Desert-dwelling African elephants (*Loxodonta africana*) in Namibia dig wells to purify drinking water

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Abstract

In the arid regions of southern Africa, elephants (*Loxodonta africana*) are known to dig wells using their feet and trunks to access water beneath the surface of dry sandy riverbeds. This behaviour is observed even in areas where surface water is readily available. Desert-dwelling elephants of northwestern Namibia also routinely damage borehole infrastructure to access water, even when water is available in artificial drinking pools. This study sought to determine the qualities of the water in 'elephant wells' and boreholes that prompt elephants to go to such extremes to access it. This study compared faecal coliform bacterial counts in water sampled from recently dug elephant wells and boreholes with samples from the nearest surface water available to elephants in the arid Kunene region of northwestern Namibia. Results of 13 pairwise comparisons collected over two field seasons revealed significantly lower coliform counts in the elephant wells than in the nearest surface water or drinking pools. Coliform counts from the two boreholes in the study area, periodically damaged by elephants, were also dramatically lower. Alternatively, we found no evidence that elephant wells were less saline than nearby surface waters. We conclude that these behaviours are attempts by elephants to access less-contaminated drinking water. Understanding elephant behaviour in selecting water sources may also help in the development of more effective measures to protect artificial water sources and better provide for the needs of desert-dwelling elephants.

Résumé

Dans les régions arides d'Afrique australe, les éléphants (*Loxodonta africana*) sont connus pour creuser des puits à l'aide de leurs pattes et leurs trompes afin d'accéder à l'eau sous la surface des lits de rivières sablonneux et secs. Ce comportement est observé même dans les zones où l'eau de surface est facilement disponible. Les éléphants des déserts du nord-ouest de la Namibie endommagent régulièrement aussi les infrastructures des puits pour accéder à l'eau, même quand celle-ci est à leur disposition dans les mares artificielles immédiatement adjacentes. Cette étude visait à déterminer la qualité de l'eau dans « les puits des éléphants » et les forages qui font que les éléphants aillent à de tels extrêmes pour y accéder. Cette étude a comparé le nombre de bactéries coliformes fécaux des échantillons d'eau prise à partir des puits et des forages récemment creusés par les éléphants avec des échantillons d'eau de surface la plus proche à la disposition des éléphants dans la région aride de Kunene du nord-ouest de la Namibie. Les résultats de 13 comparaisons par paires collectées pendant deux saisons sur le terrain ont révélé des nombres de coliformes significativement plus faibles dans les puits d'éléphants par rapport à l'eau de surface la plus proche ou à la mare d'abreuvage. Les coliformes provenant des deux forages endommagés périodiquement par les éléphants dans la zone d'étude, étaient également nettement inférieurs. D'ailleurs, nous n'avons trouvé aucune preuve que les puits des éléphants étaient moins salés que les eaux de surface à proximité. Nous concluons que ce comportement de creuser des puits et de s'attaquer aux forages sont des tentatives des éléphants d'accéder à l'eau potable moins contaminée. La compréhension du comportement des éléphants dans leurs choix des sources d'eau peut également aider au développement des

contre-mesures plus efficaces pour protéger les sources d'eau artificielles et mieux répondre aux besoins des éléphants du désert et aider à leur survie à long terme.

Introduction

Elephants in the arid Kunene region of northwestern Namibia spend most of the dry season feeding on sparse vegetation and drinking from scattered water sources in the riverbeds of ephemeral rivers. These ephemeral rivers, where intermittent surface water is present, are essentially linear oases in an otherwise waterless desert. In addition to surface water, elephants also access water by digging wells with their feet and trunks in the dry sand of the riverbeds where groundwater nears the surface. These 'elephant wells' are up to 1 m deep (Figure 1a–c), and are used not only by elephants but by numerous other species as well, for example, springbok, jackals, baboons. Curiously, elephants will go to great lengths to dig wells immediately adjacent to free-flowing surface water or pools, rather than drink from those readily available water sources (Figure 1b). This behaviour is not unique to desert-dwelling elephants and has

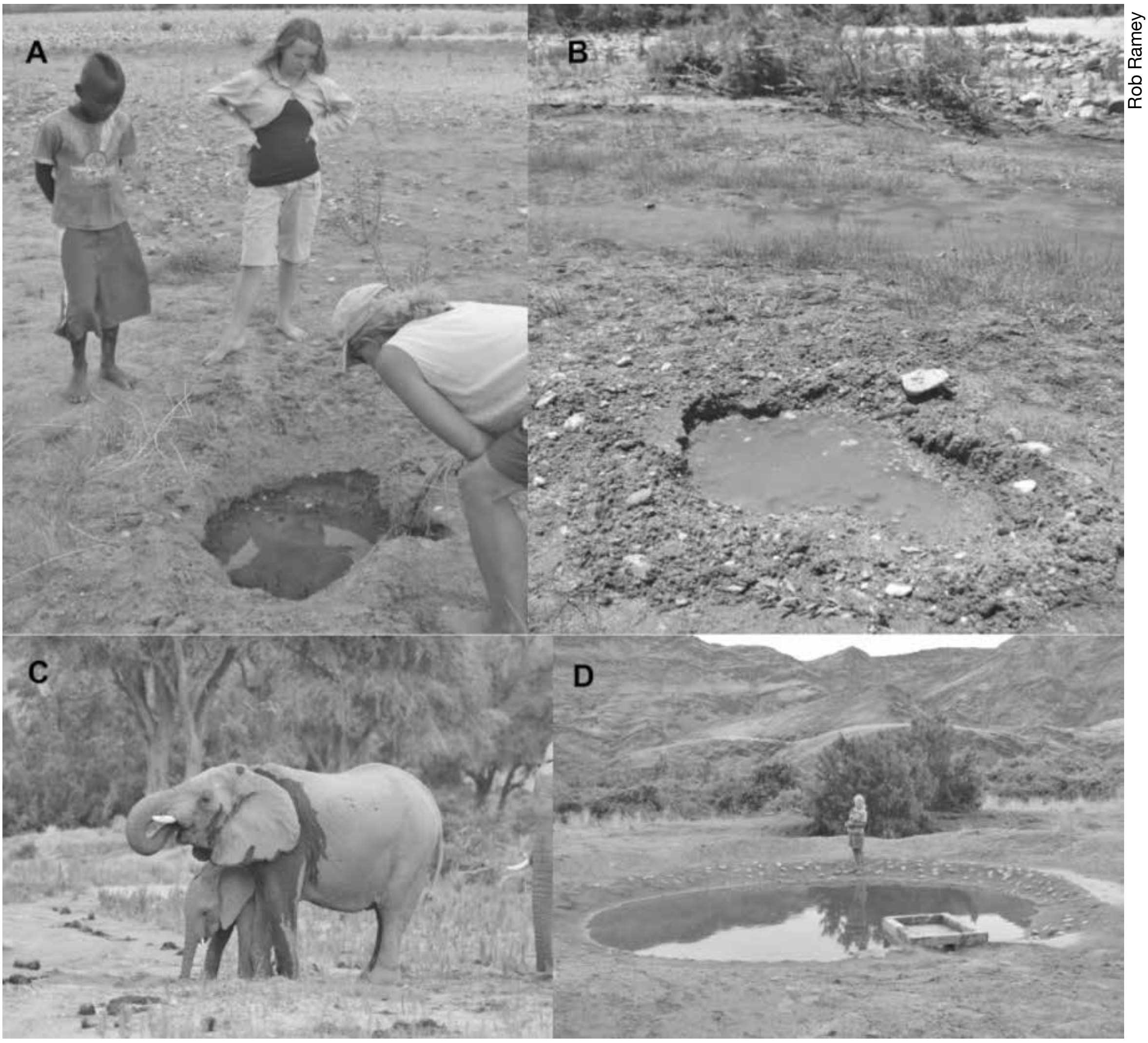

Figure 1. **A**. Shallow well dug by an elephant in a dry section of the Hoarusib River. **B**. An elephant well immediately adjacent to surface flowing water in the Hoarusib River. **C**. Elephants drinking from an elephant well in the dry bed of the Hoanib River. **D**. Artificial drinking pool at the East Presidential borehole, Hoanib River.

been documented in other elephant populations as well (Payne 1998).

In Namibia's Kunene region, humans have also drilled numerous boreholes near settlements to supply water for villages and livestock. These community boreholes attract desert-dwelling elephants, which often damage the borehole infrastructure in their attempts to reach water. In an effort to keep elephants away from human settlements in the Hoanib River catchment, two wildlife-specific boreholes were drilled in 2002 by the Ministry of Environment and Tourism (MET), and outfitted with artificial drinking pools that allow easy access by all species (Leggett 2006; Figure 1d). These measures have helped to reduce human–elephant conflict at community boreholes near Sesfontein in the Hoanib River area. Nevertheless, even with water readily available in the wildlife drinking pools, elephants routinely damage the pumps, pipes and water storage tanks of these boreholes despite extensive 'elephant-proof' armouring, for example, rock or cement walls, trenches, loose rocks, cages, and fences made of railroad iron and 10-mm steel cables.

We and others (Wanke and Wanke 2007) have observed that, especially during the dry season, surface water and wildlife drinking pools are visibly contaminated with animal faeces from many different species, including elephants. Therefore, we hypothesized that well-digging behaviour is elephants' attempts to access cleaner water, that is, less contaminated with faecal bacteria. To test our hypothesis, we applied a rapid faecal coliform assay (commonly used to assess faecal contamination in urban water and sewage systems) to 13 paired-water samples, that is, elephant well versus nearest surface source in the Kunene region. We also used the coliform assay to compare levels of contamination between wildlife-specific boreholes (pumps and storage tanks) and their adjacent drinking pools. Finally, we assayed faecal coliform levels at several natural springs, some with limited evidence of animal use.

Understanding elephant motivation and behaviour is of ultimate significance to this research in that it allows us to anticipate, and therefore reduce, points of conflict with humans, which in turn benefits elephant conservation. In this case, understanding elephant behaviour around water may help us to not only develop more effective countermeasures to protect artificial water sources, but also to better provide for the needs of these elephants and other desert species.

Methods

In 2008 and 2009 we sampled water from sources used by elephants in the Hoarusib and Hoanib Rivers of Kunene region, west of the 100-mm rainfall isohyet, in the northern Namib Desert of Namibia (Figure 2). These ephemeral rivers drain large catchment areas that have substantial human and livestock populations upstream, and are subject to seasonal flooding during the wet season. At 13 sites we collected paired water samples: one from an elephant well that was less than a day old (elephant wells seldom last more than a day or two before they collapse) and the second from the nearest surface water that could have been used by elephants. These alternative surface water sources ranged anywhere from 3 m to 1800 m from the elephant wells. We also sampled individual natural desert springs and surface pools, some of which are located in the remote gravel plains and dune fields of the Skeleton Coast National Park, where there is minimal vegetation and therefore less use by elephants and other animals (Figure 2). Finally, we sampled water from the two wildlife boreholes (known as the East and West Presidential boreholes) and their artificial drinking pools that were drilled by MET in the Hoanib River. [Note: In 2008, the East Presidential borehole was not pumping due to a malfunction. In 2009 it was repaired, but subsequently destroyed by elephants, and a sample was obtained from the gushing (broken) wellhead. At the West Presidential borehole, the 2008 sample came from a storage tank, which may explain the positive coliform count; and in 2009, the wellhead was damaged by elephants and completely failed. Both boreholes were subsequently repaired in 2010 by MET and elephant-proofed with 3-m high stone and gabion walls.]

Total coliform was estimated using Colilert-18 and Quanti-Tray/2000 MPN tests (IDEXX Laboratories, Maine, USA). Coliform bacteria counts determined by the Colilert 18/Quanti-Tray method include coliform of faecal origin as well as some species of non-faecal origin (Chao et al. 2004; Sercu et al. 2011). *Escherichia coli* is a subset of faecal coliform and one of the most common microbes in the diverse microbial community found in intestines of mammals (Rompre et al. 2002; Ley et al. 2008). Coliform bacterial load has also been used as an indicator of viral contamination in water (Gersberg et al. 2006). Wearing sterile gloves, researchers collected 100 ml of water by hand in sterile 120-ml disposable vessels with sodium thiosulfate.

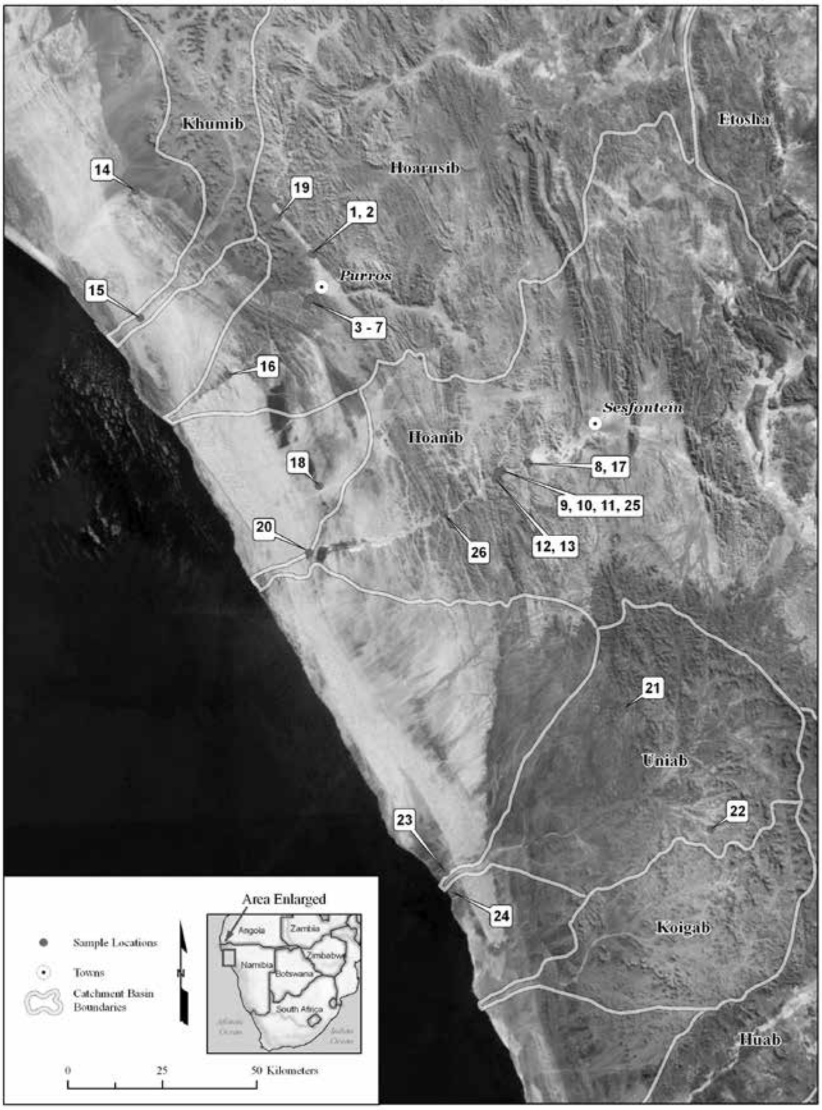

Figure 2. Study area in northwestern Namibia. Sample locations 1–13 indicate pairwise comparisons between elephant wells and the nearest readily available water source; locations 14–24 indicate springs and surface pools as follows: 14 Ogams, 15 Sarusas, 16 Hoarusib River remnant pool, 17 Hoanib River spring at Dubis, 18 Ganias, 19 Hoarusib remnant pool, 20 Auses, 21 Orupembe, 22 Zebra, 23 and 24 Uniab floodplain springs. Locations 25 and 26 are East and West Presidential boreholes.

Colilert-18 media was added to each water sample, mixed, and transferred into Quanti-Trays. Trays were heat-sealed using a modified 25-watt hair-curling iron powered by an inverter attached to a 12-volt car battery. Trays were then incubated for 18 to 20 hours at 32–37 °C (ambient air temperature during the hot dry season), or with hot water bottles at night. All pairwise samples were collected, incubated and results obtained at the same time, eliminating any bias that might result from variation in incubation temperature under field conditions. A most-probable number (MPN) table was used to estimate colony-forming units per 100 millilitres (cfu/100 ml). In cases where the coliform count exceeded the upper limit of the Colilert-18/ Quanti-Tray system (> 2,419 cfu), the upper limit was conservatively used as the final cfu value.

To test the hypothesis that elephants may dig wells to access lower salinity water, we returned to Namibia in November 2011 and gathered water samples from surface waters and nearby elephant wells, as well as from some remote desert springs from which elephants are known to drink. We obtained a total of 18 water samples from the Hoanib, Hoarusib and Uniab River systems that included four elephant wells. Salinity was measured using an HM Digital COM-100 Waterproof Combo Meter (HM Digital, Inc., Culver City, CA) that measures electrical conductivity (EC), total dissolved solids (TDS), salinity and temperature.

Results and discussion

Coliform bacterial counts (cfu/100 ml) were significantly lower in wells dug by elephants than in the nearest surface water sources (Wilcoxon matched-pairs signed-ranks test, $W+ = 8$, $W- = 83$, $p \leq 0.0061$ [Figure 3]).

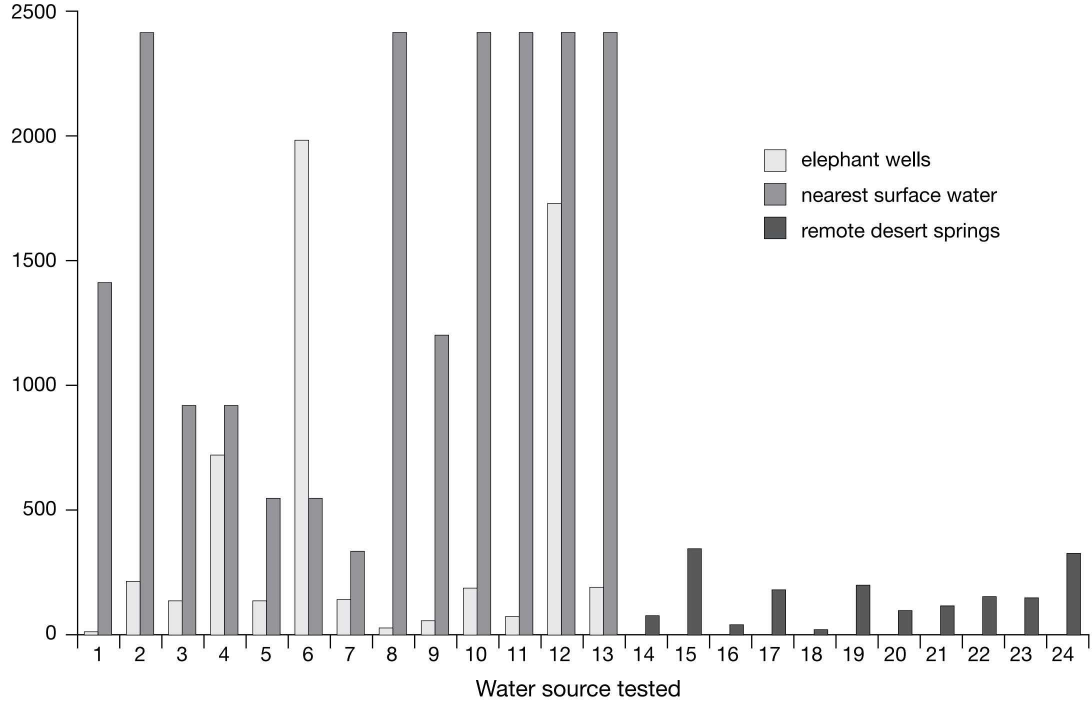

Figure 3. Pairwise comparisons (1–13) of coliform bacterial concentrations in elephant wells dug by desert-dwelling elephants (grey) compared with the nearest surface water source that could have been used by the elephants (dark grey). Numbers indicate the sample locations depicted in Figure 2. Comparisons 1–8 involved elephant wells dug next to flowing streams (3–100 m apart, mean = 32 m), and comparisons 9–13 involved elephant wells next to remnant pools or artificial drinking pools (30–1,800 m apart, mean = 1,092 m). Coliform counts from remote natural springs are shown in no. 14 to 24. Samples from surface water sources in comparisons 2, 8 and 10–13 exceeded the upper detection limit of the IDEXX kits (> 2,419 cfu/100 ml).

The coliform load in the majority of the elephant wells was close to that found in remote springs (elephant wells: mean 430 cfu, range 0–1,986 cfu, n = 13; remote springs: mean 153 cfu, range 37.0–344.8 cfu, n = 11), although two of the elephant wells sampled had relatively high coliform counts (sample locations 6 and 12). At the East and West Presidential boreholes (wildlife-specific), coliform bacterial loads in the artificial drinking pools were high (980 to > 2,419 cfu/100 ml) compared with water sampled directly from the wellheads or from the adjacent storage tanks (0–6.3 cfu/100 ml).

The possible hypotheses, that higher salinity of surface water prompts elephants to seek less-saline water or that elephants seek higher saline water because it harbours fewer coliforms, do not appear to explain why elephants dig shallow wells next to flowing streams. We found no correlation between salinity and coliform count in elephant wells and alternative water sources. The Hoarusib and Hoanib Rivers drain large catchments and flood annually, and with a few notable exceptions (elephants rarely visit springs near the coast) are fresh to slightly saline. For example, the measured conductivity and total dissolved solids of wetlands along the intermittently flowing stretch of the Hoanib River where we sampled elephant wells, had measured levels that were suitable for consumption by domestic stock and wildlife, e.g. conductivity 2.3–5.5 mS/S, and total dissolved solids 1,040–1,700 mg/litres during the dry season (Knight 1995; Leggett et al. 2003). Furthermore, two of three elephant-dug wells in the Hoanib River were much more saline than nearby alternative water sources at artificial drinking pools (3,100 and 4,570 ppm in the elephant wells vs. 2,290 and 2,840 ppm in the artificial drinker pools). One elephant well sampled in the Hoarusib River was of a slightly lower salinity than the alternative water source, a flowing stream 20 m away (1,400 ppm vs. 1,590 ppm); however, both are classified as 'good quality for livestock' (Bagley et al. 1997). The Hoarusib River has more flowing surface water and is readily drunk year-round by people, livestock and wildlife.

These results are consistent with our hypothesis that elephants dig wells in the sandy riverbeds primarily to access cleaner (less bacteria-contaminated) water. Just as humans dig wells and use sand filters to purify drinking water (Elliott et al. 2008), elephants go to considerable effort to dig wells even when free-flowing water is often only metres away. Likewise, our results are consistent with the hypothesis that elephants break into borehole pumps and storage tanks to gain access to cleaner water than is readily available in the adjacent drinking pools. It is unknown whether elephants discriminate among the potential water sources based on taste or their well-developed sense of smell, or both.

Of historical significance, clean drinking water was obtained from elephant wells in the Hoarusib River during a 1943 overland rescue expedition. The rescuers filled their water barrels from elephant wells near Purros before proceeding across the waterless gravel plains and dune fields to aid shipwrecked survivors on the Skeleton Coast (Marsh 1944).

The results of this study have important implications for managing elephants in the desert regions (in particular, wildlife boreholes) as well as human–elephant conflict at community boreholes. If purer sources of water can be provided for elephants at artificial drinking pools, this could alleviate elephants' desire to break into wellheads and destroy pipes and storage tanks. It is neither difficult nor expensive to add elephant drinking cribs (troughs) between the storage tanks and drinking pools so that elephants can access clean water before it enters the pool and faeces contaminate it. Elephant drinking cribs added between storage tanks and drinking pools simultaneously reduce faecal contamination and evaporation because they are continually flushed with fresh water (Wanke and Wanke 2007). Preliminary data from arid eastern Namibia suggest that human–elephant conflict at water points is reduced when elephant cribs are added, and that elephants selectively drink from cribs rather than drinking pools (Matson 2006). While we have shown that elephants prefer to drink from cleaner sources of water, including wells they have dug themselves, the precise mechanism for their choice (i.e. taste or smell) is unknown. Future experimental research could be used to address this question.

As human and livestock population densities in the Kunene region increase, so does the microbial load running downstream. This will affect all available surface water, except for springs that are outside rivers. Notably, Ganias, the most remote spring in this study, had the lowest coliform count (Figure 3). It is also of such low volume that it takes several minutes to refill after a single oryx drinks from it.

Elephant damage to artificial boreholes is an emerging issue and is expected to become more of a problem because of increased human and livestock populations and reduced government subsidies, thus shifting the responsibility for repairs to local communities and conservancies (Hossain and Helao 2008). If damage from elephants is costly in terms of time and money, local communities will be less likely to tolerate elephant populations in their area, thus further shrinking the range of Namibia's desert-dwelling elephants. Therefore, any action that can be taken to reduce elephant damage to boreholes and water sources is a wise investment for both humans and animals.

Ethics statement

This research was conducted under the Ministry of Environment and Tourism research and collection permits 1298/2008, 1393/2009, and 1508/2010 for research on the effects of climate change on desert-dwelling elephants of Namibia in Etosha National Park, Skeleton Coast National Park, Kunene and Omusati regions of Namibia.

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