MANAGEMENT

Systems approach towards surface water distribution in Kruger National Park, South Africa

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Abstract

There was concerted effort, especially between the 1960s and 1990s, to increase the distribution of surface water in Kruger National Park (KNP). As a consequence, most of the park was within easy walking distance of a permanent water source for large, mobile herbivores during the peak of the water-for-game programme. This situation was unnatural and led to various unintended ecological effects. In reaction to this and in response to changing conservation and management paradigms, the water provision policy was revised in 1997. Since the policy change, about two-thirds of the more than 300 boreholes have been closed and many catchment dams have been breached in an ongoing process. This new approach towards water provision has a strong spatial focus and aims to recreate and mimic a more natural mosaic of spatio-temporal variability in surface water availability. KNP managers hope that the change in water provision will induce spatial and temporal variation in how elephants utilize landscapes, which is a key objective of the current KNP Elephant Management Plan. Although it seems unlikely that the reduced availability of water has had any numerical effects on the elephant population thus far, it did induce some spatial changes: elephants are now even more strongly attracted to the large river systems than before. More research is needed to ascertain whether surface water manipulation in KNP, where water is naturally relatively widely distributed, is effective in creating spatio-temporal refugia for biodiversity that are sensitive towards elephant impacts.

Résumé

L'on a vu des efforts concertés, surtout entre les années 1960 et 1990, d'augmenter la distribution de l'eau de surface dans le Parc National Kruger (PNK). En conséquence, la plus grande partie du parc se trouvait à une courte distance de marche d'une source d'eau permanente pour les grands herbivores mobiles lors du pic du programme de l'eau-pour-la-faune. Cette situation était anormale et a conduit à divers effets écologiques inattendus. En réaction à cela et en réponse à l'évolution des paradigmes de conservation et de gestion, la politique d'approvisionnement en eau a été révisée en 1997. Depuis le changement de politique, environ deux tiers des plus de 300 forages ont été fermés et de nombreux barrages de captage percés dans un processus continu. Cette nouvelle approche d'approvisionnement en eau a une forte concentration spatiale et vise à recréer et à imiter une mosaïque plus naturelle de variabilité spatio-temporelle de la disponibilité en eau de surface. Les gestionnaires du PNK espèrent que la variation de l'approvisionnement en eau va induire des variations spatiales et temporelles dans la façon dont les éléphants utilisent les paysages, ce qui est un objectif clé du plan actuel de gestion des éléphants du PNK. Bien qu'il semble peu probable que la disponibilité réduite de l'eau ait eu des effets numériques sur la population des éléphants à ce jour, elle a induit quelques changements

spatiaux: les éléphants sont encore plus fortement attirés par les grands systèmes fluviaux qu'auparavant. Il faut plus de recherche pour déterminer si la manipulation des eaux de surface dans le PNK où l'eau est assez largement distribué naturellement, est efficace dans la création de refuges spatio-temporels de la biodiversité sensibles aux impacts des éléphants.

History of artificial water provision in Kruger National Park

Artificial water sources in Kruger National Park (KNP) consist of borehole-fed water points and constructed catchment dams in ephemeral rivers. These were introduced from as early as 1911, but a concerted effort was made, especially in the 1960s, when a dry cycle occurred just as the western boundary fence was completed. Initially the water provision programme was primarily intended to stabilize existing water, supply water where water supposedly previously existed and provide water during periods of severe droughts (Pienaar 1970). This was further amplified by the perception that the lowveld was experiencing progressive desiccation (Pienaar 1985). However, by 1995, 365 boreholes and about 50 earth dams had been constructed throughout the park, leaving less than 20% of the park farther than 5 km from permanent water during a severe drought (Gaylard et al. 2003). This was clearly an unnatural situation.

Revision of water provision policy

During the 1980s and early 1990s, it became evident that the wide distribution of artificial water sources in KNP and surrounding parks had various ecological effects. These effects included elevated starvation-induced mortality of herbivores due to wide-scale overgrazing during severe droughts (Walker et al. 1987), altered herbivore distribution patterns (Smit et al. 2007a), changed predation patterns with detrimental effects on the rare antelope (Harrington et al. 1999; Owen-Smith and Mills 2006), as well as effects on woody vegetation structure (Brits et al. 2002) and herbaceous species composition (Parker and Witkowski 1999). These unnatural effects of water provision together with the change in paradigm for KNP from a *nature-in-balance* management approach towards a *nature-evolving* approach (Grant et al. 2002; du Toit et al. 2003) led to a revision of the water provision policy in 1997 (Pienaar et al. 1997). The revision of the policy paved the way for the closure of numerous boreholes and the breaching and rehabilitation of various catchment dams. This process of reducing and manipulating the distribution of artificial waterholes is still ongoing as capacity and funding allows, as new phases are rolled out and as decisions are revised through the adaptive management process (see Figure 1 for the historical and current distribution of boreholes).

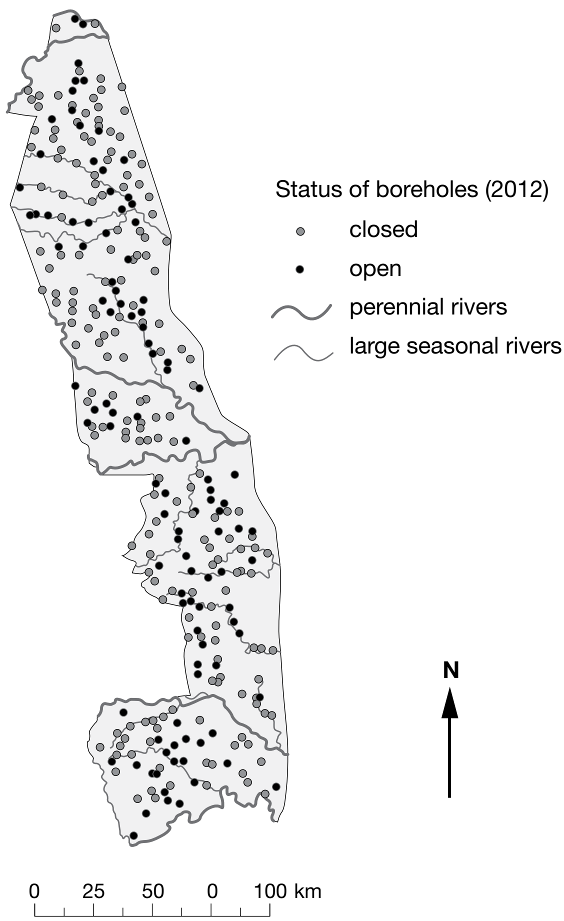

Figure 1. Distribution of borehole-fed artificial waterholes in Kruger National Park in the early 1990s (grey and black dots combined) and 2012 (black dots only). Note how the boreholes have been reduced to about a third of their historical extent.

The dilemma of artificial water provision (or non-provision)

The process of reversing the wide-scale provision of surface water in the park, as outlined above, is complex. A multitude of objectives make competing claims for management actions regarding water provision. For example, the artificial water provision network will look different when developed with tourism objectives in mind (e.g. numerous waterholes next to tourist roads) compared with when it was designed for managing elephant impact (e.g. no or very few waterholes) or to benefit relationships with neighbouring communities (e.g. strategic placement of waterholes to discourage elephants from breaking fences to reach water sources outside the park). In fact, over and above the issues listed above, the artificial water network would look different yet again when designed based on consideration of, for example, the limitations imposed by the fence on migratory patterns of herbivores, the spread of disease (anthrax and algal blooms), poaching foci, groundwater resource management, overgrazing and erosion control, predictions of drier and hotter future conditions, continual deterioration of quality and quantity of water entering the park's rivers, etc. In short, for some criteria water provision seems sensible while for others it seems detrimental. It is therefore evident that no silver bullet solution exists towards water provision that will satisfy the multitude of competing objectives. This complexity has led KNP to taking a systems approach towards water provision rather than a symptomatic or issue-based approach that futilely aims to optimize competing claims (Smit et al. 2008).

Systems approach towards water provision

Surface water availability in KNP changes over various temporal and spatial scales. This variability is driven by the spatio-temporal variability in rainfall and the arrangement of geological and topographical features in the landscape (Redfern et al. 2005). However, the historical wide-scale provision of artificial waterholes largely suppressed this spatio-temporal variability, especially during drought periods (Smit and Grant 2009). The new systems approach towards water provision therefore purposefully avoids providing water evenly across the landscape or providing water in areas that are naturally dry. These criteria provided the 'rule set' for evaluating the desirability of existing waterholes. For example, if an artificial waterhole occurred in an area that is naturally dry, then it was earmarked for closure, whereas if a waterhole occurred in an area that is close to a naturally occurring permanent water source, it could be condoned for tourism purposes without having huge systemic effects. The artificial water provision network that emerged after applying these rules resulted in a much reduced and changed distribution of waterholes—only about a third of the original boreholes are still operational, with others still earmarked for future closure. These closures were an attempt to restore a mosaic of water availability across the KNP landscape, creating 1) areas that are always in close proximity to perennial water—e.g. areas close to perennial rivers or the remaining boreholes, 2) areas that are hardly ever close to perennial water in the dry season—e.g. areas on the northern basaltic plains and 3) areas that vary in their availability of water based on localized conditions—e.g. areas next to ephemeral rivers where the availability of pools vary between seasons and years. It is assumed that the wider range of spatio-temporal water availability will create heterogeneous utilization patterns, creating conditions suitable for a wider suite of biodiversity than would be the case with a dense and even distribution of water.

KNP Elephant Management Plan and water provision policy

Since the 1990s, elephant management in KNP has moved away from a largely numerical approach where the elephant population was kept within a narrow range (6,000–8,500, Joubert 1986) towards the current spatial approach where elephant impacts rather than numbers are managed through inducing spatial and temporal variation in how they utilize the landscape (SANParks 2013). Restoring the spatial limitations of the landscape is crucial to this new approach, and the two main strategies available for achieving this are 1) increasing the area available for elephants and 2) restoring the heterogeneous resource limitations that previously existed. Management partly implemented these two strategies 1) by dropping fences between KNP and more than 1 million hectares of contiguous conservation land including the Limpopo National Park in Mozambique on the eastern boundary and private game reserves in South Africa on the western boundary and 2) by reducing the distribution of artificial waterholes. This approach resulted in larger areas for elephants to roam with a wider range of surface water availability. These changes should result in increased spatio-temporal variability in elephant distribution and impact.

It is important to note that the process of restoring the natural variability in water availability was not introduced specifically for achieving elephant management objectives. In fact, the elephant and the water provision management plans converged because both subscribed to a broader systems approach philosophy. As such, the new systems approach towards artificial water provision in KNP provides an important tool in the multipronged approach towards achieving the objectives as set out in the KNP Elephant management plan (SANParks 2013).

Numerical and spatial responses of elephants to closure of artificial water points

The closure of more than two-thirds of KNP's boreholes and the breaching of various artificial dams since the 1990s did not have any noticeable short-term numerical effect on the park's elephant population (Figure 2). It can be argued that this may be due to the fact that elephants in KNP have not yet experienced water limitations after waterhole closure. At regional scales, however, numerical responses vary considerably (SANParks unpublished data), some of which may reflect responses to resource availability at regional scales. It is likely that the effect of closing waterholes will only become evident during a severe drought and allowing the elephant population to respond following the release from culling pressure.

Although the closure of waterholes did not induce noticeable park-wide numerical effects after 15 years of extensive waterhole closure, there is some evidence suggesting spatial responses (Figure 3). Localized dry season elephant densities have increased disproportionally around large perennial rivers and large seasonal rivers compared with smaller streams and areas far removed from rivers where localized densities have shown only limited changes (Smit and Ferreira 2010). It is therefore suggested that dry season utilization patterns have intensified around most large rivers in recent years in response to the closure of artificial water sources and the moratorium on culling.

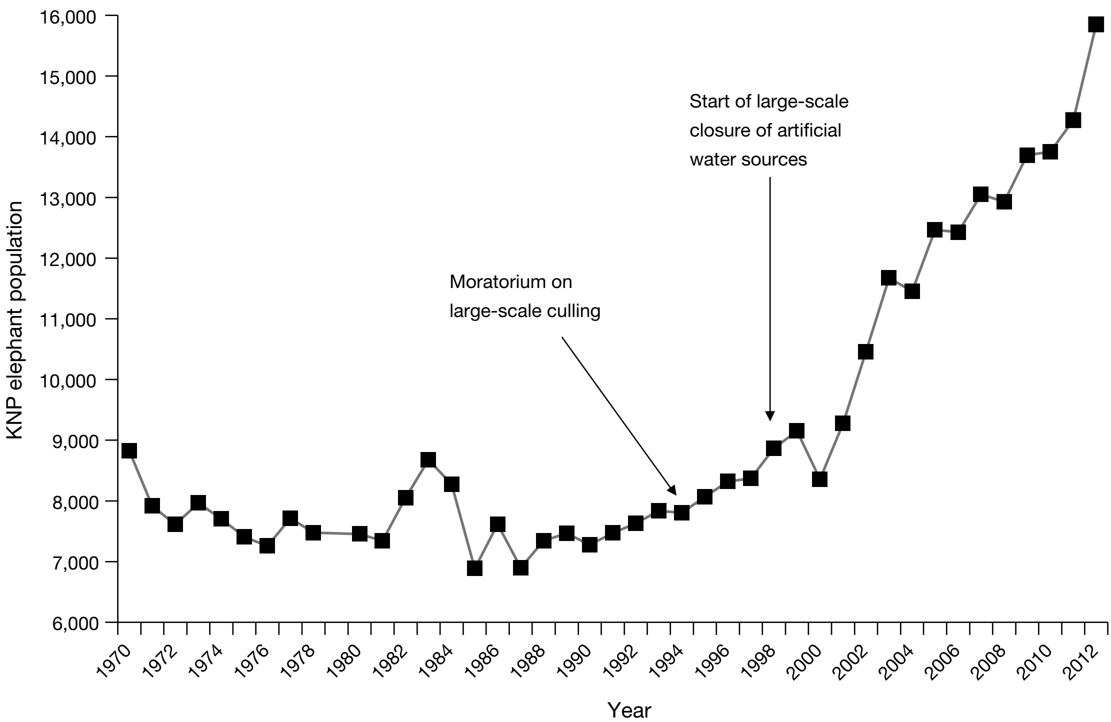

Figure 2. Kruger National Park (KNP) elephant population has not shown a noticeable numerical response at the park level to the wide-scale removal of artificial waterholes after revision of the policy in 1997.

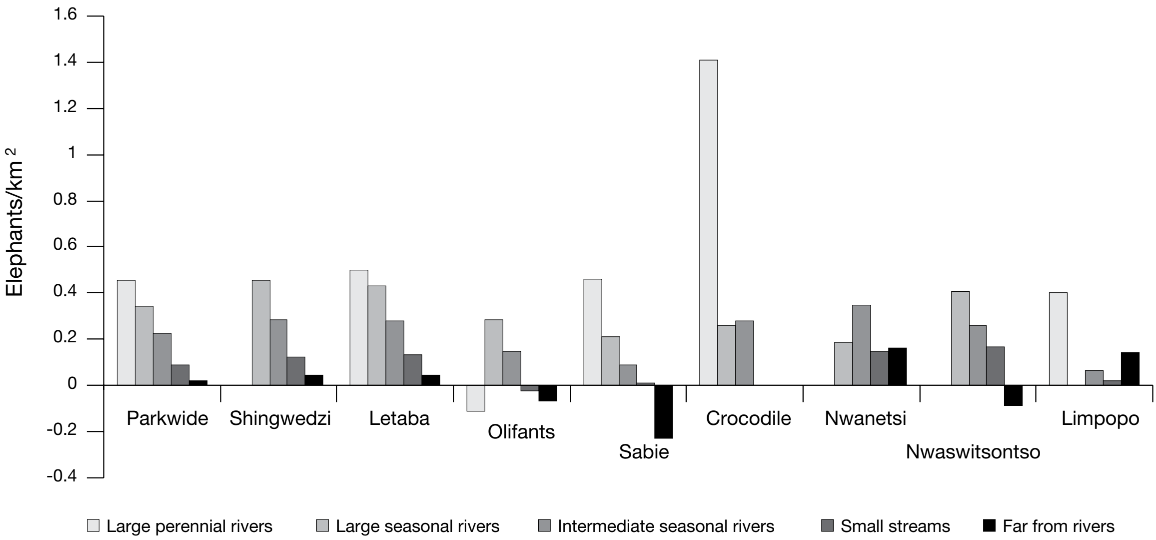

Figure 3. Changes in average elephant density in 2-km wide buffers around different sized rivers in various major catchments between an era of low-intensity management (i.e. era of reduced artificial water provision and no culling, 1997–2007) and an era of high-intensity management (i.e. era of large-scale water provision and active culling, 1985–1994). Positive values indicate increases in elephant densities between the two eras; negative values indicate decreases. Note how elephant densities responded spatially to the combined effects of reducing artificial water provision and stopping the culling—not only did the elephant densities respond spatially *within* a catchment (with densities generally increasing more around larger rivers than smaller rivers), the densities also responded spatially *between* catchments (e.g. the densities around the Crocodile River increased by 1.4 individuals/km^2 whereas densities decreased by 0.1 individuals/km^2 around the Olifants River) (based on data from Smit and Ferreira 2010).

Creation of water-remote refugia for biodiversity sensitive to elephant effects

Although elephants are water dependent and routinely drink from artificial water sources in KNP (Figure 4), it is unknown if and to what extent reducing artificial waterholes has changed the intensity and landscape-scale distribution of their impact. Considering the focus of the current Elephant Management Plan on spatio-temporal impacts of elephants rather than on population numbers per se (SANParks 2013), it is critical to ascertain how the manipulation of surface water has and can further be used as a tool to influence the intensity and distribution of elephant impact

Figure 4. Elephant bull drinking from artificial waterhole in Kruger National Park.

across the KNP landscape. In light of recent studies illustrating the high rate at which elephants are currently transforming woody vegetation structure in certain KNP landscapes (Asner and Levick 2012; Vanak et al. 2012; Levick and Asner 2013), this is a critical research gap that needs urgent attention. Considering the ability of elephants to move large distances between forage and water resources and the widespread distribution of naturally occurring water in KNP during most years, it is unclear how effective the closure of artificial water sources has been and can be in creating so-called 'water-remote areas' where the impact of elephants would be lower (Owen-Smith et al. 2006; see Fensham and Fairfax 2008 for a discussion on the importance of water-remote areas). Figure 5 illustrates that under the historical water provision scenario (> 300 boreholes), only 1% of the entire KNP was more than 10 km from the closest borehole or perennial river. Surprisingly, however, only an additional 10% of the park is currently farther than 10 km from the closest borehole or perennial river even after more than 200 boreholes have been closed. The possible future scenario, with about 60 boreholes remaining operational, will result in about 25% of the park occurring farther than 10 km from a borehole or perennial river, compared with 67% of the park being farther than 10 km from a perennial river if all boreholes were to be closed. What this clearly illustrates is that even though water availability has been drastically reduced by approximately two-thirds in the past 15 years, this has contributed relatively little to creating additional water-remote areas. As such, the closure of artificial surface water sources may still be inadequate to create sufficient spatial refugia for biodiversity aspects that are sensitive to elephant impacts. For example, most trees within the park are still within easy access for elephants from the closest permanent water source, and as a consequence are at risk of getting exposed

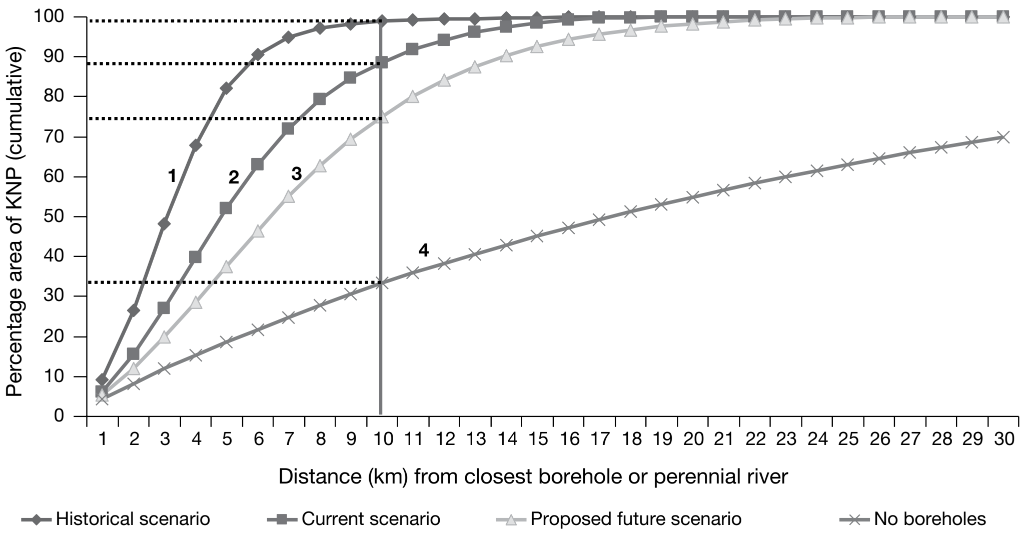

Figure 5. Cumulative percentage area of Kruger National Park (Y-axis) at incremental distances from the closest borehole or perennial river (X-axis). Assuming that elephants can move 10 km between water and forage resources daily, only 1% of KNP occurred in areas that can be considered 'water remote' for elephants and as such only 1% of the park occurred outside the zone of potential elephant impact during the peak of the water provision programme (**1** [historical scenario] > 300 boreholes). With the current distribution of just more than 100 boreholes (**2** [current scenario]), 11% of the park occurs farther than 10 km from the closest borehole or closest perennial river, with 25% of the park under the scenario planned for the future (**3** [proposed future scenario]). When no boreholes are present, 66% of the park occurs more than 10 km from the closest perennial river (**4** [no boreholes]). The waterhole closure will, however, have more of an effect on species that prefer to travel no more than 5 km per day between forage and water resources (e.g. meso-herbivores like zebra and wildebeest), with 50% of the park already farther than 5 km from the closest borehole or perennial river (compared with less than 20% under historical conditions). Note that seasonal rivers, dams, fountains and pans were excluded from this analysis and therefore the scenarios depicted here present severe drought conditions. In most years, however, the cumulative graphs would be even more skewed towards the upper left corner with less area occurring far from the closest perennial water source.

to elephant impact. The influence of surface water manipulation on elephant density, distribution and movement patterns will most likely be significantly smaller in KNP than in systems with a more restricted distribution of natural surface water where artificial waterholes have been shown to exert extensive spatial and demographical responses, e.g. Chobe (Verlinden and Gavor 1998), Hwange (Chamaillé-Jammes et al. 2007a), Etosha (de Beer and van Aarde 2008) and other African savannah parks (Loarie et al. 2009). Care should therefore be taken to have realistic expectations on the influence that Kruger's management can potentially exert on the park's elephant density and distribution by ways of manipulating artificial water sources (see debate between Smit et al. 2007b and Chamaillé-Jammes et al. 2007b).

Conclusions

Applying a systems approach philosophy, KNP has since the late 1990s moved away from providing water widely and evenly across the landscape, moving towards a reduced distribution of artificial water sources. The closing of waterholes and the breaching of catchment dams are an ongoing process to mimic the natural variability in surface water availability more closely within the constraints imposed by fences and stakeholder relationships (e.g. tourists, neighbouring land-users). It is anticipated that the current water provision scenario induces more spatial and temporal variation in how herbivores utilize the landscape than was the case at the peak of the water-for-game programme, resulting in a more natural and ultimately more resilient system.

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