An Investigation into the Efficiency of Utilization of Artificial Game Water Supplies by Wildlife Species in the North Eastern Kalahari Region of Hwange National Park in Zimbabwe

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Abstract An observational study was carried out to determine the efficiency of utilization of artificial game water supplies and the demand for water by wildlife species at selected water points in the North Eastern Kalahari region of Hwange National Park, Zimbabwe. Six water points were randomly selected from the two distinct vegetation types. Data was collected from May to November 2005 and this included borehole yield, evaporation and seepage rates as well as wildlife water consumption. Analysis of variance was then carried out in a two level nested design to analyse the data using the GENSTAT 7th edition statistical package software. The study showed that they were significant differences (p<0.001) in the borehole yield, evaporation, seepage and the amount of water consumed during different times of the year and at water points within the different vegetation types. The study has shown that the amount of water pumped by a borehole will meet the dry season water requirements of wildlife species early in the dry season but will fail as the dry season progresses. It is recommended that pumping of water begins early in March and that as the dry season progresses there is need to supplement water supply at certain water points.

Keywords: Hwange National Park, artificial game water supplies, water consumption, water availability, evaporation and seepage

1. Introduction

Hwange National Park is the largest game reserve in Zimbabwe and the third largest in Africa [25]. The major objective for the creation of the park was to increase populations of large herbivores for tourism and maintenance of biological diversity for genetic conservation. This was to be achieved by creating Artificial game water supplies (AGWS) to meet the water requirements of the water dependent wildlife species [10], a decrease in carnivore population and early dry season burning [25]. Artificial game water supplies effectively increased the dry season habitat available to water dependent species from 24% in 1935 to 71% in 1989. The major increase was seen in the elephant population, which was about 2000 in 1930 and increased to about 11000 in 1965 [6] and about 45000 in 1996. Presently there are estimated to be about 65000 elephants in the park [26].

The creation of AGWS has been faced with a lot of challenges chief among them the increase in elephant populations, shortage of funds and resources to sustain the system as well as inadequate research and monitoring [10]. Due to water shortages there has been seasonal migrations of wildlife to neighboring Namibia and Botswana [16] and this been viewed as a major threat to biodiversity. Artificial game water supplies are long seen as the solution to such migrations. However, there is insufficient knowledge on the amount of water supplied by the existing network of boreholes and factors such as evaporation and seepage losses have not been thoroughly explored [13]. In addition to that a detailed estimate of water demand by wildlife species at various water points at HNP is not known [26]. Hence this research was carried out so as to assess artificial game water supplies and the dry season water requirements of wildlife in HNP. This was to give a general overview of the state of AGWS in the park and hence the efficiency of the system.

For a long time the study of waterholes has created a lot of interest amongst wildlife managers [2], and is actually one of the most active fields of research in African ecology [15]. In HNP AGWS are amongst the top research priorities [14]. Water is and has long been a contentious and fundamental management tool for HNP and there is need to analyse the whole complex of water and other related issues.

Knowledge of water demand by wildlife species in the park can help us to calculate the carrying capacities of the park in terms of available water[4,21]. This is very crucial

as there have been reports of overpopulation especially of elephants at HNP [25]. Such a research will give answers as to whether the current population of wildlife is sustainable as far as the management's capacity to provide water is concerned. Furthermore there has been much debate about the cost effectiveness of the current method of water supply. This will aid in determining the economics of pumping water for 20 hours per day which is the current regime. This is very important especially considering the harsh economic climate currently bedeviling the country of Zimbabwe. This is particularly seen in the escalating fuel costs as well as fuel shortages. Consequently a cost effective method of water supply will be adopted. Knowledge of both water supply and demand is vital to the management of the Park as it will help in finding the actual efficiencies of AGWS .

Usually AGWS are created at random in a game park, however when these water points are established without careful planning this leads to the, "water point syndrome" [4]. This is the deterioration of the veld through trampling, overgrazing and soil erosion. This is a common feature with waterholes [8,18,23,24]. At HNP there has been a suggestion on rotational pumping this is the idea of closing some waterholes so as to rest them and reduce habitat degradation around the area by decreasing grazing pressure [19]. Thus after knowing water demand at different waterholes decisions can be made on which waterholes to close without compromising on water supply and at the same time allowing for the recovery of the vegetation. This is very important because appropriate spacing between artificial water points will apportion vegetation impacts evenly between the parks and allow plants a period of recovery from severe grazing pressure

[14]. Furthermore the removal or closure of water points could be used to restrict use of habitats and thus avoid human-animal conflicts, excessive animal densities and reduce animal-rangeland conflicts [1].

The research will also benefit most wildlife managers in areas with the same ecological environment as HNP. This is because they are a few scientific publications on the utilization of waterholes by animals on game ranches in the different geographic regions of Southern Africa [4].

2. Materials and Methods

2.1. Study Site

The study was carried at Hwange National Park which is situated in the Northwest of Zimbabwe and has been divided into a number of management compartments of which this study was conducted in the North eastern Kalahari area commonly referred to as Main Camp. The average rainfall of the area is about 620mm with minimum and maximum temperatures of between 24°C and 33°C. In July temperatures have been recorded to drop as low as 4.6°C with occasionally black frost after every five years.

There are a vast number of water points at HNP which consists of pans, seeps, springs and pools. The majority of these are seasonal containing water during the rainy season only. Artificial water points are sunk close to a number of pans to pump water into them. The North Eastern Kalahari region consists of 40% of the artificial water points of which they were 13 operational boreholes during the study.
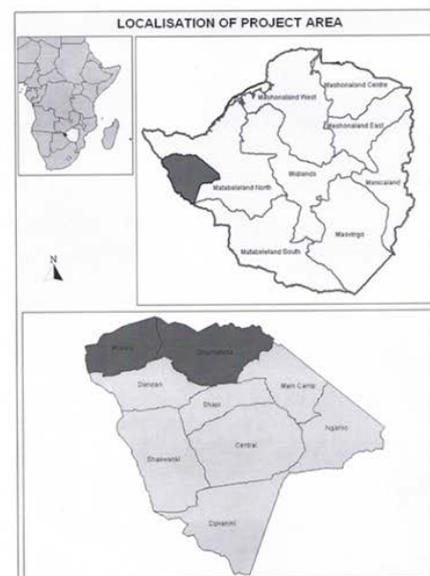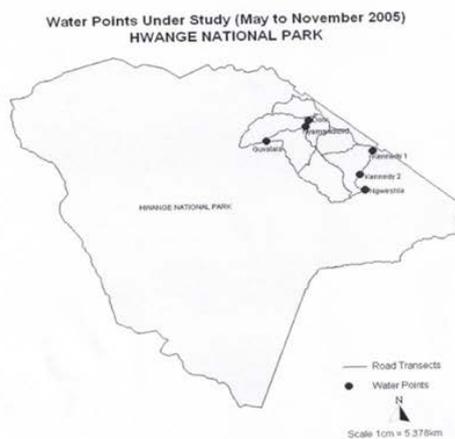
Figure 1. Study Area

Large mammal community is dominated by elephant which make up 70% of the total biomass whilst buffalo, giraffe and Impala make up 24% the remaining 6% is made up of carnivores and birds species.

2.2. Study Sites

Information on operational borehole statistics around the Main Camp area was gathered and the area was

divided into two main blocks according to vegetation type. The first block consisted of the woodland and shrubland (*Colophospermum Mopane* and *Combretum* spp) and the second block consisted of the grassland and open vleis (*Heteropogon a*nd *Eragrostis* spp).

Six water points were randomly selected from the thirteen operation boreholes in the area taking into account accessibility by road and the water quality characteristics

such a s alkalinity, acidity and saltiness. Thus they were three water points in each block (Figure 1).

2.3. Data Collection

24 hour animal observational counts were conducted every full moon of the month from May to November 2005 at each water point. At the same time water yield by a borehole at each point as well as the volume of water in a pan were recorded. For yield this was done by using a 3000ml measuring cylinder and a stop watch. The amount of water flowing through the trough per second was recorded. This was repeated 20 times to improve accuracy and the average was to be calculated. A water canoe was used to sail across the pan and the depth of the pan at various points was measured using a calibrated dip stick. The perimeter of the pan was used found by using a tape measure.

The data collected was used in the determination of water consumption, water yield per day, evaporation and seepage estimates.

Water consumption (W_c) per day =24 hour animal counts for each animal *$0.1045*m^{0.88}$ [13] where 'm' is the average species body mass. The values were obtained from the biomass estimated weights of wildlife species [24].

$$\text{Water yield} \left(W_y\right) \text{ per day}$$
$$= W_p \begin{pmatrix} \text{average water} \\ \text{pumped per second} \end{pmatrix}$$
$$*\left(20\text{hrs}*60\text{min}*60\text{sec}\right).$$

Volume of water in the pan=$\pi r^2 h$, where 'r' is the average radius of the pan (perimeter=$2\pi r$) and 'h' is the average depth of the pan.

Evaporation estimates (W_e)=W_v*r^2*y, where 'r' is the radius of the pan and 'y' is the evaporation rate obtained from the Meterological Office.

The inflow-outflow rate principle was used to estimate seepage losses (W_s) [20] - briefly a 5 litre cylindrical container was ¾ filled with soil obtained from the pan under study and water was added into the soil and the rate at which water was percolating was noted. Extrapolation was done to find out the rate at which water percolated to the ground. This was then extrapolated to find the rate at which water percolated to the ground in the water pan.

$$\frac{ds}{dt} = \frac{W_b - W_a}{\text{time taken}}$$

as the dry season and pumping progressed, a correction factor of 0.1 was used. This was to account for soil saturation and hence decreases in seepage losses [13]

$$W_s = \frac{ds}{dt} \times W_v$$

Seepage rate = Volume / area / time.

This information was used to determine the amount of water available to wildlife per day $W_a=W_y-(W_e+W_s)$ and this was paralleled to the amount of water consumed per day.

2.4. Data Analysis

An analysis of variance was carried at the 95% confidence limit in a 2 level nested design to show the differences in water consumption and water yield at water points located in two different water points. The Least Significance Difference value was used to separate the means where they were statistically different.

3. Results

3.1. Artificial Game Water Supplies

They were significant differences in evaporation and seepage (p<0.001) during different times of the year but no differences for borehole yield (p=0.687). They were significant differences in borehole yield, evaporation and seepage between the two vegetation types and at water points within the two vegetation types (p<0.001). See Table 1, Table 2 and Table 3.

Table 1. Volume of b/hole yield, evaporation and seepage in different times of the year

Month	B/hole yield (m³/day)	Evaporation (m³/day)	Seepage (m³/day)
May	100	14.67[a]	19.83[h]
June	99.67	15.77[a]	17.87[g]
July	99	15.67[a]	16.3[f]
August	99	19.28[b]	15.31[e]
September	99.5	24.21[c]	13.18[c]
October	99.17	27.15[d]	11.95[b]
November	99	27.12[d]	10.72[a]
Grand Mean		20.56	15.01
LSD		2.7	0.8
C.V. %		9.48	4.48

*means with different superscripts in the columns are significantly different.

Table 2. Volume of b/hole yield, evaporation and seepage in the two vegetation types

Vegetation	B/hole yield (m³/day)	Evaporation (m³/day)	Seepage (m³/day)
Grassland	98.62[a]	17.43[a]	15.22[b]
Shrub&woodland	100.05[b]	23.64[b]	14.8[a]
Grand Mean	99.33	20.56	15.01
LSD	1.31	1.9	0.4
C.V. %	1.2	7.9	3.2

*means with different superscripts are significantly different.

Table 3. Volume of b/hole yield, evaporation and seepage at water points nested within different vegetation types

Vegetation	Water point	B/hole yield (m³/day)	Evaporation (m³/day)	Seepage (m³/day)
Shrub&woodlands	Dom	85.43[b]	17.9[b]	13.27[c]
Shrub&woodlands	Guvalala	88.14[c]	16.13[b]	12.71[b]
Shrub&woodlands	Nyamandlovu	126.57[f]	41.34[e]	18.25[e]
Grasslands	Kennedy1	70.71[a]	12.01[a]	9.33[a]
Grasslands	Kennedy2	111.14[d]	18.88[bc]	21.14[f]
Grasslands	Ngweshla	114[e]	28.87[d]	16.07[d]
*means with different superscripts across columns are significantly different.				
Grand Mean		99.33	20.56	15.01
LSD		1.31	1.9	0.4
C.V.%		1.2	7.9	3.2

Table 4. Water consumption (m3/day) during different times of the year

Month	Water consumption (m^3/day)
May	52.8^{bc}
June	33.3^{ab}
July	6.8^a
August	72.5^c
September	72^c
October	73.3^c
November	84.5^d

*means with different superscripts across columns are significantly different.

Grand Mean	56.5
LSD	29.5
C.V.%	44.3

3.2. Water Consumption

They were significant differences in the amount of water consumed during different times of the year (p<0.001) and at water points within different vegetation types (p<0.001) but they were no significant differences in the different vegetation types (p=0.625) Table 4 and Table 5.

Table 5. Water consumption at water points nested within different vegetation types

Vegetation type	Water point	Water consumption (m^3/day)
Shrub&woodlands	Dom	21.7^a
Shrub&woodlands	Guvalala	56.9^b
Shrub&woodlands	Nyamandlovu	96.6^c
Grasslands	Kennedy1	41.4^{ab}
Grasslands	Kennedy2	45.4^{ab}
Grasslands	Ngweshla	76.9^{bc}

*means with different superscripts across columns are significantly different

Grand Mean	56.5
LSD	27.33
C.V. %	44.3

Table 6. Variations in the volume in b/hole yield, evaporation, seepage and animal consumption during different times of the year

Month	B/hole yield (m^3/day)	Evaporation (m^3/day)	Seepage (m^3/day)	Animal consumption(m^3/day)
May	100.00^c	19.46^a	12.83^a	52.83^b
June	99.67^c	19.52^a	16.37^a	33.33^b
July	99.00^c	18.49^b	16.6^{ab}	7.92^a
August	99.00^c	14.71^a	12.89^a	72.34^b
September	99.50^c	22.59^a	15.58^a	72^b
October	99.17^c	22.03^a	15.95^a	73.33^b
November	99.00^c	19.78^a	14.72^a	84.5^b

*means with different superscripts across columns are significantly different

Grand Mean	47.6
LSD	11.7
C.V.%	44

3.3. Artificial Game Water Supplies and Water Consumption

They were significant differences in the volume of borehole yield, evaporation, seepage and water consumption during different times of the year (p=0.028) and at water points within different vegetation types (p=0.009) Table 6 and Table 7.

Table 7. Variations in b/hole yield, evaporation, seepage and animal consumption at water points nested within different vegetation types

Vegetation	Water point	B/hole yield (m^3/day)	Evaporation (m^3/day)n	Seepage (m^3/day)	Animal consumption (m^3/day)
Shrub&woodlands	Dom	85.43^b	17.39^a	16.78^a	19.63^a
Shrub&woodlands	Guvalala	88.14^c	18.36^a	15.48^a	55.71^b
Shrub&woodlands	Nyamandlovu	126.57^c	22.79^b	12.71^a	94.49^c
Grasslands	Kennedy1	70.71^c	19.13^a	15.83^a	43.51^b
Grasslands	Kennedy2	111.14^c	22.14^a	15.02^a	47.38^b
Grasslands	Ngweshla	86.24^c	22.79^a	14.11^a	78.94^b

*means with different superscripts across columns are significantly different

Grand Mean	47.6
LSD	9.04
C.V.%	44

3.4. Efficiency of Artificial Game Water Supplies

The results show that there are times when the combined effect of evaporation, seepage and animal consumption exceed the amount of water supplied Figure 2. This also occurs at different water points Figure 3.

4. Discussion

The study has shown that there were significant differences in borehole yield at water points nested within different vegetation types and there were no significant differences in the borehole yield at different times of the year. Borehole yield is affected by a number of factors, the number of new boreholes in the vicinity, the year-to-year variations in rainfall, borehole depth, type of soil, the detrimental effects of locally planting large number of trees through increased transpiration and the type of engine used to pump water [12]. Desk studies revealed that at HNP water is pumped into the pans using monopump engines with different pump unit sizes. Basically there are two major pump unit sizes used at HNP, the BH30 and the BH50 engines with a standard average yield of 4.5m^3 per hour and 6.0m^3 per hour respectively. This translates to

90m^3 and 120m^3 per day assuming a 20-hour pumping day, which is applied at HNP. In this study it was established that the average yield of the BH30 and BH50 engines was 82.4m^3 and 111.35m^3 respectively. This shows that there is a 8-11% loss before water actually goes into the water pans. This might be attributed to a number of factors. The Kalahari sands have great open spaces and water yield will be low, periodic droughts have resulted in incessant rainfall below the normal expected for example the 2004-2005 season received about 280mm, which is below the

anticipated 620mm this affects borehole yield. In addition to that there have been postulations about the depletion of ground water resources at most water points [26]. The close spacing of the boreholes [14] might lead to competition in underground water resources hence lower yields. In addition to that the boreholes are now very old and they have become inefficient over the years. This is due to leakages which might occur in the system and reduced overall efficiency due to the, 'wear and tear effect', of the old engines. There are also increased frictional forces.

Percentage of evaporation, seepage and animal consumption relative to borehole yield
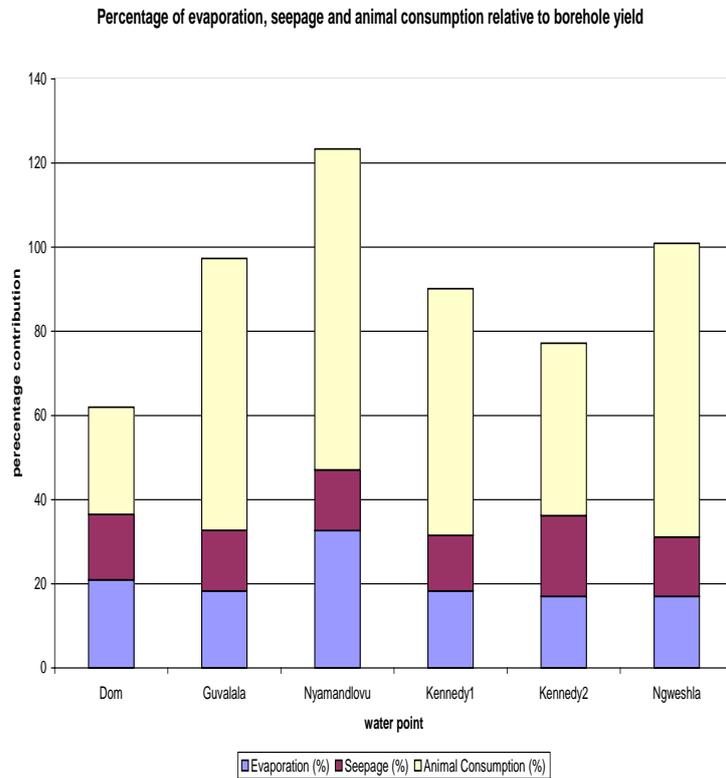
Figure 2. Evaporation, seepage and animal consumption as a percentage of borehole yield at different times of the year

Percentage of evaporation, seepage and animal consumption relative to borehole yield
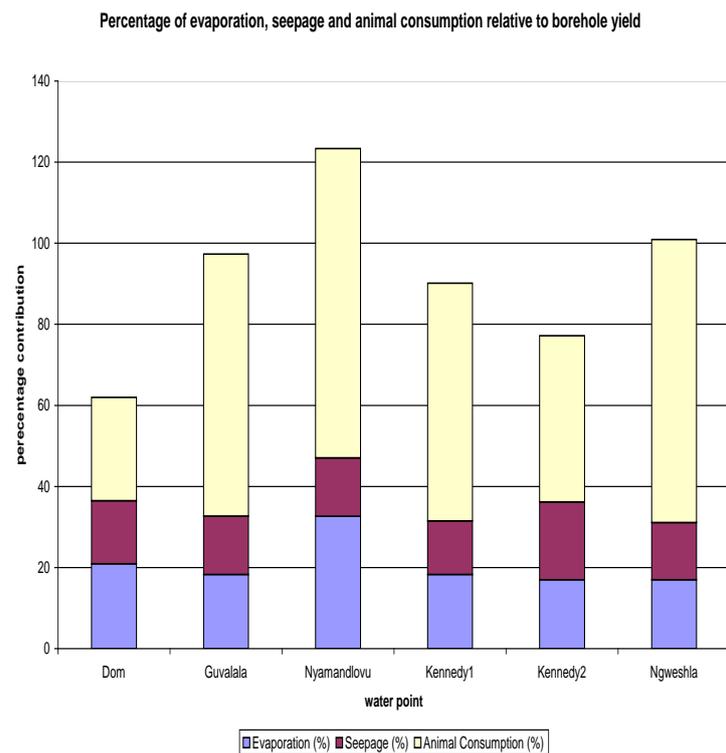
Figure 3. Evaporation, seepage and animal consumption as percentage of borehole yield at different water points

In different months there were no significant differences in borehole yield because the overall factor affecting the yield of boreholes is the same throughout the park. In semi-arid and arid environments water availability is highly seasonally and this means it will vary at different times of the year [24].

This study has revealed that there were significant differences in the amount of water lost through evaporation and seepage at different times of the year and at water points located within different vegetation types. Information obtained from the Meterological department of Zimbabwe revealed that evaporation rates for HNP increases as the year progresses. Evaporation is affected by a number of factors wind speed, presence of impurities in the water, temperature, relative humidity and the size of the water body [9]. As the year progresses evaporation increase because of the increase in temperature and relative humidity. In this study evaporation was the greatest in October and November and least in June and July. This is because in October and November thus when the highest temperature was recorded and in June and July thus when the lowest temperature was recorded. They are also temperature variations amongst the different water points [22]. During the study temperature variations amongst water points were also observed and hence differences in evaporation rates. The differences in evaporation at water points within two different vegetation types can be largely attributed to the differences in the pan sizes of the individual water points. The pan with the greatest size in this case Nyamandlovu shows the highest evaporation whilst the pan with the lowest size show the least evaporation (Kennedy 1).

The accuracy of seepage depends on the inflow rate, outflow rate, evaporation and the perimeter of the area. In this case the inflow rate is the borehole yield and the outflow is the water consumption and evaporation. The rate of seepage is seen to decrease however as the year progresses, this is largely attributed to soil saturation in the water points [13]. The difference between the water points is largely attributed to the differences in soil type, size of the water pan, as well as the rate of inflow and outflow. Kennedy 2 shows the highest seepage rates as compared to other water points, this might be largely attributed to the soil type which predominates the area. There area is the beginning of a muddy and swampy vlei which runs up to the Simmamalisha areas and hence because of this there are possibilities of high seepage areas as compared to other water points.

The study has shown that there were significant differences in the amount of water consumed by wildlife at different times of the year and at water points located within different vegetation types. The drinking behaviour of animals is affected by locality, man and seasonal conditions [24]. Location may inhibit some animals to visit water points for drinking purposes. Elephants are very particular when it comes to drinking water [22]. They usually prefer water points with cool and clean water [4]. Since they constitute 70% of the total biomass in HNP, they are a keystone species in the Park [5] and thus will influence waterhole utilisation to a large extent. From the water hole counts data it was established that elephants visited Nyamandlovu, Guvalala and Ngweshla more than the other water points. This might be largely attributed to the water point characteristics in terms of water quality. At

HNP water points can be classified as 'salt lick type', alkali type and the acidic type [22]. This classification has been updated by using the results of the water quality chemical analysis of the water points in HNP carried out in June 2004 [7]. Elephants constituted 70% to 95% of the animal visits to water points during the time of study. They seem to prefer the salt lick type and the alkaline type of water points. In Southern Africa it has been seen that a high diversity of animals use artificial water points for both drinking water and mineral salts present in water [11]. This could be a probable explanation of the large number of animals in the salt lick type of pans and the alkaline pans that also bear some high levels of salts in the water.

Nyamandlovu and Ngweshla are the major tourist destinations in the North Eastern Kalahari region of the park and less animal visits are expected [22] due to human interference. Park regulations normally require tourists to return to camp at 1800 hours so they will have to leave some of the more distant water points by 1500 and 1600 hours. Animals come to drink from this time onwards. Most of the elephant visits were recorded at night probably due to the influence of tourists during the day and the high temperatures experienced during the day. This is a mechanism that animals use to maintain a labile body temperature by evaporative cooling [3]. The observers had much less impact, as they would hide in trees overlooking the pans or some vehicles at some distance from the pan. This might be the probable reason for the high water consumption at these major tourist centres. Dom is not a major tourists centre but recorded the least water consumption which might be due to its location that overrides human influence where by animals may not prefer it as it is an acidic type of pan. Guvalala is also a major tourist centre in the Park but the water consumption was significantly lower than that of Nyamandlovu and Ngweshla. This might be due to its location as an acidic type of pan hence it was least preferred. To a large extent location of the water point seems to exert a great influence on the water consumption as compared to the influence of man.

Man can also influence wildlife through his management activities. Animals are habitually and will tend to visit the sane pans throughout the year. Some water points are renowned to have water all year round. Therefore wildlife would prefer such water points where they know water is readily available. It is a management objective that when there is a labour crisis or fuel shortages to run borehole engines, water points close to the station are serviced whilst those that are far away are sacrificed. Thus water will tend to be available at some pans and not at others. In this case water points such as Dom, Nyamandlovu, Kennedy1 and Kennedy 2 are least affected. The fuel crises that rocked the park in July and August might have led to discrepancies in water consumption at Guvalala as compared to other water point. Guvalala was also faced with a lot of inconsistencies, which included incessant pump breakdowns (July, September and October) and fuel shortages which affected water availability and consequently water consumption.

Water consumption is also dependant upon the seasonal conditions. These have a large bearing on the physiology, body condition and available forage [8]. In this study more animals congregated at the water points as the dry season progressed however there was a significant drop in the

amount of water consumed by wildlife in the month of July. Information obtained from the Meterological Office revealed that at HNP July is the coldest month, hence water demand is expected to be low during this time of the year. The greatest water consumed was in the month of November. As the dry season progresses there are a lot of significant ecological and physiological changes, which occur in the habitat and wildlife respectively. Forage availability is low such that even the water independent species like the eland which depend on succulent feeds for their water requirements are also seen at water points [4]. Interestingly in HNP the eland was seen at water points in August and October at Ngweshla, Kennedy and Nyamandlovu water points. Also at this time the animals need a lot of water to meet their breeding requirements [17], a good example are the elephants.

Water availability has an important bearing on the structure and efficiency of the large mammal communities [24]. This can also be seen in other semi- arid ecosystems where it has been recorded that the extent and distribution of water in the dry season throughout the Masai area of Tanzania is probably the most important limiting factor in the number and distribution of game animals in the Savanna of East Africa and the carrying capacity of the country as a whole. Wildlife would therefore tend to migrate into areas where water is readily available. This also explains why in this study vegetation had no effect on the consumption of water by wildlife. [24] Concluded that when water is not available animals are bound by the localised distribution of water and spread out over a large area during the wet season. This basically means that water availability is a large determinant of the dry season concentration of wildlife around water points regardless of the vegetation type in question. That is why it is a crucial parameter in calculating the carrying capacity of a range [4]. Similar findings have been made in the Kruger National Park, South Africa, where the provision of artificial water sources had no effect on the natural patterns of habitat use by large herbivorous animals [21].

Water efficiency compares water consumption, evaporation and seepage relative to the borehole yield. This is important, as it will explain whether the system of supplying water is efficient in meeting the dry season water requirements. The study has shown that they are significant differences in the volume of borehole yield, evaporation, and seepage and water consumption by wildlife species. This is seen at different times of the year and at water points nested within different vegetation types. Generally it is shown that of the amount of water pumped by the engine, 56% is consumed by the animals, 20.7% is lost through evaporation and 15.17% is lost through seepage. Much of the pumped water is consumed by the wildlife. It was noticed the system of pumping water is overwhelmed at different times of the year and at different water points. There are times when the combined amount of evaporation, seepage and water consumed exceed the amount of water being pumped by the boreholes. The waterholes are muddy and water is only found at the trough and not much spills over into the water hole. This results in monopoly at drinking holes by elephants which congregate round the water troughs. Thus most of the animal visits at water points were largely attributed to elephants.

5. Conclusion

Observations during the study found out that the different engines (BH30 and BH50) currently being used at HNP use fuel at the same rates. From an economic stand point it is recommended that the BH50 engines be used since they yield more water. They might be expensive to buy but in the long run they will prove to be worthy since the maintenance costs of the two engines are the same yet the BH50 performs better. Of the amount of water that is pumped by the engines, a significant proportion 6% is lost before the water goes into the water pan. Therefore it is necessary to incorporate experienced hydrologists to investigate the losses that occur in the underground pipes up to the stage water enters the water pan. Ways to reduce water loss can then be found so that the borehole yields may reach the standard yields.

It has been established that evaporation and seepage contribute significantly (36%) to the amount of water losses in the water pans. As has been previously suggested, it is further recommended that ways be devised in order to reduce these losses. These include constructing concrete bottomed water pans that are rectangular in shape. This is in contrast to the present system where the pans are circular in shape hence the high rates of evaporation and seepage. The concrete and shape of the pan will greatly reduce seepage and evaporation respectively. The rectangular shape has a smaller surface area.

The amount of water consumed by wildlife varies with the time of the year and at water points in different vegetation types. The effect of time will help in planning the appropriate phase to begin pumping. Pumping begins after the rainy season is over usually mid-April to beginning of May. A delay in pumping can overwhelm the system as the dry season progresses due to increased animal demand. It is recommended to start pumping in March so as to build up reserves when the dry season comes. This will also reduce seepage losses since the rains would have saturated the soils.

There are differences in the volume of borehole yield, seepage, evaporation and water consumption at different times of the year and at water points within different vegetation types. Borehole yield is greater than the other parameters but this occurs at different times and at different water points. At certain times and water points the borehole yield is overwhelmed by the combined effect of evaporation, seepage and water consumption. Therefore it is recommended that at those water points where boreholes yield is overwhelmed it is necessary to supplement water supply. This can be done by using two engines to pump water at a water point. This management option was adopted at Nyamandlovu pan in August 2005. This was because of the reduction in water levels, which had reached alarming levels because of increased water demand. The desired results were achieved as the water levels were seen to increase due to increased supply otherwise the pan would have dried up.

As a scope of further study it is recommended that ways be devised to improve the reliability and accuracy of calculating seepage, evaporation as well as animal consumption. For instance in calculating animal consumption, the adult species body mass was used. To improve accuracy the age structure of the various animals visiting the water points should be taken into consideration.

Artificial game water supplies are a vital tool in the management of the park as they contribute immensely to the provision of water to wildlife species.

Acknowledgements

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