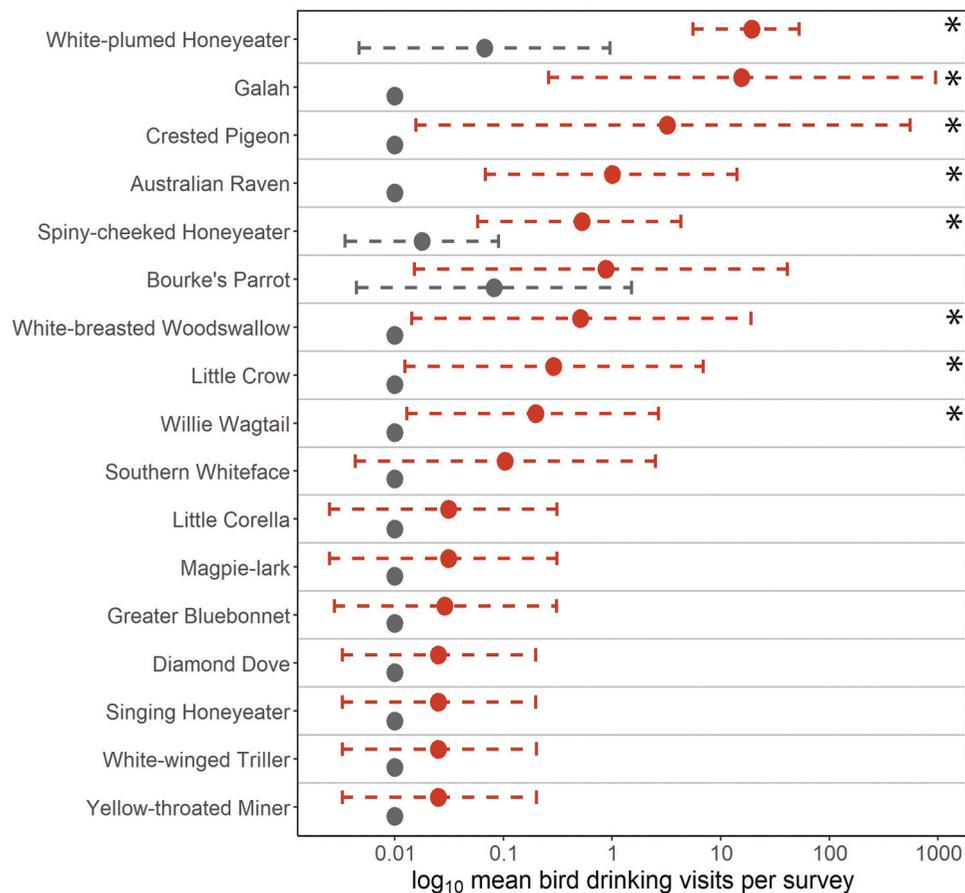


Figure 2. Species-specific mean (\pm s.d.) number of drinking visits of birds ($\log_{10}(x + 0.01)$ scale), at an artificial waterpoint in semi-arid Sturt National Park per three-hour survey, before ($n = 5$; orange) and after ($n = 8$; grey) rainfall in an extended dry period. * represents species with significant differences in their visits before and after rainfall (see Appendix C Table C2).

Increased drinking activity in the mornings and evenings across the study period matched previously recorded patterns of avian drinking behaviour in Australian drylands (e.g. Davies 1972; Fisher *et al.* 1972), coinciding with avoidance of heat exposure in the middle of the day, or to predators, particularly in species which typically drink before first light and after dark (e.g. Bourke's Parrot; Fisher *et al.* 1972). This persistent pattern, before and after the resource pulse, indicates consistency of this behaviour in Australian drylands (Fisher *et al.* 1972). Birds never drank, birds never drank after the rainfall event in the middle of the day when they did during this period before the event (Figure 1(a)), suggesting that these birds may opportunistically drink available surface water or obtain their water requirements in other ways.

After rainfall, species seemed to shift away from reliance on the artificial water (Figure 1(b)), presumably to capitalise on available surface water and food. White-breasted Woodswallow (which roosted at Wild Deserts Field Station during surveys) and Willie Wagtail are both largely insectivorous and probably exploited increased insect activity after the rainfall. However, the woodswallows also preferred drinking from the bird bath, which was not surveyed, so drinking activity may have occurred undetected. Corvids (Australian Raven and Little Crow) and granivores (e.g. Crested Pigeon and Galah) probably exploited increased surface water dispersed across the landscape and the increased moisture content in their food sources (e.g. seedbank and green shoots) once available.

The distinction between visits before and after rainfall was most obvious for Crested Pigeon, with no visits after rainfall, compared to up to 656 visits before during one survey (Appendix B Table B1; Figure B1). The artificial water may have supported most of their population in the area before the rainfall, although this would have been dependent on their ability to source food in the area during this period. Two dead pigeons opportunistically collected before the rainfall event had crops containing only seeds, predominantly: *Trichodesma zeylanicum*, but also *Bulbine semibarbata*, *Dodonaea viscosa*, *Lepidium sp.*, *Maireana sp.*, and *Synostemon rhytidospermus*. All of these plants are dependent on natural rainfall patterns to fruit and produce seeds. Crested Pigeons visiting the artificial waterpoint before the rainfall had a foraging range of 15–20 km based on our incidental observations, so could have depleted soil seedbank resources more than at distances further away, with potential, unexplored implications for primary production and vegetation patchiness after substantial rainfall.

Of the three species observed visiting the artificial water after rainfall (Bourke's Parrot, Spiny-cheeked Honeyeater and White-plumed Honeyeater; Appendix B Table B1), Spiny-cheeked Honeyeater was recorded only once (Appendix B Table B1); White-plumed Honeyeaters (resident at Wild Deserts Field Station) decreased after rainfall; and Bourke's Parrot visits did not significantly differ before and after rainfall (Figure 2; Appendix B Figure B1). White-plumed Honeyeaters were resident at Fort Grey, likely restricted to the planted *Eucalyptus camaldulensis* and *Eucalyptus coolabah* around the homestead. Invertebrates likely supported White-plumed Honeyeaters, although they probably capitalised on more widespread availability of resources after rainfall. Bourke's Parrots were observed to attempt nesting twice, about 3 km from the waterpoint in May, which may have contributed to a reliance on the artificial waterpoint. Other species such as Zebra Finch, which can occur and breed abundantly at the site, did not visit the artificial water source and were either sustained by available food and water in the landscape, or were in low abundances or absent from the site.

The expansion of drylands across the globe (Huang *et al.* 2016) means understanding the consequences of this landscape change on biota is important for sustainable land management and potentially mitigating further losses. As we sampled only one site and one resource pulse, our findings may not be representative of dryland bird community responses more broadly. Expansion and replication of our approach to multiple dryland waterpoints, and the examination of the variability (or consistency) of avian responses to extended dry periods and intermittent rainfall at differing scales would be a valuable next step. The use of bands or tracking devices on individuals would improve understanding of habitat use of individuals at different times (e.g. the potential concentration and subsequent flux of avian activity around artificial waterpoints) in relation to resource pulses. Further exploration of waterpoint concentration of avian function, particularly consequences of granivory for seedbanks and long-term vegetation responses would be interesting to explore. Certainly, artificial waterpoints can sustain some avifaunal communities and under increasingly prolonged, frequent, and severe droughts (BOM and CSIRO 2018) avian reliance on these potential refuges should be considered in dryland management. However, this must be balanced against ecological ramifications of these features in the landscape, such as increases in grazing pressure and feral predators around permanent water (e.g. Davies *et al.* 2010), and separating the effects of artificial water and water availability from the effects of grazing and predation will be difficult. Ultimately, our ability to determine

and predict avian and associated ecological responses to resource availability (water and food) will be valuable for the management of dryland ecosystems.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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