Shower water usage in Kruger National Park tourist accommodation: effectiveness of technology and information intervention to reduce use

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Abstract

Human freshwater consumption continues to be a growing global concern. Research and implementation of interventions on multiple fronts are required to safeguard this critical resource. Household water consumption is a significant contributor to overall freshwater use. Such indoor water use in nature-based tourism presents a challenge to this industry, but also provides opportunities to influence human behaviour and experimenting with, and mainstreaming, new technologies promoting water conservation and sustainability. Here we assess interventions to one significant source of water use (showers) in tourist accommodation in a popular nature-based tourism destination, the Kruger National Park, South Africa. Control trials utilizing information interventions (to induce behavioural change), and a novel shower technology, are implemented to identify water saving opportunities. We show that technological intervention (installation of Triton Xerophyte®) results in ∼30% overall water saving as compared to control showers. Adding water-saving infographics slightly enhances this saving, but is shown to have limited success when implemented in isolation (i.e. without the technology). In addition, we show how shower duration and water usage is related to ambient temperature, with the Triton Xerophyte® resulting in increasing water savings under cooler ambient conditions (up to ∼50% water reduction for ambient temperatures <5 °C). Encouragingly, visitors to this national park are shown to use less shower water and shower for shorter, even in control units, as compared to the general public, suggesting that these nature-based tourists may already be more mindful of water usage. Nature-based tourism agencies have a responsibility to promote water saving behaviour, and implementing technology and providing information and awareness in aid thereof may act as a catalyst for broader water-conservation in society.

Water impact

Showering is a major water consumption activity. A control trial shows how creative information aimed at national park tourists (e.g. 1 minute less showering = daily water for two impalas), combined with novel shower technology reduced consumption significantly (∼30%), whilst increasing shower convenience. At scale this translates into reduced abstraction volumes, grey water production and water heating energy demands.

Introduction

Water is fundamental to Earth's ecosystems, inclusive of human existence.[1] Human population growth and climate change are exacerbating the stresses on finite freshwater resources, and consumption for human use (both directly and indirectly) is a serious and growing concern.[2–4] Significant research attention continues to focus on interventions to use the resource sustainably.[5,6] Multipronged approaches are required to protect the integrity of freshwater resources and manage its use. Herein lies a conundrum, in that protected areas are often required to safeguard freshwater sources, yet their existence often depends on nature-based tourism, and tourists also need to use water. Tourism in general, and nature-based tourism in particular, is a large and growing global industry, and sustainability in the sector's water consumption is an unrelenting issue, with estimates of tourists' daily water usage close to 300 litres per day.[7,8] Nature-based tourism has the added responsibility of not only sustainably using water, but also of being seen to promote the water-saving premise as catalyst to change visitors' use of resources in their own homes or places of work.[9] Indeed, Fernández-Llamazares et al. (2020)[10] lament the general paucity of effective conservation messaging in nature-based tourism, which they see as a missed opportunity to change tourist behaviour. Additionally, the tourism industry and especially nature-based tourism agencies, are increasingly impelled by tourist expectations to shift their operations to more sustainable (‘green’) activities to remain commercially competitive.[11]

Water saving interventions can (and should) be applied across a swathe of components of the tourist industry because it relies on water for a variety of uses (e.g. accommodation, landscaping, activities). Interventions can also take a variety of forms (e.g. education, technology, policy). Clearly, the most effective interventions should not only be applicable to the tourism industry, but more broadly as well, and have a sustained water-conservation impact. Simple water-saving actions that require least effort (or deviation from comfort levels) by users are also most likely to be retained into everyday life.[12] As a start, the logical aim of intervention must then be for a maximum margin of water-saving, with minimum required user effort to change behaviour and with minimal loss to comfort. One area that has received significant research focus as a comparatively simple avenue for effective water-saving is in showering.

Showering is a common end-use of water in most tourist accommodation, and globally in most formal households, and is cited as a major component of total indoor household water use globally.[13,14] Interventions such as low-flow shower-heads have effectively contributed to significant water-saving globally,[15] without requiring burdensome user effort or behavioural change.[12] However, Tiefenbeck et al. (2013)[16] showed that human behaviour can also result in diminished water saving when using water-saving devices, as a result of the mistaken belief that more efficient devices can counter more wasteful behaviour, in a process known as 'offsetting'. Added interventions that require greater behavioural change from users, such as limiting the total duration/volume of showers can however be highly effective for saving water, and may counter 'offsetting'. For example, a visual alarm display technology intervention in households in Australia's Gold Coast, illustrated the behaviourally induced effectiveness of alerting the user when a predefined water volume had been reached while showering, resulting in significant water savings as compared to a control group.[17] An extreme case of behavioural intervention was experienced during the 'Day Zero' scenario in Cape Town, South Africa, where severe drought brought about imminent fear of taps running dry.[18] Financially-scaled municipal 'restrictions' and wide-scale information intervention between 2015–2018 brought about substantial behavioural change in water use.[19] Consumers in Cape Town reduced their water use from 540 to 280 litres per household per day over the 36 months of this extreme drought.[19] Alleviation of the drought occasioned a steady increase in water-use in the municipality pre-Covid19 lockdowns (https://coct.co/water-dashboard/), perhaps suggesting some behavioural relapse by consumers. This despite projections indicating the potential for recurrent 'Day Zero' scenarios in the region.[20] Similarly, in a longitudinal study, Stewart et al. (2010)[21] empirically showed how initial successful prompting to change behaviour faded after four months when end-user shower water use mirrored pre-intervention levels – old habits die hard. Thus, technological devices that inform users of their water usage, though initially successful in inducing water saving behaviour, do not instil a permanent change. It would appear that technological intervention that targets both a subliminal user change in behaviour and automatic effortless water-saving (i.e. without the need for conscious user behavioural change) would be most effective for a long-term solution to water wastage.

Nature-based tourism management agencies, such as South African National Parks (SANParks), who manages the Kruger National Park (KNP), have the potential to conserve water through such a range of interventions. Here we use a nine-month control trial in permanent accommodation units in Skukuza rest camp, KNP, South Africa to:

1) assess the efficacy of educational (behaviour) and/or technological intervention in saving shower water. We make use of (a) information displays, and (b) a new shower technology, Triton Xerophyte® that combines various features to conserve water, including pre-shower flow constraint until water is suitably heated, suggested shower duration, pause functionality and elimination of temperature/flow fluctuation,

2) establish novel baseline data on water use for this accommodation type in this National Park,

3) assess the influence of ambient temperature on shower water use parameters,

4) aid this conservation agency (SANParks) in providing evidence of efforts to implement and promote water use sustainability for tourists.

The objectives above contribute to various gaps identified in a review of the energy and water saving literature in tourism accommodation, by Warren and Becken (2017).[22] The review identified that most studies focused on electricity saving, with limited focus on water savings (10%) in tourism accommodation. In addition, Africa was underrepresented (4%) and a paucity of information for non-hotel tourism accommodation was identified. Lastly, the review revealed a lack of studies combining the complex interactions between the built environment, technology, climate and behaviour to which objectives 1 and 3 above explicitly contribute.

Materials & methods

Study site

Skukuza (24.9964° S, 31.5919° E) is the largest tourist rest camp in South Africa's renowned Kruger National Park and attracted the largest proportion of the more than 400 000 annual overnight visitors to this wildlife reserve. The camp has a variety of accommodation types, ranging from camping, self-catering chalets and upmarket establishments. We selected 10 riverfront accommodation chalets of the same type (i.e. offering the same amenities and number of beds (2) per unit) for inclusion in this study. Three of these chalets were part of the control group and seven chalets part of the experimental group. The experimental design was as follows:

Experimental description	**Chalet #**
Control (no intervention)	94, 95, 96 (n = 3)
Infographic only	92, 93 (n = 2)
Technology only	86, 87, 88, 91 (n = 4)
Technology and infographic	89 (n = 1)

The experimental trial was conducted between 27 November 2020 and 23 August 2021, thus spanning Austral summer and winter seasons. Daily ambient temperature data for inclusion in analyses was sourced from the iLeaf automated weather station located *approximately 500 m from the chalets (https://www.ileaf.co.za).*

Technological intervention

The Triton Xerophyte®, is a newly patented water-saving digital shower (IWSX (Pty) Ltd., Pretoria, South Africa & Triton Showers, Nuneaton, United Kingdom; https://tritonxerophyte.com/). This device features an electronically controlled mixer that recirculates water until warm water is available and only then released from the showerhead, i.e. no suboptimal temperature water is wasted down the drain while waiting for the water to heat up, which is a problem especially in situations where the hot water source (e.g. boiler/geyser) and shower are far from each other. The Triton Xerophyte® also features a pre-defined shower duration timer with automatic termination (including alarm warning 30 seconds prior to termination), although a user can choose to immediately restart a new shower session without delay. All Triton Xerophytes® used in this trial were pre-set for 3-minute shower duration with an optimal temperature (38° Celsius) and flow rate (~4 litres per minute). The device could be paused at any time during the shower duration, ceasing water flow, and restarted at will with the temperature maintained during the pause for comfortable resumption of water flow. Although set at default settings for a comfortable shower experience under typical conditions, visitors had full control over the water temperature and flow rate using simple buttons and dials. A poster explaining how to operate the Triton Xerophyte was also affixed in each shower. The technology's website (https://tritonxerophyte.com/) was also displayed allowing visitors to access further product details at their discretion.

The Triton Xerophyte® mixer unit is fitted between the hot water source and the shower head, as close to the latter as possible (see ESI† Fig. S1). In this study all mixers were fitted within 1 m of the showerhead. Note that the mixer is not an instant water heater, it monitors and recirculates water from a traditional hot water source (e.g. heat pumps in this study) until the desired temperature is reached, before allowing release from the showerhead. All showers in both the control and experimental groups were fitted with identical showerheads. Five experimental chalets were fitted with Triton Xerophyte® mixer units, of which one chalet additionally included separate water-saving infographics (see below).

Information (behavioural) intervention

Infographic posters (see ESI† Fig. S2 and S3) containing water-saving tips and local environmentally relevant information concerning water conservation, were prominently displayed in three experimental chalets (one of which in combination with a Triton Xerophyte® mixer unit). The one infographic (placed in the bathroom) converted volumes of water typically used for a range of everyday activities (e.g. showering, toilet flushing, filling washing basin) into ecological metrics (e.g. 1 minute less showering equates to drinking water for two impalas for a day). The principle behind this infographic was to express the water usage in metrics that visitors to a national park are likely to care about, instead of the rather impersonal, but more familiar, volume metric. The second infographic (placed at the washing basin in the kitchen) introduced visitors to the source of water servicing the units, namely the Sabie River. All of the chalets overlook the Sabie River from where water is extracted, purified and delivered to the units. This second infographic provided information about the biodiversity and human livelihoods dependent on the river. The idea with this infographic was to reconnect visitors to the resource they are dependent on, and fostering a mind-set of sharing this resource with humans and biodiversity ("people and nature" framing sensu Mace, 2014[23]).

Water usage measurement

Shower water usage in all 10 chalets in the study was measured with a Sensus 220C® water meter (Xylem Inc., Johannesburg, South Africa). The water meters were connected between the Triton Xerophyte® and the showerhead in the experimental chalets and before the showerhead in the control chalets.

Each water meter was connected to an Arduino Uno Microprocessor (https://www.arduino.cc) with a reed switch pulse reader that had a pulse output with a pulse resolution of 2 pulses per litre. Each Arduino was fitted with an 868 MHz radio frequency module that connected to Gemtek indoor low-power wide-area network (LoRa) gateway.

Custom coded software was created to detect a pulse from the pulse reader, start counting pulses and start a timer to measure water usage and shower time. Once the pulses stop, the timer stops and the software calculates the shower duration and the number of pulses received. In so doing the litres used in one shower session equals the total pulses from start to finish divided by two (viz. 2 pulses per litre).

Once the pulses stop, the software waits 30 seconds and sends the information via the LoRa network to the global collaborative Internet of Things system called The Things Network (TTN), which is a crowd-sourced, open and decentralized LoRaWAN network. From TTN the data is sent to Pipedream, a production-scale serverless platform. In Pipedream, we created a workflow for each device (i.e. shower meter) that forwards and auto-populates the desired data into Google Sheets.

Data feed interruptions due to network failure:

1. 2021/01/11 – 2021/01/28 – 17 days.

2. 2021/05/09 – 2021/05/16 – 7 days.

Analyses

For each shower event the (i) total duration of shower, and (ii) total volume of water used were measured, allowing also for calculation of (iii) flow rate. Each shower event had a chalet identifier, date and time stamp and was linked to a treatment. Four treatments were included, namely control chalets with no water saving intervention (C), chalets with infographics (I), chalets with Triton Xerophyte® (X) and a single chalet with both the Triton Xerophyte® installed and infographic displayed (XI). The time stamp for each showering event was rounded to the closest hour and associated with the ambient temperature obtained from the Skukuza weather station. Chalet occupancy information was used to exclude shower events that may have been due to maintenance or cleaning of the units (although cleaning of units may not routinely involve extended opening of the shower).

We compared efficiency of interventions by comparing average shower time (in seconds) and average shower volume (in litres) across the four different treatments. We also calculated flow rate (litres per minute) of each shower event. To test the efficiency of the technology intervention across a temperature gradient, we combined shower events in chalets displaying infographics with the control or Triton Xerophyte® treatments respectively depending on whether the technology was present in the chalet or not. This was done in order to increase the sample size for treatment effects across a temperature range, especially at the more extreme temperatures where fewer shower events were measured. As such, 576 shower events in chalets displaying infographics but excluding a Triton Xerophyte® (I) were added to the control treatment (C), whilst 176 shower events in chalets displaying an infographic and including a Triton Xerophyte® (XI) were added to the Triton Xerophyte® treatment (X). This recombination of data was justified based on the small treatment effect of the infographic treatment (see results) and in order to evaluate the effectiveness of the Triton Xerophyte® across a temperature gradient compared to a non-technology control, where it was expected that temperature may play a bigger role in shower usage.

Results

A total of 2467 discrete shower sessions (control = 621; infographic = 567; Triton Xerophyte® = 1103; Triton Xerophyte® plus infographic = 176) were recorded across the 10 study chalets. The total occupancy of each chalet could not be controlled, but this is inconsequential as individual shower events were measured. A clear diel pattern of shower activity was evident across all chalets combined, with peaks at around 6–8 am and again at 8–9 pm (ESI† Fig. S4).

The average time of a shower (without any intervention) was 4½ minutes, with average volume of use equal to 25 litres (Fig. 1). Not shown in Fig. 1, but calculated separately; the duration of 80% of the showers varied between 1 min 37 s (10th percentile) and 8 min 30 s (90th percentile), and used between 8 (10th percentile) and 97 (90th percentile) litres.

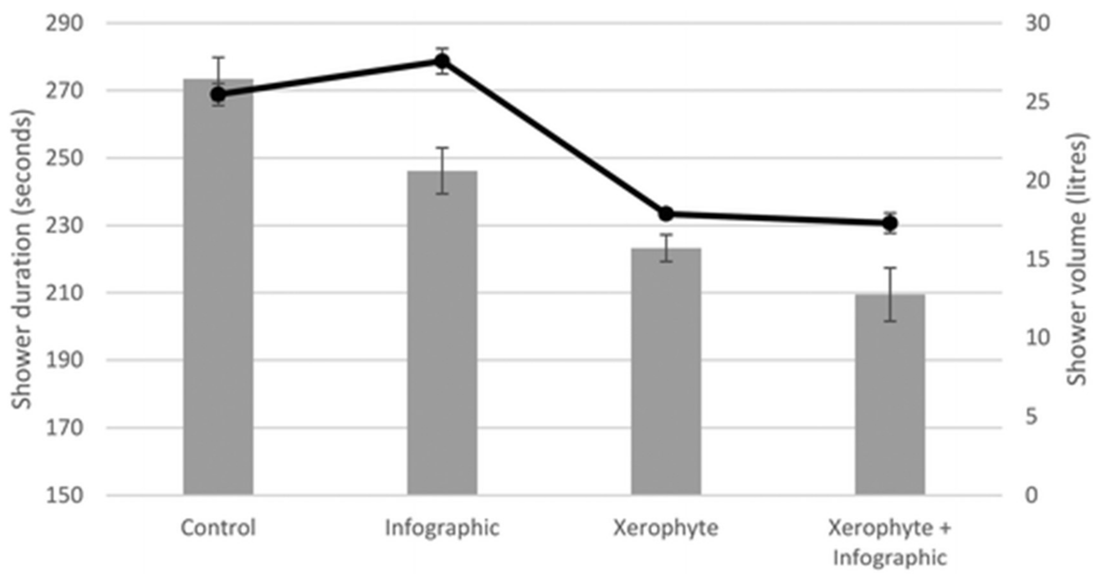

Fig. 1 Average (with standard error) shower duration (bars) and volume (line) for the four treatments.

Efficiency of interventions

Shower duration. Compared to the control group, the average shower's duration was reduced by the introduction of infographics (27 seconds; 10.0% reduction) and by the installation of the Triton Xerophyte® technology (50 seconds; 18.3% reduction), with the largest effect measured when both these interventions are used in combination (63 seconds; 23.4% reduction) (Fig. 1).

Shower volume. Compared to the control group, the average shower's volume increased in the chalets displaying the infographics (2.1 litres; 8.3% increase), whilst it declined for the Triton Xerophyte® technology chalets (7.6 litres; 29.8% reduction), with the largest effect when the infographics and technology are combined (8.2 litres reduction; 32.1%) (Fig. 1).

Shower flow rate. The flow rate in the control group was 5.72 litres per minute (sdev = 2.22), compared to 6.82 litres per minute (sdev = 1.90) for the chalets displaying an infographic, 4.83 litres per minute (sdev = 0.51) for chalets with the Triton Xerophyte® and 4.99 litres per minute (sdev = 0.35) for chalets with both the infographic and technology treatment.

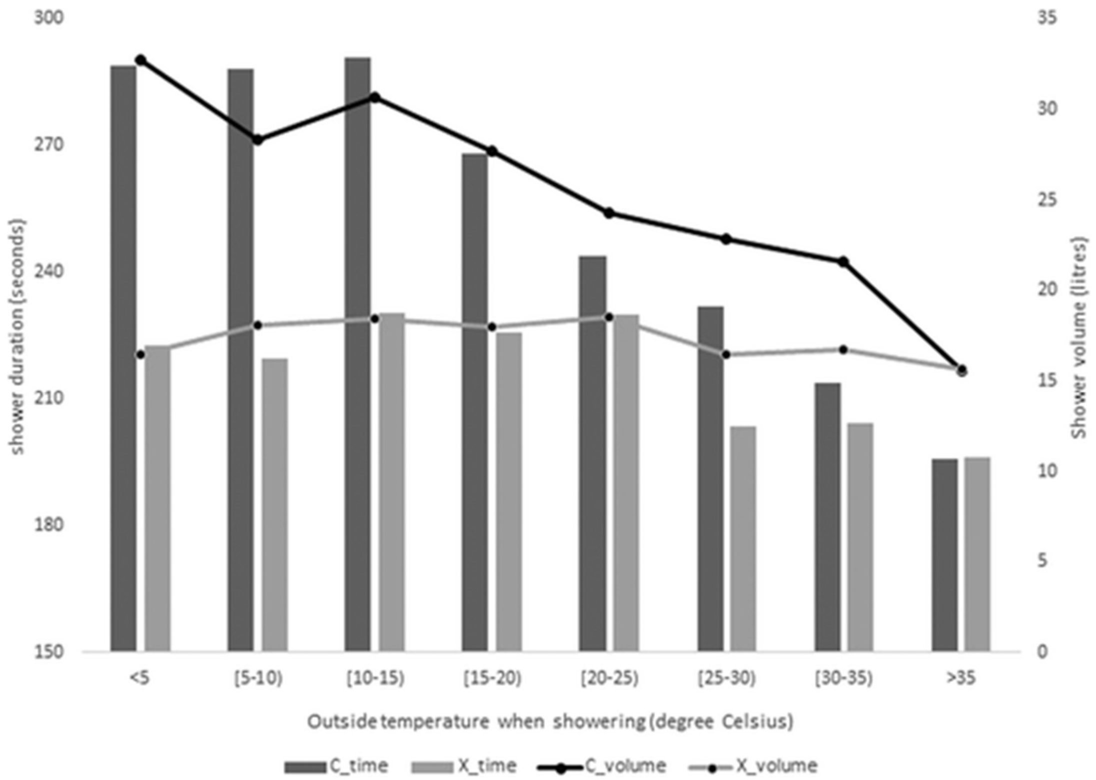

Fig. 2 Average shower duration (bars) and volume (lines) for the control (C) and Triton Xerophyte® (X) treatments across an ambient temperature gradient.

Efficacy of interventions at a range of ambient temperatures

For the control treatment, average showering duration and volumes increased at lower outside temperatures. Triton Xerophyte® treatment showed no trend in average showering volume across the temperature range and some indication of shorter showering when ambient temperatures reached >25 °C (Fig. 2). For temperatures below 15 °C, average showering time in the Triton Xerophyte® group was reduced by around 1 minute and average showering volumes by between ~10–15 litres when compared to the control treatment. The water saving margin between the control and Triton Xerophyte® groups increased as temperatures decreased (Fig. 2; ESI† Fig. S5).

The Triton Xerophyte® treatment resulted in a consistent, narrower band of shower volumes across the outside temperature gradient as compared to the control group. The Triton Xerophyte® is more effective in reducing "wasteful" showers than further reducing already "economical" showers (i.e. the Triton Xerophyte® treatment reduces the 90th percentile significantly more than the 10th percentile; Fig. 3).

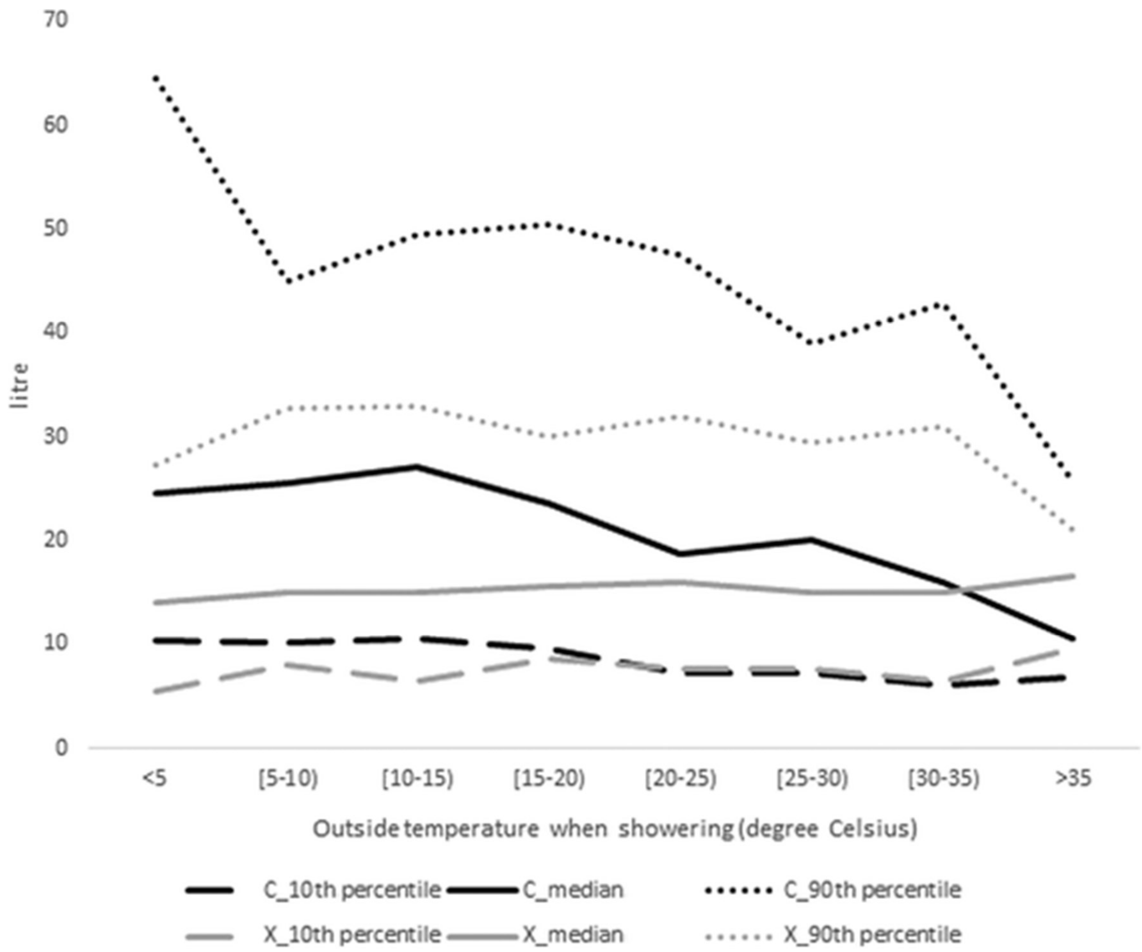

Fig. 3 Shower volume for 10th percentile, median and 90th percentile for control (C) and Triton Xerophyte® (X) treatments.

Discussion

Substantial savings in shower water can be achieved through synergistic interventions that promote behavioural change in users and that facilitate easy functionality in water-saving technology. We show in control trials in Kruger National Park self-catering accommodation, that water savings of around 30% can be achieved through installation of a novel technology, the Triton Xerophyte®, under typical conditions. This technology eliminates wastage while the user waits for water to reach an optimal showering temperature, promotes showering within a pre-set time, allows pause/restart functionality and effectively manages temperature and/or flow irregularities in the water supply. The addition of easily understandable, visually appealing information posters on display in accommodation units prompts user behaviour modification that moderately enhances water saving when applied alongside the technology. Such information display in the absence of the Triton Xerophyte® technology resulted in reduced average shower duration (~10%), but increased water usage was measured as compared to Triton Xerophyte® and control accommodation units.

We suspect the reason for the infographics resulting in an increase in shower water volume (despite a slight decrease in showering duration), may be due to various flow rates across the showers, even though the shower infrastructure was the same across units (the infographic treatment had the highest average flow rate across all treatments). It can therefore be argued that if flow rates were more strictly controlled to remain constant across all treatments, infographics could likely have resulted in some decrease of water usage. The Triton Xerophyte® reduced showering duration as well as showering volume, with bigger reductions measured in volume than in showering duration. This suggests that the technology possibly also decreased the flow rate (i.e. most likely the default flow rate setting on the Triton Xerophyte® was lower and easier to control than the flow rate that tourists would typically use when manually opening taps in the control showers). Furthermore, we make note that the Triton Xerophyte® was set at a 3-minutes default setting (but which could easily be adjusted by the user for a shorter or longer shower), and we expect (to be tested in the second phase of the experiment) that the shower time and volume of water can be further reduced by setting the default showering time at less than 3 minutes. Although education and messaging aimed at instilling water-conscious behaviour achieved limited success in our study, this intervention showed some promise and has the advantage of being immediate and implementable at low cost. Differences in water use practices by visitors are a result of a variety of drivers, including but not limited to; visitor origin, tourism destination, accommodation type, reasons for stay, demography.[24] Considering these drivers, it can also be expected that the type of information and the most appropriate messaging approach may also differ between individuals. Thus, while education can help to instil water-conscious behaviour, the variety of drivers of water use practices[25] suggest that other interventions (e.g. technology) may be useful in achieving water saving outcomes regardless of individual user heterogeneity. Further experimentation can be used to explore a range of messaging and visualization approaches to possibly increase the efficiency of this intervention (e.g. more colourful infographics employing less text), but our results suggest that these may have to be complimented with technology interventions for maximum efficacy. In addition, although the infographics were prominently displayed at key water usage areas of the tourism units (i.e. mirror of the bathroom and above kitchen sink), we had no way of knowing whether visitors noticed and read the infographics. Furthermore, the act of showering, like many other environmental behaviours that are largely habitual and deeply embedded in our everyday routines, are much harder to change and are often largely “automatic”[26] as compared to more deliberate actions which require more cognitive processing and attention. This suggests that information sharing like infographics may have limited success to change habitual behaviour. Informing visitors that water usage is monitored, linking it to social norms and incentivising water saving with a reward system[27] may be further avenues to explore in order to change behaviour linked to habitual water usage actions like showering.

As aligned with our second study objective, we benchmarked our results against other studies and recognized that the average shower volume and duration varies considerably between studies. Jacobs and Haarhoff (2004)[28] estimated that a typical shower in a suburban area in South Africa uses 59.1 litres per event, with another South African study estimating 92 litres per person per day.[29] Measuring 759 shower events at a South African University, the average shower duration was 9 min 33 s, using 83.0 litres per event and with an average flow rate of 8.7 litres per minute.[30] Studies in Australia reported volumes of 45 litres per person per day[31] and 42.7 litres per person per day,[32] whilst a study in the USA measured 59 litres per shower event.[33] Prado and Gonçalves (1998)[34] measured average showering time of 7 minutes in Brazilian apartments. Considering these shower duration and volume estimates, the 4 min and 30 s and 25 litres per shower event as measured in our control units compares very favourably even before any additional interventions. This may be partly attributed to the low-flow shower heads that were already utilized in all the units, but considering the significantly shorter showering times measured here, it is also likely that visitors to the park are already more water-conscious compared to the general public.

Weather has been shown to be a significant determinant of shower water use, particularly as it affects shower duration as ambient temperature decreases.[13] Similarly, we show (in answer to our third objective) that ambient temperature had a dramatic influence on the amount of water used in control showers. Encouragingly, experimental showers fitted with the Triton Xerophyte® technology showed added water saving as ambient temperature decreased when compared to the control group. Showers in the control group run for longer and use more water when it is colder than when it is hotter. This effect was not observed for the Triton Xerophyte® group where shower duration and volume were largely constant across the temperature gradient. This clear discrepancy across the temperature gradient between control and Triton Xerophyte® showers suggest that shower time and volume is not so much driven by “showering pleasure” across a temperature gradient (i.e. that visitors may shower longer when it is colder in order to get warm), but rather that significant sub-optimal temperature shower water goes to waste (down the drain) before reaching the desired temperature in control showers. The increased water and time expenditure in the control group during colder temperatures is thus most likely because the water in the pipes is colder and therefore the shower runs for longer to reach the desired temperature. In fact, the problem of suboptimal temperature water being wasted before the shower can be comfortably commenced is acknowledged as a substantial contributor to shower water wastage. It has been estimated for instance in UK households, that up to 10% of total water used is wasted through waiting for an adequate temperature to be reached at showers and kitchen/washbasin faucets.[35] Recent research has attempted elaborate solutions to this loss of water before the shower water temperature is adequate. Mahmoud (2021)[36] proposed a system using an in-line electrical heater with fuzzy MISO logic controller, and tested a homemade prototype with good results. Zheng et al. (2020)[37] designed an elaborate water circulatory system including electromagnetic valve, control system and circulation pump to solve this water wastage. The Triton Xerophyte® is to our knowledge the first commercially available product that solves this problem without the need for its own heating system or elaborate plumbing reconfiguration; eliminating water wastage by simply installing the mixer unit between the hot water source and showerhead. It would appear from our results that the Triton Xerophyte® would increase water savings in cold environments/infrastructure with poorly insulated pipes coming from the hot water source, or where such water must travel long distances from the hot water source to the outlet.

Our results suggest that technology that is capable of regulating and maintaining a constant shower water temperature once it commences may reduce shower water volume. Having a "guaranteed" comfortable showering temperature when the ambient temperature is cold will reduce the fiddling with taps (manual mixing) that is typical in most traditional showers. Hence, where technology can assist users to get to the act of showering more quickly as compared to spending more time waiting for water to heat up and then adjusting the running taps to attain a comfortable water temperature before starting to shower. The Triton Xerophyte®, which we used as such a technology in this study, achieves more water-saving at colder temperatures where it results in the biggest gains (e.g. at <5 °C, saving 16 litres of water (~50% reduction) as compared to control showers). When it gets really hot (>35 °C) and visitors are more prone to taking colder showers, then the water-saving benefit is eliminated where shower duration and volume water usage is similar between treatments. As such, it is clear from our results that different technologies may be more appropriate in different contexts, and the technology we tested here will clearly have its biggest impact being installed in areas with colder climates and/or where there are long distances between the heating system (e.g. geyser) and water outlet (e.g. shower).

In line with our final study objective, the findings here are encouraging beyond the realm of saving water in tourism infrastructure. Technology, combined with relevant prompting information as experienced by visitors in this study may act as catalysts for water-saving shower behaviour and possible investment in water-saving technology at private homes as well. Various off-the-shelf technologies and tools, ranging in prices and sophistication from a simple egg-timer fixed with a suction cup to the wall of the shower and water-saving shower nozzles, to the more sophisticated Triton Xerophyte® are available. These can be used independently or together, to for example, reduce water wastage through controlling the flow rate, ensuring water is delivered at appropriate temperature, re-using the grey water and controlling (or suggesting) appropriate shower durations. Nature-based organizations can play a role in exposing visitors at their accommodation offerings to various technologies and providing them with powerful water saving messages and information.

Showers can be responsible for a large proportion of indoor water use (e.g. between 26% and 46% of household indoor water use[38]), but also energy use (e.g. 32% of household energy demand[34]). Here we found that through integrating appropriate water-saving information and technology, shower volume can be significantly reduced. This does not only reduce the impact of water abstraction on aquatic ecosystems, but also reduces the financial and environmental costs (e.g. energy requirements) of purifying and delivering water to the end-user. In addition, lower shower volumes also reduce the volume of water that needs to be piped and treated at the wastewater treatment plants. Another critical saving is the energy saved by heating smaller volumes of water to the required temperature. Prado and Gonçalves (1998)[34] showed that the energy demand in Brazilian apartments is lower than 0.5 kW before turning on the shower and directly after turning on the shower it increases to about 5 kW. They estimated that the average monthly consumption of a shower was 48 kWh per apartment, which represented 32% of the apartments' average consumption. To heat water from 20 °C to 40.2 °C (the average comfortable shower temperature in South Africa[28]) will require 1.37 kWh for 59 litres (SA shower volume average), 0.58 kWh for 25 litres (control treatment) and 0.4 kWh for 17 litres (Triton Xerophyte® + infographics treatment) of water (https://bloglocation.com/art/water-heating-calculator-for-time-energy-power). Taking the average shower volume (17.3 litres per shower event) when all our study interventions are implemented (water-saving infographics plus Triton Xerophyte® technology) and comparing it to the average shower volume measured in the control units (25.5 litres per shower event), these interventions could have saved KNP 3.28 million litres of water and 72 000 kWh in the 2019/2020 financial year when just over 400 000 overnight visitors stayed over in the KNP (assuming each overnight visitor showered once per day and that no water was lost through leaks). If the KNP was required to pay municipal rates for water usage (∼R47/kilolitre) (with 1 South African Rand {R}, equivalent to 0.064 American dollars {$}), the 3280 KL saved in the 2019/20 financial year (= R154 160) plus the savings on electricity as priced at the time (= R1.33 × 72 000 kWh = R95 760) would have resulted in cost saving of close to R250 000 per annum. Equipping all of the ∼1700 showers in KNP with Triton Xerophytes® (at ∼R10 000 cost price/unit) will require a capital outlay of ∼R17m. This suggests that the annual cost recovery, specifically for KNP, will be relatively small on the initial capital outlay. These savings will also be influenced by the local costs of water and electricity as well as appropriate maintenance plans (including training on installing and basic maintenance of the equipment) and replacement costs. However, costs other than financial costs (e.g. ecological costs of abstracting, heating and transporting more water) and broader benefits (e.g. water saving awareness) also need to be considered. Corporate sponsorship may be an appropriate avenue to explore to assist with procurement of such equipment for SANParks. Savings brought about by the Triton Xerophyte® intervention in the KNP where users already seem to use less water than the average South African suburban user, indicates that greater savings are probable where users are less water conscious.

Conclusions

Protected areas are increasingly under pressure to generate their own funding. Nature-based tourism is one of the most popular ways in which to generate these funds. Although nature-based tourism is often portrayed as “non-consumptive” and “green”, large volumes of tourists have significant environmental impacts in terms of water abstraction, energy demands and waste production. As such, in staying true to their original mandate of environmental protection and management, it is in the best interest of conservation areas like National Parks to encourage responsible tourism and sustainable operational practices.

This can be achieved by (i) promoting water-saving behaviour of their visitors through appropriate messaging and education/awareness, (ii) showing their commitment as conservation agencies by 'putting words into action' with technological intervention, and (iii) set an example through their own water behaviour practices (e.g. water-wise gardening; well-maintained water reticulation systems; zero tolerance to leaking toilets, taps and faucets; water-wise housekeeping practises). Dube and Nhamo (2020)[39] recommend investment in retrofitting and redesigning some of the tourism infrastructure in the Kruger National Park to facilitate water and energy saving, and ensure climate resilience and sustainable tourism in the face of a changing climate. Acquiring, installing and retrofitting technology and redesigning some tourism infrastructure can be unaffordable to already financially constrained conservation organisations. Incremental investment over the long-term in water-saving technology such as the Triton Xerophyte® can in some cases be a more economical and logistically feasible alternative to consider than redesigning existing tourism infrastructure. However, shorter-term opportunities exist for corporate social responsibility sponsorship to assist conservation organizations to not only save water and electricity, but to use these nature-based destinations as catalysts for affecting change more broadly in society. Importantly, even with such external financial support, the savings through these technological interventions may be offset if the conservation organizations do not set a good example through water saving practices throughout their entire conservation and visitor operations.

Conflicts of interest

PJNdB is part of the team that developed the Triton Xerophyte® water saving technology and is a shareholder in IWSX (Pty) Ltd., that jointly manufactures this technology.

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