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Original Investigation

Large mammals in Ruaha National Park, Tanzania, dig for water when water stops flowing and water bacterial load increases

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ABSTRACT

As water is essential for life, animals have adaptations that increase their ability to survive during periods of water shortage. Accessing water by digging is one behavioural adaptation to water shortage used by some African mammals. Digging might also provide access to higher quality water below ground when surface water quality is poor. We investigated the digging of waterholes by wildlife in the Ruaha National Park (NP), in central Tanzania, during three dry seasons (June to November from 2011 to 2013). We monitored surface water availability and water quality at 10 sites along the Great Ruaha River (GRR) and eight non-GRR sites. We used camera-traps and direct observations to determine when and where digging to access water occurred. Elephant (*Loxodonta africana*), plains zebra (*Equus quagga*), warthog (*Phacochoerus africanus*) and yellow baboon (*Papio cynocephalus*) dug waterholes and a further four species drunk from these holes. Waterholes were dug later in the dry season along the GRR (October) than at other sites (July). The likelihood of digging and drinking from waterholes was lower along the GRR than at non-GRR sites and did not depend on the absence of surface water but increased when surface water stopped flowing. Digging of waterholes was also significantly more likely when the bacterial load in available surface water increased but was independent of salinity levels. *Escherichia coli* load, indicative of faecal contamination, significantly increased with total aerobic bacterial load. Our results suggest that digging is an adaptation to avoid the ingestion of poor quality surface water highly contaminated with faeces, and thereby possibly also potentially pathogenic microbes, in addition to providing access to water when surface water is absent. Our findings also highlight (1) the essential role of the GRR as the key water source for wildlife in the Ruaha NP during the dry season, and (2) that maintenance of water flow throughout the dry season is essential to prevent deterioration of water quality in the GRR.

Introduction

Water is essential for life. Where water availability is seasonally limited, animals have evolved physiological and behavioural adaptations to survive periods of water shortage (e.g. Tieleman et al., 2003; Willmer et al., 2005; Withers and Cooper, 2014). In semi-arid areas of Africa, rainfall during the wet season provides wildlife with numerous water sources in terms of ephemeral rivers and water pools. As a result of low rainfall during the dry season, ephemeral water sources dry out and water flow in permanent rivers declines. These changes in the distribution and abundance of water can have a profound impact on mammalian species that need to regularly drink water to survive (Redfern et al., 2003; Western, 1975).

As the availability of surface water declines, wildlife usage of the remaining sources of surface water increases, as does faecal contamination, bacterial load and eutrophication of water sources (Ramey et al., 2013; Wanke and Wanke, 2007), particularly where there is little or no water flow. The coliform bacterium *Escherichia coli* is an indicator of faecal contamination of water (Hellberg and Chu, 2015) and *E. coli* is transmitted when water contaminated with infected faeces is ingested (Johnson et al., 2004). The aggregation of animals at water sources can result in increased transmission of infectious and water borne diseases (Bengis et al., 2002; Keet et al., 1996; Lindeque and Turnbull, 1994) and, in the case of virulent diseases, can lead to significant declines in wildlife populations (East et al., 2010; Lindeque and Turnbull, 1994). Furthermore, water evaporation during periods of dry weather would result in rising water salinity which could reduce the value of water for drinking.

It is well documented that the African savannah elephant (*Loxodonta africana*) can access water below the surface of the ground by digging holes, sometimes to a depth of more than 1 m (Dudley et al., 2001; Poché, 1974; Ramey et al., 2013). Other

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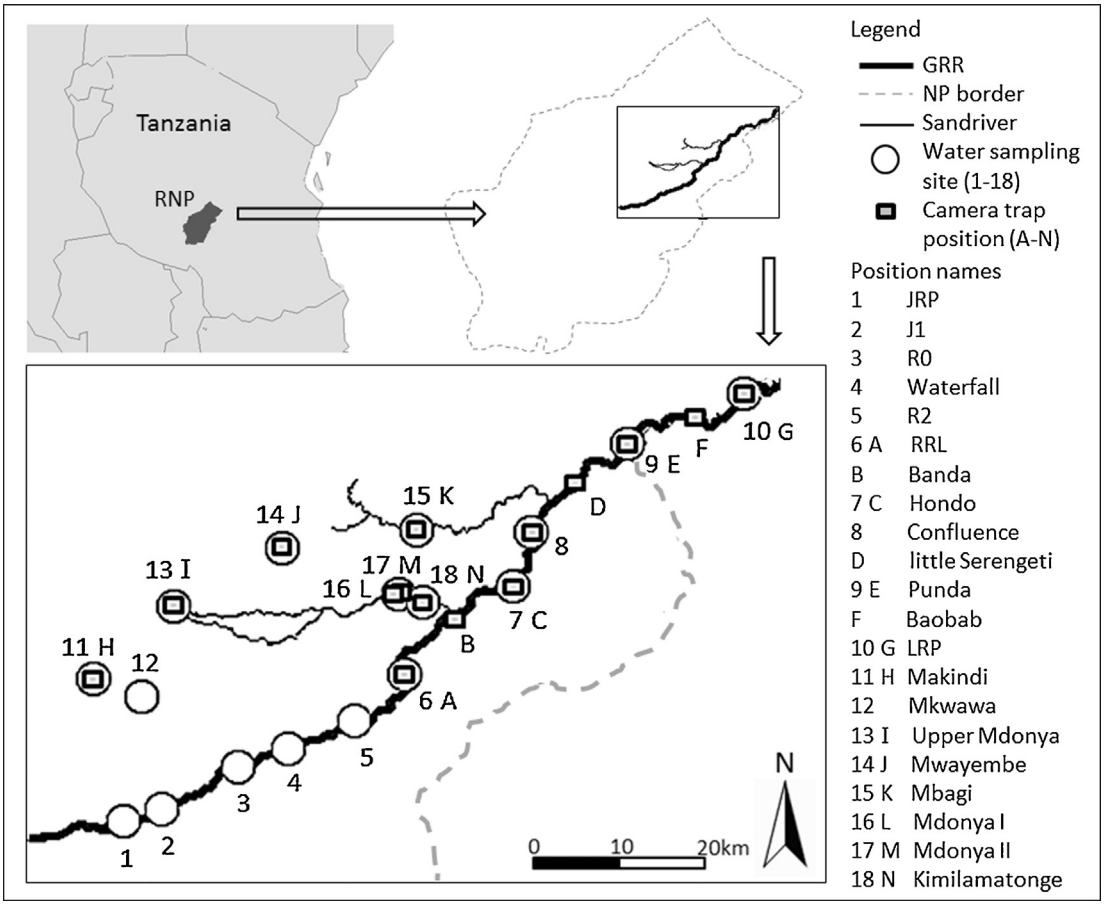

Fig. 1. Ruaha National Park (RNP) in central Tanzania. Sites monitored for the presence or absence of water were located along the Great Ruaha River (GRR, sites 1–10, B, D, F) and non-GRR sites which included pools in dry sand rivers (sites 13, 15–18) and isolated springs (sites 11, 12, 14). Open circles: sites where water samples were taken along the Great Ruaha River (sampling sites 1–10) and at non-GRR sites (sampling sites 11–18). Square boxes: positions where camera traps where set up along the Great Ruaha River (sites A–G) and non-GRR sites (sites H–N).

African mammals that dig to access water include chimpanzee (*Pan troglodytes*) (McGrew et al., 2007), chacma baboon (*Papio ursinus*), gemsbok (*Oryx gazella*) and plains zebra (*Equus quagga*) (Epaphras et al., 2008; Hamilton, 1985). Surprisingly there has been little research on this behaviour. Currently it is unclear which factors determine where, when and why African mammals dig to access water. We investigated this behaviour in an African habitat during the dry season, the annual six-month period when little or no precipitation occurred. We reasoned that animals should not spend energy and time digging for water when surface water of a reasonable quality was available. We predicted that digging should occur not only when the availability of surface water was absent or limited but also when the quality of surface water was poor in terms of increased salinity and bacterial contamination. We tested these predictions by studying digging behaviour and water quality in the Ruaha National Park (NP) in central Tanzania, at sites along the Great Ruaha River (GRR), which is the main source of surface water in the park, and at sites with surface water in other locations in the park (Fig. 1).

Methods

Study site

The study was conducted in Ruaha National Park (Ruaha NP) in central Tanzania which forms the core of the Greater Ruaha ecosystem, one of the largest wilderness areas (encompassing approximately 110,000 km^2) in Africa. The study area was a 130 km stretch of the Great Ruaha River (GRR) and an area 25 km north-west of GRR (Fig. 1). Ruaha NP encompasses a transitional vegetation zone between the East African *Acacia-Commiphora* zone and the Southern African *Brachystegia* and *Miombo* zone (Barnes, 1983; Bjørnstad, 1976) and harbours a high biodiversity of larger mammals (Barnes, 1983). Mean annual rainfall is approximately 580 mm, mostly falling during the wet season from November to May (Barnes, 1983). The dry season typically spans June to November, when the study was conducted during 2011, 2012 and 2013.

Sources of surface water

The GRR (Fig. 1) is the main permanent water source for wildlife in the Ruaha NP. Large-scale human utilisation of water upstream of the Ruaha NP, particularly for agricultural irrigation since 1993, has significantly reduced its flow during the dry season (Mtahiko et al., 2006). During the dry seasons of our study, large sections of the GRR dried up, leaving discrete water pools separated by expanses of dry river bed. Tributaries of the GRR that contained flowing water during the wet season dried up at the beginning of the dry season and turned into dry sand-rivers containing occasional discrete water pools. There were other isolated sources of surface water, some of which (as detailed in the results) persisted throughout the dry season. In addition, numerous transient rain-fed water pools formed away from rivers during wet seasons and dried up during dry seasons. We assessed the persistence of water in the larger (minimum diameter of 5 m) rain fed pools, but