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Assessment of quality of water provided for wildlife in the Central Kalahari Game Reserve, Botswana

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A R T I C L E I N F O

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A B S T R A C T

Arid and semi-arid environments have low and unpredictable rainfall patterns resulting in limited availability of surface water for wildlife. In the Central Kalahari Game Reserve (CKGR) wildlife populations have lost access to natural surface water through cordon fences, livestock and human encroachment along the access routes. Artificial waterholes have been developed in the reserve to compensate for this loss. However, there have not been any assessments of the quality of water provided for wildlife and how that may be contributing to populations declines in the CKGR. We assessed water quality from 12 artificial waterholes against both Botswana and international livestock standards for drinking. Overall the quality of water provided is poor and poses a health risk to both animals and humans. Eight out of twelve boreholes tested exceeded the maximum acceptable Total Dissolved Solids (TDS) limits while three and four boreholes have toxic levels of lead and arsenic, respectively. Thus, pumping ground water could have more negative than positive impacts on wildlife thus defeating the intended management purpose. Failure to provide water of acceptable quality is a major concern for wildlife management in the CKGR and it may underlie some wildlife declines in the reserve. These findings confirm that restriction of populations from natural water sources create complex management challenges, especially where safe and sustainable alternative sources are scarce. Restriction of access of the population to natural water sources by fences and provision of poor quality water could compromise the overall fitness of wildlife populations and contribute to their decline.

1. Introduction

Arid and semi-arid environments have low rainfall and prolonged hot and dry periods. Wildlife populations in these environments are limited by access to water within commutable distance from food resources (Rosenstock et al., 1999). Similarly, natural surface water in the Central Kalahari Game Reserve (CKGR) is very limited and only available in pans for a short time with no natural surface water available in the reserve for most of the dry season, as is typical of the Kalahari ecosystem. Habitat loss and fragmentation have deprived wildlife populations' access to key water resources outside the reserve, which has resulted in drastic declines of herbivore populations, especially during drought periods (Williamson et al., 1988). Wildebeest in the Kalahari depended on the Boteti river system during drought, but this resource was cut from the population by veterinary cordon fences since the late 70s (Owens and Owens, 1984). Artificial waterholes were developed since 1984 (Bonifica, 1992) in the reserve to increase the viability of wildlife populations by compensating for lost access to permanent water sources outside the reserve.

Worldwide, development of artificial water for wildlife has become a major management intervention to address effects of habitat loss, especially in arid and semi-arid environments (Dolan, 2006). However, this has not been without controversy and criticism, particularly on its effects on distribution and movement of wildlife (Smit et al., 2007), decline of some rare species (Harrington et al., 1999), as well as carnivore hunting strategies (Harrington et al., 1999; Rosenstock et al., 2004). Nonetheless, it possible that some ecosystems could collapse without artificial provision of water, especially where natural water has been lost or access prevented by human induced development (Williamson et al., 1988).

Both availability and quality of water have effects on population dynamics. Poor water quality has been observed to reduce reproductive rates and survival rates of animal populations, resulting in potential population declines (Pokras and Kneeland, 2009). Surprisingly, specific research on water quality and its possible effects on wildlife populations has been limited (Rosenstock et al., 1999; Wolanski and Gerata, 2001),

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therefore neglecting the potential negative effects of artificial water provision for wildlife on animal health and production (Simpson et al., 2011). Other than a limited study on total dissolved solids (TDS) of the water from the developed waterholes (Bonifica, 1992), after decades of provision of water to wildlife in the CKGR there has never been a comprehensive study conducted to investigate the quality of water at artificial water points and its impact on the ecosystem. Other water quality characteristics, such as presence of toxic heavy metals were not tested. Toxic levels of heavy metal can compromise the ability of prey to respond to potential predation (McPherson et al., 2004), thereby increasing vulnerability of prey.

Water from the boreholes is usually pumped into ponds for animals to drink. This exposes the water to seasonal atmospheric environmental variability such as wind and temperature (Vega et al., 1998), leading to evaporation into the air as well as and filtration of salts and solids as water sinks into the soil, potentially resulting in increase in the concentration of salts and other impurities that cannot evaporate or filtered into the soil. The increase in the concentration of salts may worsen the quality of the water available to animals.

There are records of elevated blood lead levels in vultures in and around the CKGR (Kenny et al., 2015). Sources of the lead have not been established. There is a strong suspicion that lead ammunitions are the source but underground water is also a possible source. Arsenic effects on humans have been well documented and it is regarded as a carcinogen (Vainio and Wilbourn, 1992; Ng et al., 2003). Effects of long term ingestion of arsenic include damages of internal organs such as kidney, liver, bladder and lungs (IARC, 2004). These effects have been reported in animals as well (Biswas et al., 2000; Ng et al., 2003). Consumption of arsenic is generally caused through drinking water (Ng et al., 2003).

Considering the potential risks of poor water quality for wildlife and its consequences for conservation, the general objective of this study was to test water quality from the artificial waterholes within the CKGR and Khutse Game Reserve (KGR) to determine whether water quality fell within recommended safety standards. The specific objectives of this study were to (1) to determine seasonal variations in water quality in the study area, (2) to compare water quality of the waterholes between the waterhole outlet and the pond, and (3) to compare water quality of the waterholes against Botswana (and international) water standards for livestock. The quality of the water from the ponds were expected to be poorer than that from the boreholes due to water evaporation and filtration of salts and other impurities. The water quality was expected to worsen in the dry season due to lack of recharge from rainfall to counteract inputs of solutes from mineralisation processes in the geosphere.

2. Study area

The Central Kalahari Game Reserve (52,145 km^2) and the Khutse Game Reserve (2550 km^2) formed the study area. The area falls within 21°00' – 23°00′ S and 22°47.5’ – 25°25′ E. The study area temperatures range from −6 °C in winter to 43 °C summer, with mean annual rainfall ranging from 350 to 400 mm (DHV, 1980, unpublished). There is no permanent surface water in the reserves, but 13 artificial waterholes have been developed for wildlife (Fig. 1). The wildlife population in the area includes large ungulates such as giraffe (*Giraffa camelopardalis*), eland (*Taurotragus oryx*), blue wildebeest (*Connochaetes taurinus*), gemsbok (*Oryx gazella*), kudu (*Tragelaphus strepsiceros*) and springbok (*Antidorcus marsupialis*), and large carnivores such as lion, leopard (*Panthera pardus*), cheetah, wild dog and brown hyaena.

3. Methods

Water samples were collected from 12 of the 13 waterholes in September 2013, January 2014 and June 2014 and tested for quality. January represented the wet season, whereas June and September

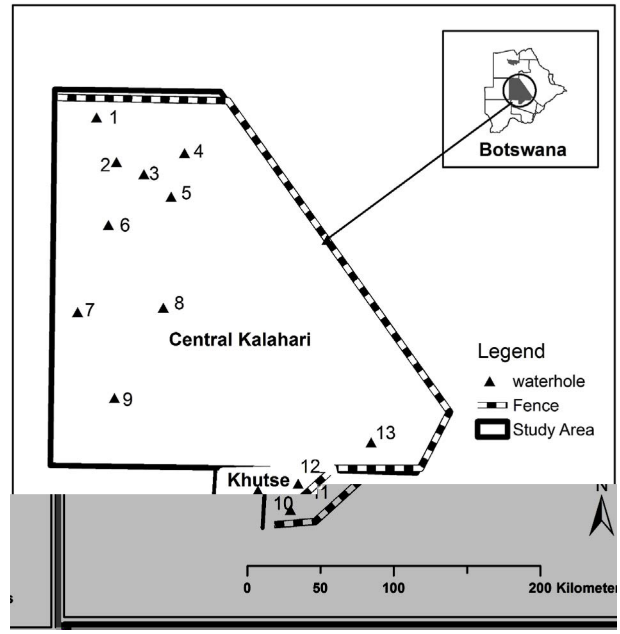

Fig. 1. Showing study area and locations of waterholes in the Central Kalahari and Khutse Game Reserves. 1 = Motlopi, 2 = Passarge, 3 = Tau, 4 = Sunday, 5 = Letiahau, 6 = Piper, 7 = Xade, 8 = Xaka, 9 = Quee, 10 = Moreswe, 11 = Molose, 12 = Khutse, 13 = New waterhole.

represented the dry season. Data collected in June was only used for Passarge waterhole because the waterhole was dry in September sampling. The 13th waterhole (labelled 13 in Fig. 1), was new (and not currently used by wildlife) and could not be reached due to logistical reasons. Three of the waterholes were within KGR and the rest in the CKGR. The quality of the water was tested by collecting samples from the ponds and outlet that releases water into the ponds. Samples were tested for pH, Electrical Conductivity and Total Dissolved Solids (TDS) using standard procedures (Rice et al., 2012) at the Okavango Research Institute environmental laboratory in Maun. Analysis for calcium, magnesium, lead and zinc were conducted using Atomic Absorption Spectrometry (AAS). A Flame Photometer was used to analyse for sodium, and Inductively Coupled Plasma Optical Emission Spectrometry (ICS-OES) was used to test for arsenic concentration. Due to lack of standards for wildlife, the water quality was compared to the Botswana Standards for livestock and poultry specification (BOBS, 2010) and international guidelines summarised by Rosenstock et al. (2004). Concentrations of TDS were compared between seasons and between water outlets and ponds of each waterhole using paired *t*-test. Lead and arsenic concentrations were not normally distributed; therefore, Wilcoxon paired test was used to compare concentration of lead and arsenic between seasons, and between outlets and ponds.

4. Results

All the artificial waterholes recorded levels of calcium, magnesium, potassium and zinc that were lower than the maximum acceptable levels (Table 1). Six of the waterholes recorded levels of sodium that are higher than the maximum limit, in at least one season. All artificial waterholes, except Letiahau, Khutse and Motlopi had pH values above the Botswana recommended range of 5.5–8.3 for livestock.

Eight out of 12 waterholes recorded levels of TDS higher than the conservative recommended limit of 3000 mg/L (Rosenstock et al., 2004), while six are above the highest recommended range (Rosenstock et al., 2004; BOBS, 2010). Only Quee, Xaka, Xade and Piper were below the TDS conservative limit (3000 mg/L). Xaka and Quee had less than 1000 mg/L TDS, whereas Khutse, Letiahau and Moreswe had over 10,000 mg/L (Fig. 2). Seasonal comparison of TDS did not show