Hot birds drink more: patterns and drivers of water visitation in a fynbos bird community

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Complete List of Authors:	Lee, Alan; Percy Fitzpatrick Institute of African Ornithology; South African National Biodiversity Institute Barnard, Phoebe; Percy Fitzpatrick Institute of African Ornithology; South African National Biodiversity Institute Wright, Dale; BirdLife South Africa
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Hot birds drink more: patterns and drivers of water visitation in a fynbos bird community

Alan T.K. Lee [1, 2 *], Dale Wright [3] and Phoebe Barnard [1, 2]

[1] Climate Change BioAdaptation, South African National Biodiversity Institute, Private Bag X7, Claremont 7735, South Africa.

[2] Percy FitzPatrick Institute of African Ornithology, DST-NRF Centre of Excellence, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa.

[3] BirdLife South Africa, Private Bag X5000, Parklands 2121, Johannesburg, South Africa

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***** *Correspondence:* alan.tk.lee@googlemail.com

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Abstract

Water is essential for the survival and distribution of many species, but water supplies in many parts of the world are under threat due to climate change. In South Africa, various global climate-change models suggest a drier future for the winter rainfall regions with implications for survival of plant and animal species of the fynbos region. We documented bird species drinking at five natural water sources at a semi-arid fynbos site through time-lapse cameras to explore which birds are drinking when. We modelled the total numbers of birds observed drinking as a function of diet, mass and relative abundance and found that granivores were observed drinking most frequently, with the more common species most frequently recorded. Daily drinking rates at the species level for the ten most frequently observed species were generally best explained by daily temperature; with higher drinking rates on hotter days, as well as time since last rainfall. However, daily drinking patterns were poorly explained by diurnal temperature trends at the hourly level and we were unable to document sufficient predators to comment on the influence on predator avoidance or other heat mitigation strategies. Finally, we discuss the implications of our observations for the set of fynbos endemic passerines.

Introduction

Water is essential for the survival and distribution of many species, but water supplies in many parts of the world are under threat due to climate change. In South Africa global climate-change models predicted that the Mediterranean climate of the Western Cape would become warmer and drier (Midgley et al., 2002, Klausmeyer and Shaw, 2009), and evidence for this has now been reported from weather stations in protected areas (van Wilgen et al., 2015). There is also concern over the lowering of water tables due to ground water extraction, damming and land degradation, which may be influencing above ground water availability in the Western Cape (Le Maitre et al., 2009).

Many bird species rely on evaporative water loss for maintaining body temperatures (Whittow, 1976, Williams and Tieleman, 2001). As temperatures increase, water stress will increase for most species with possible lethal consequences (McKechnie and Wolf, 2009). Canaries and many other species of birds, especially granivores, need to modify their diets (Carrillo et al., 2007) or supplement their water requirements in order to maintain body water balance (MacMillen, 1990). Water supplementation may be from dew or residual rainfall, but in arid environments birds often need to drink from ephemeral streams or other water supplies (Skead, 1975). The importance of artificial water sites aimed at supplying water for livestock has been noted for many species (Fisher et al., 1972, Smit, 2013). However, some regions, such as mountain fynbos have low livestock carrying capacity (Meissner et al., 1983), and decreased natural water availability will unlikely be offset by man-made water resources in this biome.

The Cape Floristic Region (fynbos) is one of five Mediterranean-type biomes of the world. All five are considered global conservation priority areas owing to high plant species diversity and density (Myers et al., 2000). Fynbos is home to six endemic passerines and one turnicid. Of these, Cape Sugarbird, Orange-breasted Sunbird, Cape Siskin and Protea Seedeater have all been observed drinking water to some degree (Hockey et al., 2005). However, the reliance on water sources by the fynbos endemic bird species has not been quantified. These bird species generally start panting at lower temperatures compared to non-endemics in the Fynbos and are considered more vulnerable to warming due to climate change (Milne, 2014, Lee and Barnard, 2015). Although the biome was palaeoclimatically cool and moist, it is becoming increasingly warm and dry (Huntley et al., 2013).

In this study in a dry, eastern part of the fynbos biome, we determine how temperature patterns and rainfall events influence the numbers of birds drinking at selected drinking sites. We predict granivores will be the most regular visitors to water sites given reliance on water poor food resources. We also predict that the numbers of birds drinking will increase with increasing mean daily temperature and with increasing time since last significant rainfall event as these correlate with water stress. Finally, we predict that hourly drinking patterns will be correlated with periods of greatest water stress. The results have implications for the management and conservation of wetlands and water sources, as well as endemic birds across the fynbos.

Methods

This project was undertaken in and around the Blue Hill Nature Reserve (BHNR), Western Cape, South Africa. The BHNR is located in the fynbos biome at elevations between 1000 – 1500 masl, but is close to the succulent-karoo biome boundary. It thus experiences an extreme range of temperatures, from below freezing to >35 ^{o}C which allows comparisons of visitation to water points over a range of temperatures.

We monitored five natural water sources from September 2014 to June 2015 using time-lapse photography with Cuddeback Attack cameras. Regularly visited drinking sites were identified during previous field seasons. These included an annual rock-pond, sections of an ephemeral stream, a perennial stream and rocky seep. Cameras were set roughly 1.5 – 3 metres from water sources to capture the area used for drinking and to maximise resolution for bird identification. Cameras took photographs every 15 minutes automatically through the day from sunrise to sunset. We examined 34 367 photographs for the presence of birds in water or at the water edge, and excluded > 5000 photos taken at annual sites during times when no water was available. Identification rate was high: only 3.9% (107 of 2705) of individuals could not be identified to species. Bird behaviour was scored as drinking only (beak near water), bathing (belly or more of bird submersed in water), vigilant (body clear of water, not drinking) or other (preening, foraging, social behaviours).

Water visitation rates as a function of diet, mass and abundance

The total numbers of birds observed in proximity to the water through-out the study were used to create a relative index of water requirements for each species. We did not distinguish between behaviour types here as it is likely that some bathing birds also drank, and both of these behaviour categories were small compared to those scored as vigilant (Table 1). Mean bird mass was obtained from Hockey et al. (2005). We also used this source to categorize this community into preferred dietary guild: insectivore, granivore, nectarivore, frugivore, omnivore or raptor. For analysis we grouped omnivore and raptor due to low numbers in these categories in our final model. We used total capture rates from mist-netting (ringing) exercises at BHNR undertaken during 2014 and 2015 (effort = 70 days) as an index of relative abundance, as trap-rates correlates with abundance for small to medium sized birds at this study site (Lee et al., 2015). We used the MuMIn package (Barton, 2011) in R (R Core Team, 2015) to identify the best model by AIC based on a starting linear model using total visitation for each species as the dependent variable, and mass, diet and relative abundance together with all two-way interactions as independent variables.

The influence of weather on water visitation rates

For the ten species observed most frequently daily water visitation trends were examined in relation to weather data collected by an on-site weather station (Davis Vantage Vue, USA). We divided the total number of birds observed during the day at the drinking sites by the number of photos taken on that day to create an index of daily visitation rate. However, distribution of this index for all species displayed a negative exponential pattern weighted by zero, and so for analysis we simply used daily visitation observed and visitation not observed (visitation) as the dependent variable for regression. We modelled daily visitation rate as a function of mean-daily-temperature, number-of-days-since-last-rainfall and total-wind-run. We initially also considered humidity, but this variable was strongly negatively correlated with temperature ($r_s = -0.63$, $t = -13.3$, $p < 0.001$, $df = 268$) and positively correlated with rainfall ($r_s = 0.34$, $t = 5.9$, $p < 0.001$). Number of days since rain was also positively correlated with temperature due to low rainfall over the hottest months ($r_s = 0.37$, $t = 6.6$, $p < 0.001$), but we include both variables to determine the larger effect and explore interactions. As visitation differed between sites and was temporally autocorrelated for all species, we conduct our modelling using Markov chain Monte Carlo (MCMC) Bayesian methods implemented in the MCMCglmm R package (Hadfield, 2010) using site as a random effect. We explored various priors, but found the best prior for the categorical family modelling was nu and variance = 1 for fixed effects and 1 and 0.002 for the random effect. We used deviation information criteria (DIC) to select between models and examined trace plots for autocorrelation. In all cases we increased default burn-in (30 000) and number of iterations (130 000) as these provided acceptable trace plots based on a thinning value of 50.

Daily temporal visitation patterns

For 12 of the most commonly observed species we calculated the total number of individuals recorded for each hour interval and tested correlations of visitation with mean hourly temperature for the study period using Spearman's ranked correlation tests. We recorded the presence of potential predators and other mammals. However, data were too sparse to conduct meaningful analysis on predator impact on visitation by drinking birds.

Results

Water visitation rates as a function of diet, mass and abundance

Fifty three species were recorded at drinking sites, representing 36% of the estimated 146 species from the study area (Lee et al., 2015) and 91% of the species mist-netted locally for the study period (Table 1). Bird numbers at drinking sites were best explained by diet and abundance, where the only significant predictor in the best model was the interaction between the granivore dietary guild and abundance (Figure 2, Table 2). While Cape Weaver represented the top visitor in terms of individuals recorded, all records bar one were from one drinking site: the perennial stream which was also the site closest to a reed-bed with a breeding colony of this species. By contrast the second most recorded species, Cape Bunting, was observed at all sites. The three most abundant species from mist-netting at the study site were Orange-Breasted Sunbird, Cape Sugarbird and Malachite Sunbird, which were all observed at water, but visitation rates were low given abundance for these nectarivores. Likewise, the most common insectivores, Familiar Chat and Karoo Prinia, were rarely observed as was the omnivorous Cape White-eye. The ratio of total visitation/abundance was highest for Cape Canary, Cape Wagtail, Common Waxbill and Cape Turtle Dove. The most common insectivore observed was the Cape Wagtail, a species known to forage in association with water courses. The only raptor observed was a Jackal Buzzard on one occasion.

A surprising result was the consistently small group sizes recorded at the drinking sites with none of the common species recorded in mean group sizes greater than two (Table 1). The largest flock observed at a drinking site was for Cape Siskin, with 25 birds in the photo frame. While total flock size may be under-represented in the photo frame, the mean group sizes utilizing water at a given instant presented here are certainly representative of drinking habits for these species at this location. There may be temporal partitioning of the water resources over the drinking sessions for those species more commonly considered social or flocking species; including Cape Weaver, Cape Siskin, Common Waxbill and Cape Canary; but the photo intervals used in this study could not capture this aspect of the birds' behaviour.

The influence of weather on water visitation rates

Mean daily temperature was either the only or the most significant predictor variable of weather variables considered for the top 10 most frequently observed species (Table 3), with increasing visitation with increasing temperature in all cases. Time since rain was a significant positive predictor of visitation for six of these species, with the interaction between mean daily temperature and time since rain a significant predictor for a further six species. This interaction was consistently negative and interpreted as increased visitation at lower temperatures with increasing time since rain. Wind was a non-significant predictor in the best model for only one species, Cape Bunting, with all other models performing better excluding this variable.

Daily temporal patterns of drinking

Granivores generally drank throughout the day, exceptions being Protea Seedeater and Yellow Canary which showed peak numbers prior to midday (Figure 3). Orange-breasted Sunbird also visited relatively early in the morning, surprisingly given temperatures peaked later and that temperature is a predictor of drinking for this species. Cape Bulbul and Cape Turtle Dove showed a bimodal visitation pattern with a lull during the middle of the day. Only four of the top 12 species showed significant positive correlations between visitation and the mean of hourly temperature (Brimstone Canary, Cape Weaver, Common Waxbill, Yellow Bishop; $r_s > 0.61$, $p < 0.03$), suggesting other factors influence daily patterns of visitation for the majority of species e.g. predator avoidance strategies. However, records of predators were very low: the known bird predator, Cape Grey Mongoose, was observed on 10 occasions and Honey Badger once. Rock Hyrax, by comparison, were observed on 9 occasions. Jackal Buzzard was the only raptor observed. No other predators (felines, snakes) were observed.

Discussion

Which birds are visiting drinking sites?

Drinking was commonly observed among the set of common species at this fynbos site, but drinking rates were low. Total visitation among this community of bird species was best described by abundance within the set of seed-eating species. This community of birds thus conforms to global trends of water reliance by birds, which are normally dominated by granivores (Okahisa et al., 2015).

By contrast the most common species at this site as determined by mist-netting were the nectarivores. Visitation to water for the purpose of drinking by any nectarivores is unexpected given the high liquid content of their diets (e.g. Mbatha et al., 2002). Insectivores, despite representing a large proportion of the bird community, were rarely observed at drinking sites. It is generally expected that insectivores obtain sufficient moisture through their arthropod rich diet (Bartholomew and Cade, 1963). Generally, visitation across this fynbos bird community could be described as low compared to drinking described from water points in desert environments (Abdu, 2015), although the breadth of species observed was higher than we expected: all the fynbos endemic bird species with the exception of Victorin's Warbler were observed either drinking or bathing.

There is remarkably little literature on the reasons for visitation of terrestrial bird species to water sources. While drinking is well documented for some arid zone regions (Fisher et al., 1972, Smyth and Coulombe, 1971, Bartholomew and Cade, 1963), most frequently observed species in this study both drank and bathed. Bathing sites are used by a variety of bird species for feather maintenance and pest control (Slessers, 1970, Verbeek, 1991). Both drinking and bathing will allow cooling and hence daily visitation was best explained by temperature. It is likely that bathing is used as an additional body temperature regulation technique, although we cannot rule out that pest or parasite activity is also correlated with temperature.

Future studies should focus on reasons for differences between site selection, as visitation rates were dramatically different for the five sites considered here. Low sample size precluded analysis of site characteristics favoured by the fynbos bird species, but the perennial stream had highest visitation rates, followed by the isolated ephemeral site and then other ephemeral stream sites. If access to reliable water sources is required for the persistence of local bird populations for some species, then drying trends across the fynbos are cause for concern.

The influence of weather on water visitation rates

Temperature was the most important variable explaining daily visitation of birds to water sites at this fynbos site, with visitation increasing with increasing mean daily temperature. Laboratory studies have shown a positive correlation between increasing temperature and an increase in water consumption for a variety of passerines (Bartholomew and Dawson, 1953, Bartholomew and Cade, 1956, Williams and Koenig, 1980). Field observation studies also found a nonsignificant positive correlation between drinking visits and maximum temperature in Monterey County, California (Williams and Koenig, 1980). In the later study, individual birds were observed to move 0.8 – 2.5km in order to access spring water. Some species have been shown to use behavioural strategies (e.g. use of rock shade, switching diet to green vegetation or insects) while others are physiologically well adapted to dealing with water stress by modifying the water content in their excreta (Smyth and Bartholomew, 1966).

The correlation between time-since-rain and temperature may mask the influence that time-since-rain has on visitation to water sources. However, for those species where this interaction was identified as significant, visitation increased with time-since-rain especially for lower temperatures. We do not expect that water requirements are reduced with rainfall events, but rather that alternative and/or more convenient water sources become available in the form of ephemeral puddles for example. Evaporative heat dissipation is affected by the humidity of the atmosphere (Lasiewski et al., 1966): high humidity reduces the efficiency of heat lost through evaporation; but we did not observe increased visitation with increased humidity. Lower humidity at increasing temperatures during this study may have facilitated evaporative-water-loss as a cooling mechanism at this study site.

Daily temporal patterns of drinking

While daily visitation was best explained by mean daily temperature across the study period, this pattern was not as clearly seen at the daily level, where a significant positive correlation between daily temperature by hour and visitation was seen for four of twelve species. Some studies have suggested that daily temporal patterns of visitation are determined by predation risk as the risk of predation is high at isolated free-standing water surfaces because birds can be easily spotted by their predators (Cade, 1965). Falcons and goshawks were frequently observed hunting at artificial water points, mainly targeting doves in the Namib Desert (Cade 1965). Aside from aerial predators, ground predators such as mongoose and snakes put birds drinking at risk (Lazarus and Symonds, 1992). Molokwu et al. (2010) suggest that the risk of predation had a stronger influence on foraging bird behaviours than high temperatures within a west African savannah; and predation risk has been attributed to highly synchronised drinking patters of sandgrouse (Berry et al., 2001). That pattern was little supported at this fynbos site using our study technique, where predator presence was low but where drinking was observed throughout the day for most granivores, suggesting low predation pressure. For Orange-breasted Sunbird and Protea Seedeater, with pre-midday drinking peaks and high levels of bathing these patterns match those observed elsewhere associated with feather maintenance and preening (Murphy et al., 2011).

Drinking in large groups is of advantage as individual vigilance levels can be decreased (Roberts, 1996), yet mean group size for all species was surprisingly low albeit with high levels of individual vigilance observed overall. It is likely that at this site that visitation for most the most frequent species are based on a water-needs basis with greater visitation during periods of greatest water stress, rather than being predator-avoidance mediated. These patterns may be confounded on an intra-day level where possible other heat avoidance strategies are employed at certain times of the day e.g. shade seeking (du Plessis et al., 2012).

Conservation implications for fynbos birds

The impact of extreme weather events on bird populations is of growing concern to conservation biologists. Heat waves have been attributed to mortalities for multiple bird species in different environments (Saunders et al., 2011, McKechnie and Wolf, 2009). Extreme heat waves might disrupt the apparent temporal partitioning of access to the resources, as exhibited by granivores we observed; leading to higher flocking and reduced access to water for individual birds. Furthermore extreme heat events may lead to behaviour changes including retiring to shaded areas, in turn reducing the ability to forage and drink, with knock on physiological consequences (Saunders et al., 2011).

Climate change models suggest drying of the fynbos (Klausmeyer and Shaw, 2009), and whilst bird populations can recover from short-term or single drought events (George, Fowler et al. 1992), longer periods or sequential drought events may lead to long-term reductions in productivity and bird population declines of water dependent species. The distribution of some bird species may also be limited by access to surface water (Williams, Koenig 1980).

There are two fynbos endemic granivores: Cape Siskin and Protea Seedeater. While these did not drink more than expected by our model considering diet and abundance, these species are still habitat restricted and are thus especially vulnerable to changes in water availability under drier climate scenarios. While we were not able to preclude that the endemic nectarivores Orange-breasted Sunbird and Cape Sugarbird drank water, their behaviour seemed to be dominated by a preference for bathing. Given the restricted range of all these species coupled with decreasing winter rainfall, it is foreseeable that the extra burden placed by water stress will be detrimental to populations of these birds, especially the granivorous species.

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Table 1: A table of the species recorded at the drinking sites at Blue Hill Nature Reserve ordered by most frequently recorded. Species endemic to the fynbos biome are indicated with *. Visitation is the total number of birds recorded from all photos during the study. Diet represents major dietary guild: gran – granivore, insec – insectivore, nect – nectarivore, frug – frugivore and omni – omnivore. Trap rate are the total number of birds captured during 2014/2015 at the study site. Main behaviour categories are: drinking, bathing, vigilant and other. Where drinking totals are higher than bathing totals, these values are highlighted in **bold.** Grp size: mean group size ± standard deviation of numbers of birds per photo where the species was present.

Name	**Diet**	**Visitation**	*Trap rate*	Drinking	Bathing	Vigilant	Other	Grp size
Cape Weaver, Ploceus capensis (Linnaeus, 1766)	gran	**351**	*25*	24	162	147	18	1.4 ± 0.9
Cape Bunting, Emberiza capensis (Linnaeus, 1766)	gran	**313**	*26*	**48**	14	234	17	1.1 ± 0.3
Yellow Bishop, Euplectes capensis (Linnaeus, 1766)	gran	**300**	*48*	18	89	180	13	1.2 ± 0.6
Cape Canary, Serinus canicollis (Swainson, 1838)	gran	**212**	*5*	**37**	17	143	15	1.3 ± 0.9
Common Waxbill, Estrilda astrild (Linnaeus, 1758)	gran	**181**	*5*	31	40	74	36	1.9 ± 1.9
Protea Seedeater*, Serinus leucopterus (Sharpe, 1871)	gran	**154**	*11*	14	30	103	7	1.1 ± 0.4
Cape Siskin*, Serinus totta (Sparrman, 1786)	gran	**136**	*15*	20	21	85	10	1.5 ± 2.6
Cape Turtle Dove, Streptopelia capicola (Sundevall, 1857)	gran	**103**	*3*	**10**	6	71	16	1.1 ± 0.3
Yellow Canary, Serinus flaviventris (Swainson, 1828)	gran	**93**	*13*	10	11	70	2	1.2 ± 0.4
Orange-breasted Sunbird*, Nectarinia violacea (Linnaeus, 1766)	nect	**88**	*118*	5	20	51	12	1.2 ± 0.6
Cape Wagtail, Motacilla capensis (Linnaeus, 1766)	insec	**81**	*2*	1	4	44	32	1.1 ± 0.4
Brimstone Canary, Serinus sulphuratus (Linnaeus, 1766)	gran	**60**	*7*	**12**	4	42	2	1.1 ± 0.3
Cape Bulbul, Pycnonotus capensis (Linnaeus, 1766)	frug	**57**	*35*	4	10	40	3	1.2 ± 0.4
Cape Robin-Chat, Cossypha caffra (Linnaeus, 1771)	insec	**49**	*38*	5	7	34	3	1 ± 0.1
Cape Spurfowl, Pternistis capensis (Gmelin, 1789)	gran	**41**	*0*	**16**	0	10	15	1.3 ± 0.5

Red-winged Starling, Onychognathus morio (Linnaeus, 1766)	frug	**40**	*7*	4	12	22	2	1.4 ± 0.8
Southern Double-collared Sunbird, Nectarinia chalybea (Linnaeus, 1766)	nect	**38**	*86*	4	11	19	4	1.1 ± 0.2
Red-necked Spurfowl, Pternistis afer (Müller, 1776)	gran	**33**	*1*	**10**	0	8	15	1.4 ± 0.7
Common Starling, Sturnus vulgaris (Linnaeus, 1758)	omni	**31**	*1*	1	14	16	0	1.6 ± 0.9
Bokmakierie, Telophorus zeylonus (Linnaeus, 1766)	insec	**22**	*7*	1	8	10	3	1 ± 0
Olive Thrush, Turdus olivaceus (Linnaeus, 1766)	insec	**21**	*4*	**4**	3	12	2	1 ± 0
Malachite Sunbird, Nectarinia famosa (Linnaeus, 1766)	nect	**19**	*95*	0	11	6	2	1.1 ± 0.3
Common Fiscal, Lanius collaris (Linnaeus, 1766)	insec	**18**	*17*	0	9	9	0	1.1 ± 0.2
Speckled Mousebird, Colius striatus (Gmelin, 1789)	frug	**18**	*41*	6	6	6	0	1.6 ± 0.9
Streaky-headed Seedeater, Serinus gularis (Smith, 1836)	gran	**18**	*4*	1	5	12	0	1.3 ± 0.5
Cape Sugarbird*, Promerops cafer (Linnaeus, 1758)	nect	**16**	*146*	0	4	7	5	1.1 ± 0.5
Cinnamon-breasted Bunting, Emberiza tahapisi (Smith, 1836)	gran	**16**	*1*	**5**	0	10	1	1.1 ± 0.2
Speckled Pigeon, Columba guinea (Linnaeus, 1758)	gran	**13**	*1*	**3**	1	9	0	1.1 ± 0.3
Fiscal Flycatcher, Sigelus silens (Shaw, 1809)	insec	**11**	*5*	0	3	7	1	1.4 ± 0.7
Black-headed Heron, Ardea melanocephala (Vigors & Children, 1826)	omni	**6**		0	0	3	3	1 ± 0
Fork-tailed Drongo, Dicrurus adsimilis (Bechstein, 1794)	insec	**6**	*1*	0	1	2	3	1 ± 0
Karoo Prinia, Prinia maculosa (Boddaert, 1783)	insec	**6**	*26*	0	2	2	2	1 ± 0
Cape White-eye, Zosterops virens (Sundevall, 1850)	omni	**5**	*87*	**1**	0	4	0	1.3 ± 0.4
Long-billed Pipit, Anthus similis (Jerdon, 1840)	insec	**5**	*3*	0	0	4	1	1 ± 0
Familiar Chat, Cercomela familiaris (Wilkes, 1817)	insec	**4**	*7*	0	0	4	0	1 ± 0

Neddicky, Cisticola fulvicapilla (Vieillot, 1817)	insec	**4**	*7*	0	3	1	0	1 ± 0
African Stonechat, Saxicola torquatus (Linnaeus, 1766)	insec	**3**	*5*	0	1	2	0	1 ± 0
Cape Grassbird, Sphenoeacus afer (Gmelin, 1789)	insec	**3**	*5*	0	2	1	0	1 ± 0
Grey-winged Francolin, Scleroptila africanus (Stephens, 1819)	gran	**3**	*0*	**1**	0	0	2	3 ± 0
Ground Woodpecker, Geocolaptes olivaceus (Gmelin, 1788)	insec	**3**	*0*	1	1	1	0	1.5 ± 0.5
Cape Rock-Thrush, Monticola rupestris (Vieillot, 1818)	insec	**2**	*10*	0	1	1	0	1 ± 0
Cape Rock-jumper*, Chaetops frenatus (Temminck, 1826)	insec	**2**	*15*	0	1	1	0	2 ± 0
Diederik Cuckoo, Chrysococcyx caprius (Boddaert, 1783)	omni	**2**	*0*	0	1	1	0	1 ± 0
Red-faced Mousebird, Urocolius indicus (Latham, 1790)	frug	**2**	*0*	**2**	0	0	0	2 ± 0
Black-headed Canary, Serinus alario (Linnaeus, 1758)	gran	**1**	*0*	0	0	1	0	1 ± 0
Cape Batis, Batis capensis (Linnaeus, 1766)	insec	**1**	*0*	0	0	0	1	1 ± 0
Greater Striped-Swallow, Hirundo cucullata (Boddaert, 1783)	insec	**1**	*1*	0	0	0	1	1 ± 0
Hadeda Ibis, Bostrychia hagedash (Latham, 1790)	insec	**1**		0	0	1	0	1 ± 0
Jackal Buzzard, Buteo rufofuscus (Forster, 1798)	raptor	**1**	*0*	0	1	0	0	1 ± 0
Pin-tailed Whydah, Vidua macroura (Pallas, 1764)	gran	**1**	*0*	0	0	1	0	1 ± 0
Rock Martin, Hirundo fuligula (Lichtenstein, 1842)	insec	**1**	*1*	0	0	1	0	1 ± 0
Southern Boubou, Laniarius ferrugineus (Gmelin, 1788)	insec	**1**	*1*	0	0	1	0	1 ± 0
Southern Masked-Weaver, Ploceus velatus (Vieillot, 1819)	gran	**1**	*1*	0	0	1	0	1 ± 0

Table 2: Best model results of total visitation as a function of dietary guild, mass and relative abundance from trapping rates (abundance) at drinking sites on Blue Hill Nature Reserve. Residual standard error: 46 on 42 degrees of freedom; adjusted R-squared: 0.69. Significant predictor results ($p < 0.001$) are highlighted in bold.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	19.399	35.749	0.543	0.590
granivore	20.685	38.058	0.544	0.590
insectivore	-12.216	37.964	-0.322	0.749
nectarivore	26.956	118.577	0.227	0.821
other	-8.118	44.658	-0.182	0.857
abundance	0.475	1.315	0.361	0.720
granivore:abundance	7.166	1.579	4.539	**0.000**
insectivore:abundance	0.137	1.696	0.081	0.936
nectarivore:abundance	-0.530	1.649	-0.321	0.750
other:abundance	-0.544	1.452	-0.375	0.710

Table 3: Model summary table for best models for visitation of bird species at drinking sites with weather variables as explanatory variables. Post.mean = posterior mean with lower and upper confidence intervals (u & l 95% CI); eff.samp = effective sample size; pMCMC = Monte Carlo Markov Chain probability; DIC = Deviation Information Criteria; dDIC = difference between best model and starting model including interactions. Significant predictor variables (pMCMC < 0.05) are highlighted in **bold.** Temp = mean daily temperature; T since rain = time in days since last rainfall event.

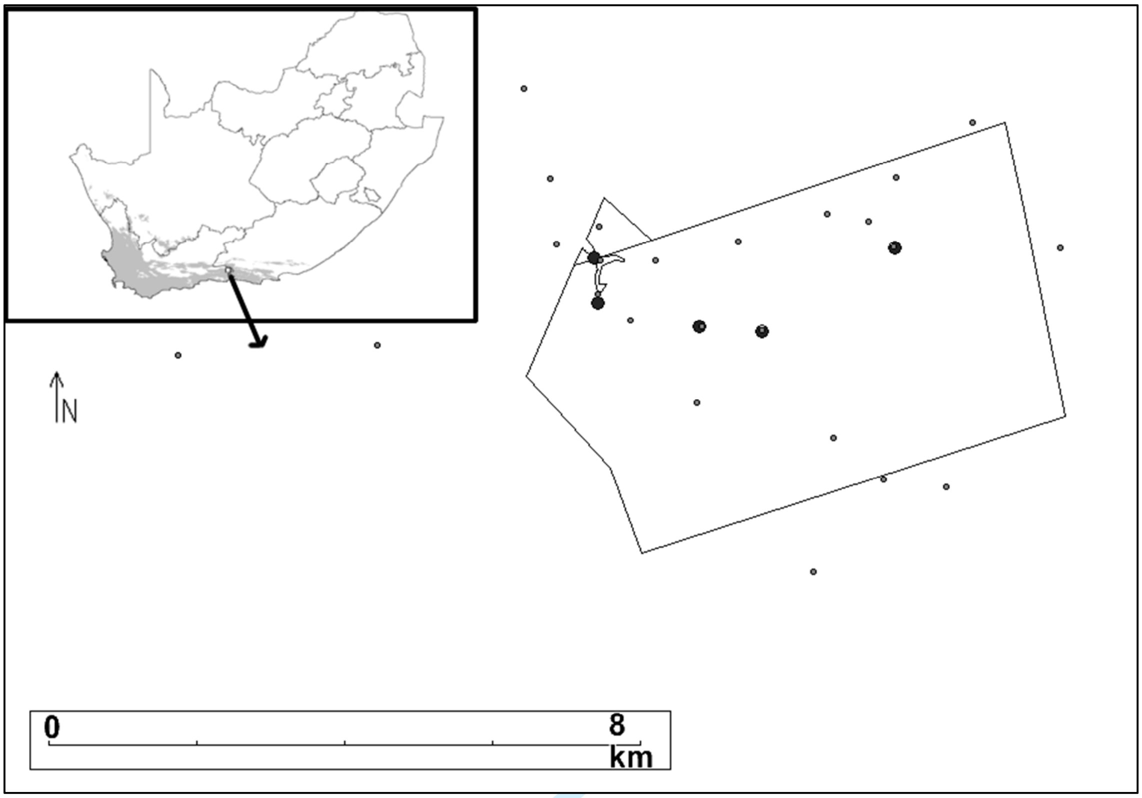
Species	Fixed Effects	post.mean	l- 95% CI	u-95% CI	eff.samp	pMCMC
Cape Weaver	Intercept	-21.7	-46	-1.6	78.2	0.039
DIC: 218	**Temp**	0.28	0.14	0.42	439	**<0.001**
dDIC: 0	T since rain	-0.1	-0.7	0.44	296	0.78
	Wind	-0.01	-0.02	0.01	539	0.31
	Temp:time	0.01	-0.02	0.05	248	0.44
Cape Bunting	Intercept	-8.5	-12.1	-5.7	798	0.002
DIC: 319	**Temp**	0.28	0.19	0.37	465	**<0.001**
dDIC: 1.82	Wind	0.01	-0.003	0.02	730	0.15
Yellow Bishop	Intercept	-13.8	-21	-8	428	0.001
DIC: 231.7	**Temp**	0.53	0.37	0.69	205.8	**<0.001**
dDIC: 0.5	**T since rain**	0.68	0.18	1.15	378	**0.002**
	Temp:time	-0.04	-0.06	-0.01	430	**0.002**
Cape Canary	Intercept	-6.7	-8.8	-4.3	836	0.001
DIC: 380.2	**Temp**	0.24	0.14	0.34	589	**<0.001**
dDIC: 1.5	T since rain	0.31	-0.06	0.66	887	0.1
	Temp:time	-0.02	-0.03	0.003	847	**0.08**
Common Waxbill	Intercept	-9.8	-13.2	-6.2	464	<0.001
DIC: 283.7	**Temp**	0.37	0.25	0.51	437	**<0.001**
dDIC: 0.88	**T since rain**	0.5	0.04	0.9	598	**0.02**
	Temp:time	-0.03	-0.05	-0.01	566	**0.02**
Protea Seedeater	Intercept	-8.5	-14.7	-2.7	262	0.01
DIC: 306.8	**Temp**	0.21	0.11	0.32	587	**<0.001**
dDIC: 1.3	**T since rain**	0.34	0.02	0.67	979	**0.04**
	Temp:time	-0.01	-0.03	0.004	919	0.14
Cape Siskin	Intercept	-11.8	-20.8	-4	120	0.01
DIC: 217.6	**Temp**	0.28	0.13	0.42	338	**<0.001**
dDIC: 1.87	**T since rain**	0.74	0.34	1.19	576	**0.001**
	Temp:time	-0.03	-0.06	-0.01	513	**0.003**
Cape Turtle Dove	Intercept	-6.6	-10.3	-3.07	1103	0.007
DIC: 353	**Temp**	0.14	0.04	0.22	859	**0.001**
dDIC: 0	T since rain	0.01	-0.34	0.34	977	0.93
	Wind	0.003	-0.008	0.016	814	0.6

	Temp:time	0.004	-0.013	0.021	1041	0.59
Yellow Canary	Intercept	-13.8	-20.6	-7.8	284	0.002
DIC: 155	**Temp**	0.36	0.17	0.53	179	**<0.001**
dDIC: 0	**T since rain**	0.66	0.15	1.21	300	**0.014**
	Wind	0.02	-0.001	0.03	418	0.087
	Temp:time	-0.3	-0.06	-0.002	299	**0.032**
Orange-breasted Sunbird	Intercept	-17.2	-26.2	-9.9	49	**0.003**
DIC: 135	**Temp**	0.6	0.34	0.86	71	**<0.001**
dDIC: 0.5	**T since rain**	1.23	0.61	1.97	105	**<0.001**
	Temp:time	-0.06	-0.1	-0.03	118	**<0.001**

Figure 1: Map of study site including drinking and mist-netting sites. Inset shows South Africa with provincial boundaries and the Cape Floristic Region (fynbos) in grey. Mist-netting locations are indicated by small, grey dots, with camera locations as larger, black circles. The rectangular outline indicates the boundaries of the Blue Hill Nature Reserve.

Figure 2: Visitation of birds at BHNR to drinking sites plotted against relative abundance (trapping rates at mist nets). Dietary guilds are indicated as colours. Labelled species are fynbos endemic bird species. A linear regression line is plotted for granivores, with confidence bands representing 95% confidence interval.

Figure 3: Diurnal drinking patterns for 12 of the most commonly observed bird species at BHNR. Error bars represent standard error.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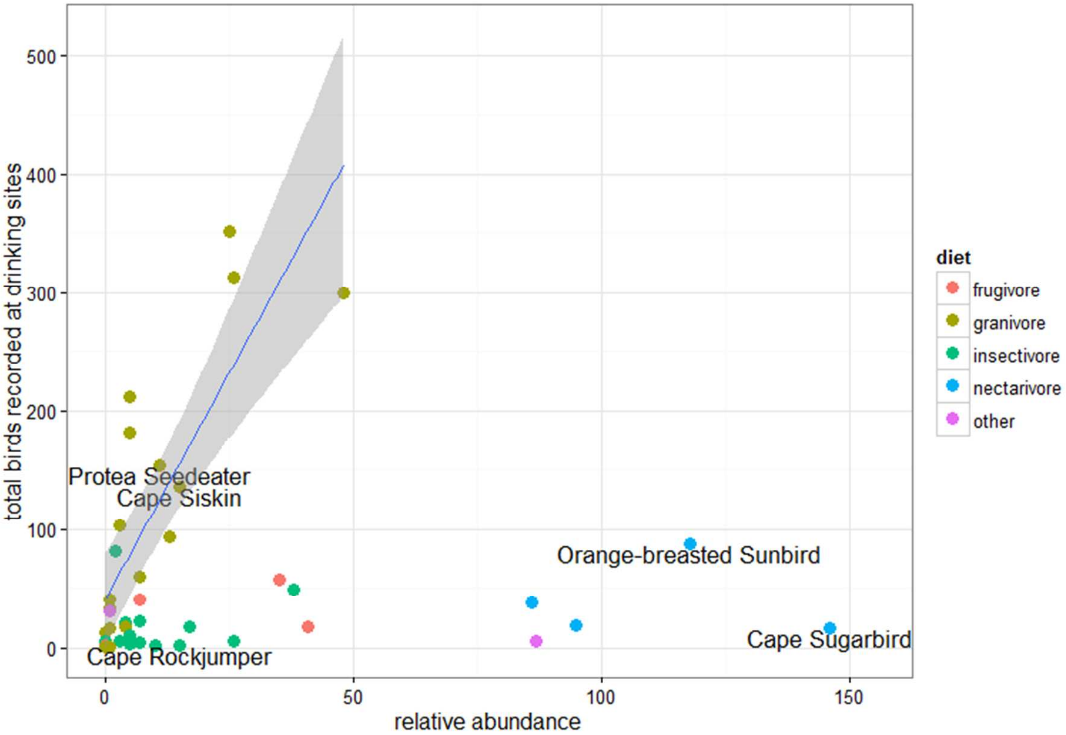
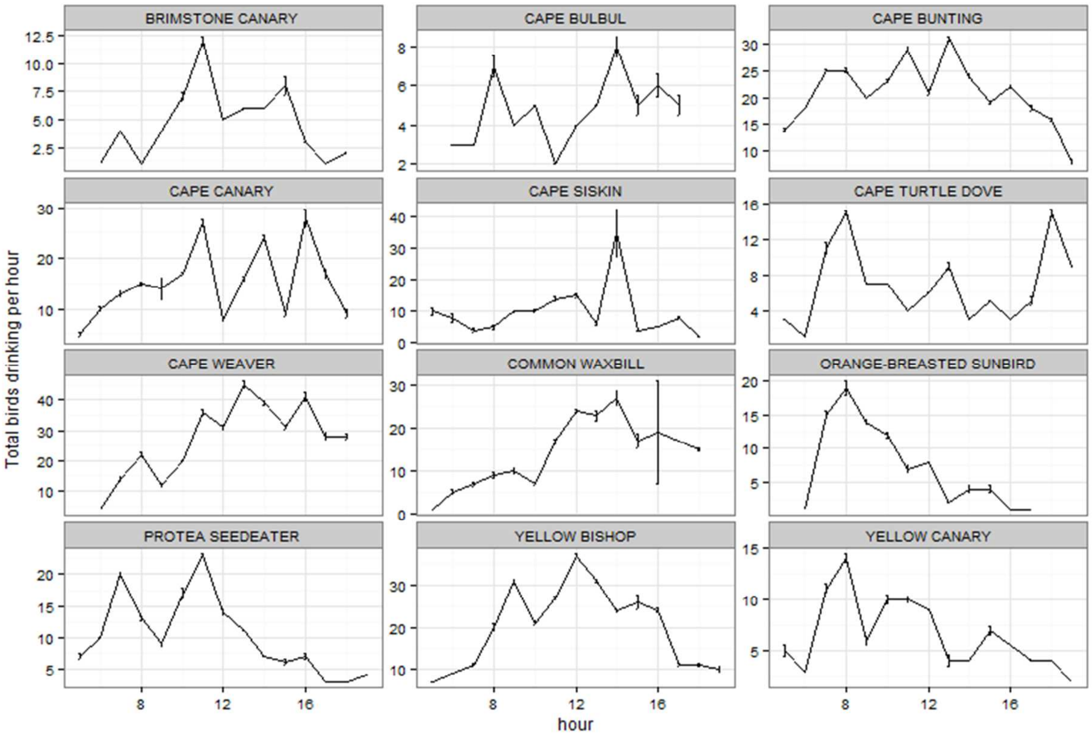

total birds recorded at drinking sites
0
100
200
300
400
500
relative abundance
0
50
100
150
Protea Seedeater
Cape Siskin
Orange-breasted Sunbird
Cape Sugarbird
Cape Rockjumper
diet
frugivore
granivore
insectivore
nectarivore
other


BRIMSTONE CANARY
CAPE BULBUL
CAPE BUNTING
CAPE CANARY
CAPE SISKIN
CAPE TURTLE DOVE
CAPE WEAVER
COMMON WAXBILL
ORANGE-BREASTED SUNBIRD
PROTEA SEEDEATER
YELLOW BISHOP
YELLOW CANARY
Total birds drinking per hour
hour
8
12
16