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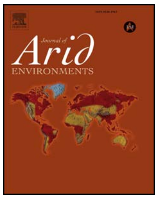

Can providing shade at water points help Kalahari birds beat the heat?

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ABSTRACT

Arid-zone birds trade-off dehydration and hyperthermia during hot weather, as they are dependent on evaporative cooling when air temperature approaches or exceeds body temperature. Water points in many arid ecosystems become surrounded by piospheres, exposing drinking birds to high radiant heat loads and exacerbating this trade-off. This challenge will be aggravated under climate warming. One possible mitigation approach is to reduce heat loads birds experience when seeking water. We experimentally shaded water points on farmland in the Kalahari. We used a Before–After Control–Impact design to assess the impact of artificial shade on species, visitation rates and visitation patterns of drinking birds. The number of species drinking was not affected by the introduction of shade, but overall visitation rates declined, despite a habituation period prior to data collection and increased use of shaded water points during the heat of the day. Of the ten most common species, one –the smallest species in the study - significantly increased and four significantly reduced visitation rates to experimentally shaded water points. Providing shade benefited few species overall, perhaps because of increased perceived predation risk. Future work should investigate the impacts of shader design in order to develop this method as a conservation tool.

1. Introduction

Water resources determine many aspects of avian behaviour and ecology in desert environments, and the distributions of arid-zone birds are often strongly linked to water sources (Fisher et al., 1972; Cade, 1965; Maclean, 1996; Davies et al., 2010). The interactions between desert birds and drinking water sources involve a number of important trade-offs. One is a trade-off between hydration status and energy conservation; taxa such as sandgrouse (Pterocliformes) travel considerable distances each day to drink at water holes (Maclean, 1983, 1996), thereby substantially increasing daily energy requirements. Another involves predation risk, because in arid environments predators often aggregate in the vicinity of waterholes (Fisher et al., 1972; Ferns and Hinsley, 1995; Cade, 1965).

An additional trade-off that may significantly influence drinking behaviour in arid-zone birds, but which has received far less attention than the two mentioned above, concerns the thermal environment birds experience while drinking. Most waterholes are fully exposed to sun, and on account of heavy use by large mammals are usually surrounded by bare areas with little or no vegetation (piospheres; James et al., 1999). The solar heat load associated with the absence of shade means that drinking birds experience environmental temperatures (a measure of the integrated heatload experienced by the animal, accounting for factors such as solar radiation and wind in addition to air temperature; Bakken, 1976; Robinson et al., 1976) far above air temperature, particularly if they drink during the hottest part of the day. In many deserts, air temperatures routinely exceed avian body temperature (∼40–42 °C), with the result that operative temperatures in full sunlight at midday may approach or even exceed 60 °C (Wolf and Walsberg, 1996). Wolf and Walsberg (1996), for instance, estimated that in the absence of wind, the operative temperature experienced by a 7-g verdin (*Auriparus flaviceps*) in the Sonoran Desert increases by at least 12 °C if the bird moves from a completely shaded perch into full sun.

The notion that birds drinking at waterholes may be exposing themselves to operative temperatures high enough to pose a severe risk of lethal hyperthermia is supported by recent data on avian heat tolerance limits. Studies in the Kalahari desert of southern Africa reveal that the maximum air temperatures tolerated by three ploceid passerines during acute (10–30 min) heat exposure under laboratory conditions ranged from 48 °C in the 10-g scaly-feathered finch (*Sporopipes squamifrons*) to 54 °C in the 40-g white-browed sparrow-weaver (*Plocepasser mahali*) (Whitfield et al., 2015). Wolf and Walsberg's (1996) estimates of the effect of solar radiation on operative

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temperatures in verdins is likely applicable to scaly-feathered finches, on account of their similar body mass. If operative temperature is also ~12 °C higher in full sunlight compared to shade for a small bird in the Kalahari, scaly-feathered finches drinking in full sun when air temperature is 40–45 °C likely face a severe risk of lethal hyperthermia, since estimated operative temperature (~52–57 °C) will be well above their heat tolerance limit (48 °C).

Trade-offs between dehydration and hyperthermia risk in birds reliant on waterholes in arid landscapes will become more pronounced under future climates. Increases in maximum air temperatures, as well as more frequent and longer heat waves (IPCC, 2007; IPCC, 2011) will result in large increases in water requirements for evaporative cooling (McKechnie and Wolf, 2010; Albright et al., 2017), as well as higher operative temperatures when drinking. Consequently, the microclimates experienced by arid-zone birds while drinking, and the possibility of manipulating those microclimates in order to reduce thermal stress, are of considerable interest in the context of the conservation and management of arid-zone bird communities.

We hypothesized that experimental moderation of the operative temperatures experienced by birds drinking at desert waterholes should reduce the severity of trade-offs arising from the high operative temperatures associated with this behaviour. If Kalahari birds are restricted in their ability to access water primarily due to high radiant heat loads, then provision of artificial shade may:

(a) Allow species that normally drink only at cooler times of day (morning) to access water throughout the day;
(b) Allow more species and/or larger numbers of individuals to drink during hot weather;
(c) Benefit smaller birds more than larger birds: small species have higher surface area – volume ratios, higher mass-specific rates of solar heat gain, and consequently a larger increment in operative temperature when they move from shade into the sun (Bakken, 1976; Robinson et al., 1976).

2. Methods

2.1. Study site

The study was conducted in October and November 2014 on a privately-owned sheep and beef farm (Murray Guest Farm, 26° 59′S, 20° 52′E) within arid-savanna habitat in the southern Kalahari, Northern Cape province of South Africa. Diurnal air temperatures in this arid zone average ~35 °C and maximum daily temperatures often exceed 40 °C during summer (October–April; Kruger and Shongwe, 2004). The area is characterized by sparse, arid savannas on deep red sands and immobile dunes with a relatively low relief (Perkins and Thomas, 1993). Rainfall is erratic and unpredictable with 100–400 mm per year occurring predominantly during summer (Lovegrove, 1993). Air temperature (at 2 m off the ground) and rainfall were measured at 10-min intervals during the course of the study using a portable weather station (Vantage Pro2, Davis Instruments, Hayward, CA), set up centrally within the study area.

2.2. Experimental design

Time constraints precluded a balanced design, therefore a before-after control-impact (BACI) experimental design (Green, 1979; Skalski and Robson, 1992) was employed to test the effect of artificial shade at water points on the numbers, timing and diversity of birds drinking. A significant interaction between experimental phase (“before” and “after”) and treatment group (“control” and “impact”) on the response variable suggests that changes at the “impacted” sites during the “after” period are likely to be due to effects of the impact itself (in our case, artificial shading) rather than to any background factor (e.g. changes in temperature and rainfall as the season progressed) that could be expected to affect all sites equally.

We chose six artificial stock water points that were already in place on the farm for the experiment. These comprised long, narrow troughs (~200–300 cm long x 20–50 cm wide and ~20–50 cm high) constructed from thick moulded plastic or metal and constantly supplied with water sourced from a borehole on the farm. All six water points were located within a 3 km radius: four within the Kalahari dunefield, and two near the edge of the dry Kuruman River bed. Water points were chosen based on stock rotation practices of the farmers, to ensure cattle would not be present in the camps in which we were working during the course of the study. After suitable water points had been identified, these were organized into three ‘pairs’ based on distance from the river bed and our initial impressions of the numbers of birds visiting each. One of each water point per pair was then assigned at random to the control (unshaded throughout the study) or treatment group (shaded during the latter half of the experiment; see below).

Open wooden frames constructed of thin wooden poles (3 m × 2 m and raised 1.5 m above the ground on six 5 cm-diameter poles) were erected over all six water points six days before the beginning of the experiment, to allow the bird community to habituate to their presence. These provided the framework to support a shade-cloth canopy in the second phase of the experiment, but cast negligible shade themselves (Figure A1). Data collection for the “before” phase of the experiment (hereafter Phase A) began on 14th October 2014 and ran for 10 days. During this time all water points were left unshaded. At the end of this period, a heavy-weight dark blue shade-cloth was stapled across the top of the frames above the three water points in the “treatment” group, blocking approximately 80% of solar radiation. A period of six days was allowed for birds to habituate to the changed situation, after which a further six days of data were collected for the “after” phase of the experiment (hereafter Phase B).

2.3. Data collection

Data on bird visitation rates to water points were collected using programmable, high-resolution LTL Acorn 5310WMG 940 nm MMS camera traps set on posts ~1 m high at a distance of ~5 m from at each water point. These cameras were programmed to take pictures of the water troughs every minute from 6:00 until 19:00, and the number and species of birds visiting were extracted from the photographs by counting birds visible on the sides of the trough in each photo and assigning these to species. We converted the number of birds counted to a visitation rate per hour, to account for the fact we could not identify individuals. This was calculated by dividing the total number of bird visits by the total number of hours recorded for each species. Only birds perched on the edge of the water troughs themselves were counted to avoid including birds just passing through but not intending to drink. Five sampling periods of 1 h each (6:00–7:00 [early morning], 9:00–10:00 [late morning], 12:00–13:00 [early afternoon], 15:00–16:00 [late afternoon] and 18:00–19:00 [evening]) were chosen for data extraction; to assess patterns of water use over the course of the day and maximize the range of air temperatures sampled (Fig. 1).

2.4. Species recorded

A total 43,507 bird visits to water points by 36 species were recorded during the course of the experiment (Table A1). Of these, ten resident species were recorded more than 350 times (Table 1). These species were included in species-specific analyses of the effect of providing shade on rates of use of water points.

2.5. Daily patterns of use of water

We used G-tests (making use of the Chi-squared distribution; Dytham, 2003) to test for differences in the time of day at which the greatest proportion of birds visited control and experimental water