

This particular arid era may perhaps be linked to protracted periods of severe cold, such as the freezing temperatures experienced in the KNP in 1941, when night temperatures as low as -13,3 °C (8 °F) were recorded and which could have exacerbated the tree mortality.

Stevenson-Hamilton's annual reports from 1902 onwards, reveal much about the climatic regime during his 44-year term of service. His conviction that the Lowveld had undergone *progressive desiccation* during his time of office is of special relevance in the context of this discussion. He repeatedly referred to the *progressive desiccation* in his reports for the years 1912, 1913, 1920, 1925, 1932 and 1944.

In this regard special note should also be taken of the location of his White game rangers' posts, as, for example, Major Fraser's station at Malunzane on the Shongololo (tributary of the Tsende) from 1904 to 1920; Coetser's establishment in 1919 of his permanent post at Punda Maria near the Shikokololo Spring, and his outpost at Dzundwini Fountain; "Tim" Healey's outpost on the Nwanedzi (1910-1913) and Harry Wolhuter's outpost at Doispan during the 1920's and 1930's. A few important pickets of Black game rangers should also be mentioned such as: Saliji, Mahlobyanine, Batavia, Nyamene, Dotholi, Kostini, Shilowa, Bangu, Gaben and others. It would have been impossible to establish ranger stations at these sites today without supplying water by artificial means.

3. *The proclamation of the Kruger National Park in 1926 and the history and development of its water stabilization programme*

It is interesting to note that the programme of creating artificial water supplies in the park strongly correlates with consecutive periods of drought, and that the first dams and windmills were erected on sites where old, established natural water sources finally dried up during the 1926-1933 drought.

This process was repeated over and over again through the years, and the rationale behind the provision of artificial water since 1931 has been to ensure a dependable water supply in those areas where old, established sources dried up for some or other reason. In later years (since 1970) the need to stabilise the erstwhile perennial rivers in order to conserve the unique aquatic life forms in these systems, has become a very important factor. The history of natural water distribution in the KNP is evidently the result of a complex (and still not clear) succession of long and short term rainfall oscillations. From a practical management viewpoint it has become necessary to determine a definite tendency. The perpetuation of those environmental features (including natural water distribution) extant at the beginning of the century would have been of greater benefit to the ecosystems of the KNP and to the utilisation of them by Man than the weakened water resources of today. In a programme intended to simulate the natural water network present in this part of the Lowveld when the park came into being, the present water system would represent only a small fraction of what would ultimately be required. It will probably never be possible to restore the water that was available in those early years as watering places for game, unless one resorted to enormously expensive programmes.

To support this contention it will be necessary to cite a number of Colonel Stevenson-Hamilton's and his successors' observations on climatic changes (and to relate these observations to Dyer's and Tyson's short term rainfall cycles).

3.1 *The dry rainfall cycle: 1897-1916*

In 1904 Stevenson-Hamilton reported as follows on the Shingwedzi Reserve:

"This reserve has many points in its favour, *much of it being swampy* and of an alluvial nature..." "I would certainly advocate the removal of certain of the isolated kraals, which are nothing but hunting camps, to the larger rivers, where there is a larger population and no game."

In 1905 he wrote: "There is no doubt that all carnivorous species of animals bear a much lesser proportion to the game than they did three years ago. This is especially noticeable in regard of the Cape hunting dog." This species was mercilessly hunted and even poisoned, during the early years of the Sabi and Shingwedzi reserves.

For the year 1911 Stevenson-Hamilton described conditions in the Sabi Game Reserve as follows: "The year 1911 has, on the whole, been a healthy one for the locality. This is due, no doubt, to the small rainfall during the hotter months, and the practical failure of the early spring rains. There has been an almost total failure of native crops south of the Olifants river."

"There has been little grass in the Sabi area since the frosts which prevailed in June and July. The game managed to pick up a living somehow. Government stock suffered in condition, and matters have not been improved by the reckless manner in which grass fires have been lighted by natives and others employed by the Selati Railway. At the end of the winter it was necessary to distribute the transport animals in different small lots at various outlying picquets to obtain suitable grass."

(It is significant that Stevenson-Hamilton seldom mentions large-scale mortality amongst the animal populations of the old Sabi and Shingwedzi reserves, comparable to the decimation of animals which occurred during the 1960s and early 1980s. The reason for this is that the game density was much lower than at present and game was not confined to a particular fenced-off area. In those days game was able to move about and even migrate in order to escape natural catastrophes, even when almost all grazing had been burnt down or had been eaten by locusts. During the droughts of the early 1900s there was also no general water shortage such as during the 1960s and 1980s, and water was still present in proximity to the available grazing.)

"There is a population of about 600 tax-paying natives and 3 500 old men, women and children in the Sabi reserve, and in the Shingwedzi, excluding Mhinga and Makuleke's locations, only about 200 all told.

Most of the natives in the Sabi are, however, located along the western border. With the exception of these, and about 600 of both sexes, including children, on two or three Landowners Association farms near the Sabi Poort, there are less than 200 north of the Sabi and none south of it. Planting is resorted to more than it used to be, and goats, sheep and fowls are kept in fairly large numbers."

In his Annual Report (1912) on the Government Game Reserves (Sabi and Shingwedzi) Stevenson-Hamilton wrote:

"Desiccation of the country. The lack of rain during the past two years had been responsible for the drying up of many pools usually considered to be permanent, and this, in a country where water is often, even under favourable conditions, difficult to find, away from the perennial streams, has made patrolling work more arduous than usual. *My opinion based on continual observation since 1902, is that there is a gradual desiccation of the whole eastern country in progress,* which an occasional season of heavy rains only temporarily alleviates. The Sand River, which is the main tributary of the Sabi, and which *normally runs at an average depth of about one foot,* has certainly shrunk noticeably since 1902, while in the Sabi River itself, islands which ten years ago were barely visible, now carry heavy crops of bush and rank grass. Kraals have been steadily shifting from year to year owing to the drying up of old sources of water supply, and the indications of old lands and villages in localities where there is at the present day no vestige whatever of water, demonstrates that the process has been long continued." (Probably since 1860, according to Hall). "Old natives will point out dried-out and overgrown stream-beds which in their young days they declared carried water all the year round. There is a considerable section of country lying between the Sand and Manzimtonto Rivers which seems to be relapsing into arid desert and which in the dry season is deserted even by the wild animals.

There are two causes which may be responsible, in part at any rate, for this undoubted process of desiccation; one is the cutting down of good timber which, where supervision is not exercised, is carried on by natives to clear their lands for crops, and by white men for commercial purposes. This condition does not exist at present within the Reserve, where natives have been entirely prohibited from clearing anything but the smaller thorn bush and scrub and white men stopped from cutting trees. But outside the Reserve, near the headwaters of many of the streams and spruits which drain it, the process is still undoubtedly in active force. On private land, among the foothills of the Drakensberg, I understand that a great deal of the best timber has been or is being cut, while little or nothing is being done to repair the wastage. South of Komatipoort a great deal of the best timber has been cut out.

The second cause is the grass fires which, purposely or accidentally lighted, rage through the country towards the end of the dry season, just when the young foliage is commencing to shoot. So far as is humanly possible we control these fires within the reserve, and local natives are severely dealt with when proved to be responsible, but unfortunately other causes exist largely outside our control ... Sparks from the engines of the trains on the Selati Railway have also been responsible for the occurrence of several considerable fires....

Only a cursory examination of the trees and country in general is sufficient to attest the damage done by these promiscuous fires, occurring as they do *year after year*. ... Heavy rains tend to wash away the upper soil where it is not adequately protected by tree roots, and so large dongas are gradually formed, which themselves attract tributaries and so the soil is gradually washed away into the main rivers. ... Young trees have little chance of arriving at maturity,

since they are mostly scorched off while still in the sapling stage. The sites of old native locations, even where they have been abandoned for as long as twenty years, are seldom covered with anything but the most stunted and useless scrub and bush and with rank ground vegetation, which later acts not only as inflammable material for fires, but serves to choke the beginning of any better vegetation."

The exposure of the soil through annual fires had undoubtedly contributed to the siltation of water holes in the seasonal rivers, just as the heavy silt-laden floods from overgrazed adjoining areas at present silt up many hippo pools and dams (barrages) in our perennial rivers. Stevenson-Hamilton failed to appreciate that a progressive, reduced precipitation over a long period was the main reason for the desiccation of the Lowveld. The general ground water table is being reduced to such an extent that "perennial" water holes and pans inevitably dry up, running streams cease flowing, marshes become dry and permanent springs stop flowing. The possibility of a reversion to the erstwhile, favourable water conditions when exceptionally copious rains fall, was made clear during the very wet cycle of 1971-1979 (the possible commencement of another long-term favourable pluvial period).

Stevenson-Hamilton reported as follows on the grazing conditions during 1912:

"Ranger Healy had to distribute his animals a few in each native kraal all over his section. I also found it necessary to keep the transport animals from headquarters moving up and down the Sabi practically all the time between August and December and to seek spots where there still was a little grazing." "Ranger Wolhuter lost several cows and most of his young stock." "Even the game showed signs of lack of food, and I cannot recall having ever seen the herds of wildebeest, zebra, tsessebe, etc. in such astonishingly poor condition as was the case at the end of November. Carcasses of *young* animals which did not survive long after birth were found especially near the Manzimtontso River."

Scarcity of food in Portuguese East Africa, as it was then known, caused a serious recrudescence of poaching by natives along the eastern border of the Kruger National Park. Compare this with recent incidents (1984) along the same border.

Commenting on the Sabi Game Reserve, Stevenson-Hamilton reported in 1913:

"The process of desiccation steadily proceeds. Each year a greater number of pools are reported dried up. As I remarked in my 1912 Annual Report, I believe this to be either permanent progressive desiccation or, at any rate, *part of a long dry cycle*, since it has been going on within the memory of the oldest natives. It seems certain that when the Zulus invaded the country a little less than one hundred years ago, it carried a very much larger population than it possibly could at present day." (cf. Hall's favourable rainfall period in his annual ring histogram for 1760-1860). "The large Ngwanitzi pools..." (*i.e.* in the upper reaches near Satara) "...have dried up for the first time in living record, and Ranger Healy had temporarily to abandon his station in December."

"A well was sunk and blasted at Sabi Bridge and a windmill erected to provide water for the Warden and his staff. It was because of the polluted state of the Sabie River, caused by effluents of the gold mines at the upper reaches of the river."

"The conduct of resident natives has been quite satisfactory. In the eastern and northern areas they had suffered so much from the famine that there had been a general exodus of the population from the district... .

Only nine permits for winter grazing (in the Pretoriuskop region) were issued to farmers. Eighty-eight hundred head of small stock were grazed and watered in this area. In spite of the drought there must have been sufficient grazing and natural water to see 8 800 head of small stock through the winter months. Under the present water conditions (natural water) this would have been quite impossible... .

From the Ngwanitzi River northwards, as far as the Olifants, I found the country almost entirely bare of grass..." (a condition which was not repeated even during the prolonged drought of the 1960's) "...as practically no rain had fallen during 1912-13. The natives had, with few exceptions, all left. ... The big game all *migrated* from a huge extent of country south of the Olifants River, and hardly a head was to be seen in what are usually their favourite haunts. ... The animals had trekked a *distance of at least 50 miles* to the west of Imbabate River (Timbavati), where, in an area usually distinguished by its extreme sterility, a heavy storm had brought up young grass."

The fact that animals under similar unfavourable environmental conditions tend to migrate from a disaster area, is clearly illustrated by the observations made by Colonel Stevenson-Hamilton.

If they did not exhibit that instinct, or if they had been prevented from migrating, quite a few animal species (particularly those which are considered as territorial) would have become extinct during the formative years of the park when extensive veld fires, prolonged drought and other disasters, such as migrating locusts, stripped the grazing and ravaged the area (*cf.* the disastrous veld fires of 1913, 1916, 1934, 1935, 1937, 1940, 1946, 1949, 1950, 1953, 1954 and 1955).

The survival possibilities for animals under disaster conditions of this nature are closely linked to the animals' physical condition, the prevailing climatic season and the tempo at which the disaster develops. When sources of food disappear almost overnight through extensive veld fires, or for a comparatively short time, as a result of the devastation of the grazing by insect pests such as harvester termites, migratory locusts, army-worms and others, the traditional migratory game species such as blue wildebeest, zebra and eland, and even the more territorial species — like sable and roan antelope, tsessebe, reedbuck, waterbuck, black rhino and warthogs — will leave the area and find sustenance elsewhere. An acute water shortage in areas where grazing is available will naturally diminish the survival options of the migrating animals.

If the food shortage in an area has come about gradually as a result of prolonged drought, especially at the beginning of the growing season, the sedentary (or territorial) game species tend to remain in the area. The

weakest individuals in such populations will then gradually starve and die. The mortality rate during such circumstances will necessarily be higher in over-populated than in sparsely populated areas. This phenomenon will be aggravated by wet, freezing conditions in spring when the blood-sugar level in many weakened animals drops below the critical minimum level. In such cases large numbers of animals lie down at night, become comatose, and do not wake up again (*cf.* the mass deaths among impala and other smaller browsers, and warthogs in the southern parts of the KNP during the spring of 1983). It was noticeable that black rhino left the disaster area during that time and migrated to the southern parts of the park where conditions for survival were more favourable.

At present mass game migrations to escape a local catastrophe such as the one described by Stevenson-Hamilton in 1913, is no longer possible because the boundary fences prevent movement out of the park. At any rate, should such migrations out of the park still be possible today the reaction of the visiting public would certainly be negative despite any attempts by the park's Information Service to explain the disappointment of a visit to a desolate and 'empty' park.

Stevenson-Hamilton continues his report on conditions in 1913: "There are considerable native locations near the Sabi Poort, and in this part of the Reserve things were more normal, though several old sites had been abandoned since my last visit, owing to pools having dried up.

Game, especially *sable antelope*, were very numerous near all my camps in this district.

In November and December I inspected the western areas north and south of the Sabi. Here, generally speaking there had been good rains, and there is a large native population. Game has increased very largely, having migrated from the north and east to the grass... .

It is proposed to establish a permanent picquet or rest house for the ranger of the northern section in the vicinity of the Sand River near the railway." (This was the Rolle game ranger's post which was used from 1910 to 1923).

"Wildebeest and *waterbuck* are certainly the most numerous species of larger antelopes in the Reserve. It is difficult to say which exist in greater numbers, though I should be inclined to think the *latter* (*waterbuck*) are the more prolific.

Sable are sometimes seen in *very large* herds, and locally are often the most numerous species existing".

In similar vein Stevenson-Hamilton wrote the following about the Shingwedzi Game Reserve in 1913: "This Reserve has suffered from drought to an equal extent with the other. The resident ranger (Major Fraser) was obliged to move his quarter for several months at the end of the dry season, owing to local pools having dried up. Recent reports have, however, been more encouraging". For the rest of Major Fraser's term of service (until 1920) it was not again necessary to move away from Malunzane because of the shortage of water. It is significant, however, that when his successor (L.H. Ledebor) was appointed, Colonel Stevenson-Hamilton left the Malunzane post unoccupied — probably because the water situation had become

doubtful — and established a new game ranger's post on the northern bank of the Letaba River. That post was shifted to its present location south of the river in 1927.

"Now that the large locations in the north and north-west..." (of the Shingwedzi-reserve) "...have been eliminated from the Reserve, the total number of native inhabitants amount to only a few hundred men, women and children, living in isolated and widely scattered kraals. During the past ten years the tendency has been to emigrate westwards on account of the lack of rain.

During the drought this year, Major Fraser found a considerable number of waterbuck dying from some unexplained cause." (In all probability this was the first reported anthrax epidemic, a disease usually associated with prolonged drought conditions). "The circumstances appeared very similar to those attending the mortality amongst the *kudu* in the Zoutpansberg district a year or two ago."

Colonel Stevenson-Hamilton went on active service during the First World War (1914-1918) and during his absence Major Fraser was in command of the conservation areas. In 1915 Fraser commented as follows on the Sabi Game Reserve:

"Very good rains during 1915. Phenomenally heavy rains in early part of the year were responsible for a good deal of sickness (malaria) among humans. The Selati Railway line was badly washed away in many places. Regarding the Nwanetzi quarters, it is a great pity that these were placed in the present position, owing to the apparently increasing drought conditions. The water supply had dried up the last three seasons. Through absence and retrenchment (because of the war), Kaapmuiden and Nwanetzi have been unoccupied for some time now. The latter since September 1914".

The Sabi Game Reserve elicited the following remarks from Fraser in 1916:

"Very scanty rainfall. The drought has been the *most severe* experienced during the last 13 years. Ranger Healy was killed in action in East Africa on 27th March 1916. Much poaching along the borders because of the drought. Actual mortality amongst game in view of starvation was noticed amongst warthog, reedbuck, kudu, impala and even duiker. Warthogs have particularly suffered. I have no hesitation in saying that 1916 has been a *very bad year* for every kind of game."

In Fraser's 1916 report for the Shingwedzi Game Reserve it is clear that: "The country until the end of October was in a very dry state. The grass had dried to such an extent that when a fire started on the path from Shingwedzi-poort to Spelonken *it swept the reserve clean to the Letaba*. Heavy rains started on the 27th October. Since then there has been a plentiful fall of rain. Crops are doing exceedingly well. Scarcity of food still exists until harvest time, as there have been no crops for more than three years".

3.2 *The wet rainfall cycle: 1917-1925*

Fraser's 1917 report for the Sabi Game Reserve reads as follows:

"The excessive rainfall has done considerable damage to quarters. I think I

may recall the season 1916-17 a record one for all game, large and small. Plenty of green food and quantities of water in vleis and rivers is no doubt one reason, but cover for the newly dropped young has a vast deal to do with it." In 1918 Fraser states:

"The excessive rainfall of 1917 left its mark and a fair amount of water could be secured by digging in the smaller rivers and dry beds. Game found this easily. The desiccation mentioned in Major Hamilton's report in 1913 was visibly checked in 1917/18. 1918 was the wettest year on record since measurements were commenced in 1907 and 40,95 inches were recorded at Skukuza... .

Influenza came as a very unpleasant surprise and I deeply regret to say it caused the death of Ranger Andrew Wolhuter — a thoroughly useful officer." He was Ranger Harry Wolhuter's brother who was temporarily appointed in Ranger De Laporte's place while the latter was on active service. "The position of the reserve north of the Letaba can only be reported as holding well behaved natives. South of the Letaba there has been and still exists a wave of insubordination. There has been an outbreak of East Coast fever along the western border. Few permits for winter grazing were issued. Very large troops of sable can often be seen from the *railway line* and by the quantity of young stock must be increasing at a great rate. *Waterbuck* probably next to wildebeest and zebra in numbers, and spread all over the reserve".

In 1918 the Witwatersrand Native Labour Association (WNLA) started recruiting Black workers from Moçambique to work in mines on the Reef. The WNLA established an assembly post and offices along the Selati line at Soekmekaar. The organisation had been recruiting Blacks for the gold mines on an *ad hoc* basis even before the Anglo-Boer War. Gaza Gray was a recruiting officer stationed at Gomondwane. During the war he had been a member of Steinaecker's Horse and afterwards acted as game ranger at Lower Sabie until May 1903, after which he continued his former activities as recruiting officer for the mines. The rondavel on the Shongololo into which Major A.A. Fraser moved in 1904 was built by a WNLA agent in 1902.

With the completion of the depot at Soekmekaar the WNLA instituted organised traffic along the three routes through the then Shingwedzi and Sabi Reserves to transport Black recruits from the eastern border to Soekmekaar. The most northerly route ran from Pafuri on the eastern border, *via* Baobab Hill to Kloppefontein, from there to Shikokololo (Punda Maria), Shikundu, Shingwedzi (outside the park), Mawambe, Shirindi, Fonsecas, Little Letaba, Lebelles Bowrie, and finally Soekmekaar. The nine rest camps were situated 15 to 20 miles apart. Further south there was another route from Massingiri in Portuguese East Africa over the Lebomboes at Longwe to Letaba (Makuba camp), and from there to M'Quinine (on the Ngwenyeni Spruit), and then further to Pioneer camp and Gravelotte station.

In the central district of the park there was a route from Isweni (on the eastern boundary at the confluence of the Sweni and Nwanedzi rivers) to Spanplek and Seis Modo (on the Timbavati River), ending at the railway station of Acornhoek.

Until 1927 (when Thorneycroft buses were brought into use) recruits were

transported by means of donkey wagons. There had to be enough shelter for the donkeys (lion-proof kraals) at the various resting places, and water for the recruits and animals. Under present conditions the recruits and trek animals would probably all have died of thirst along these routes before reaching their destinations (if they did not carry water with them).

Colonel Stevenson-Hamilton's first report on the Sabi Game Reserve after his return from active service (1919) reads: "On the whole the impression I received is that there has been a general retrogression bringing the state of things now obtaining back to about the position occupied in 1904." This state of affairs was a result of insufficient supervision and large-scale poaching during the war years.

For 1920 he continues:

"Good rains fell in the early part of the year. December and January, however, were characterized by great heat and drought and the prospects of harvests are poor."

Desiccation (Stevenson-Hamilton's comment on this phenomenon during a good rainfall cycle reads as follows):

"Despite the heavy rains of three years ago, which flooded the country, and filled all the pans and water courses, the gradual desiccation of the country still continues. With occasional setbacks of longer or shorter duration, it seems to have been going on for 100 years or more." Stevenson-Hamilton is probably correct, because Gertenbach's (1980) analysis of successive dry and wet rainfall cycles, from the beginning of the century until 1970, indicates clearly that progressively less rain was received during each consecutive cycle, when compared with the long-term average.

"The Sabi River obviously carries less water now taking the average all the year round, than it did in 1902. During the course of the late war, owing to the decrease of European and native staff, the resident natives became less amenable than had formerly been the case. Large numbers of dogs, animals which had previously been conspicuous by their absence, were bred and imported, to be used of course for hunting purposes, while many natives took advantage of the lack of supervision to enter the reserve and squat therein without leave. These matters are generally being adjusted, and the conduct of the natives shows a remarkable improvement. East Coast fever broke out among some native cattle in the south-west corner of the Sabi reserve early in 1920. Ranger Wolhuter instructed the natives of this area to move their cattle further into the reserve, away from the infected area in the White River district. All obeyed except one man with about 100 cattle. His cattle contracted the fever and all but 5 or 6 died... .

Some 9 farmers grazed their sheep in the Pretoriuskop area. Large numbers of sheep died of *blue tongue* and poverty.

Squatters. As indicated there was certainly a tendency between 1914 and 1919 for natives from outside to join their relatives living in the reserve. While the Game reserve proper, south of the Sabi river was denuded of natives in 1902, in order to facilitate the increase of game, the strip to the west, which was only added to the reserve at the end of 1903... (being full of Blacks, as it is now), "...with the idea of adding a buffer area in which the natives would be under control of the reserve staff, between the game country and the land under

white settlement... .

Kudu have now quite recovered from the rinderpest of 1896, which all but exterminated them, and are found almost everywhere. Sable antelope are now well established and numerous. Tsessebe are a somewhat local animal, but are *very numerous* in a great many places... .

Waterbuck and wildebeest are found almost everywhere and in large numbers. Reedbuck seems to have suffered from the depredations by dogs near the borders, and very few animals are found in some places where they once abounded."

The conditions within the Shingwedzi Game Reserve for 1920 and 1923 were described by Stevenson-Hamilton as follows:

"Practically all natives living within the boundaries of this reserve have now been removed to Mhinga's location." (This location had been slightly extended to include a small portion of the reserve). "Major A. Fraser has retired under the age limit in October and the vacancy has not yet been filled."

"Ranger J.J. Coetser, who controls the northern section, was appointed in 1919, and has been in temporary charge of the whole, pending a fresh appointment. The free shooting that had been going on near the Limpopo by Europeans..." (the residents of "Crooks Corner") "...has now been stopped. Game is mostly found along the Shingwedzi and Lower Letaba rivers."

From August to November (1923) there probably was an anthrax outbreak among waterbuck and kudu in the Lebombo Mountains and on the Lebombo Plains north of the Letaba River, judging from the descriptions given by Ranger Ledeboer. During the winter and spring of 1924 and the summer of 1925 the park was ravaged by locusts. This scourge was repeated in 1933-1934.

In 1925 Stevenson-Hamilton had the following to say about the Sabi Game Reserve: "During the 1924/25 season, which was exceedingly wet, the highest rainfall ever measured by any station was recorded at Punda Maria where 1 710,7 mm of rain were recorded." This was the year when conditions were so wet and swampy in the Punda Maria sandveld that a number of large matumie trees *Bretonadia salicina* toppled and died. The logs of those giant trees are still lying there and will probably provide valuable dendrochronological information, for they are very old. •

In spite of a very wet summer season, Stevenson-Hamilton again elaborated on his desiccation theory in his annual report of 1925.

"*Desiccation*: To my mind there is little doubt that there exists less water today and consequently less available food supply than was the case even half a century ago. Sites of abandoned native habitation, old watermarks, and the statement of old inhabitants seem to prove this. During the comparatively short period — something less than a quarter of a century — of which I have personal experience, I have noticed a progressive drying up of once permanent springs and pans, and this in spite of occasional seasons of exceptionally heavy rainfall.

In 1902 there existed a pan of water covering some two acres, which even in the dry season held water throughout to a depth of several inches. I was told that in earlier years it was much larger and deeper, and the winter grazers..."

(in the area around Pretoriuskop) "...and hunters made permanent camps there throughout the cold, dry season. As late as 1907 I have shot a duck on this pan. By 1914 it had decreased to an area of about ten feet of shallow water, which usually disappeared before the next rains arrived. When I saw it in 1920 after some years absence, it was quite dry, but a growth of long coarse grass and a few reeds still marked the centre of the original pan. At the present day there is little to distinguish it from any other grass covered depression although unusually heavy rain causes it temporarily to hold water, just as other depressions do.

The native name "Manzendhlovu" given to a now dry sand river, would indicate that in former days it was either permanently running; or held pools large enough to satisfy the water loving elephant.

In my opinion there are two factors which mainly delay this part of the Transvaal, away from the immediate vicinity of the permanent rivers, from lapsing into arid desert — (1) the bush timber (2) the water catchments made all over their feeding grounds by the game, especially by the wildebeeste. These small catchments, caused by the animals stamping and rolling on the same spots, do an immense amount of good in checking the off-flow of water, and therefore of soil erosion."

In 1922 Stevenson-Hamilton noticed that the Sabie River was being seriously polluted by small gold mines on its upper reaches. The degree of pollution gradually became so severe that the Sabie River virtually changed into a sterile stream. Only a very few fish species such as barbel *Clarias gariepinus* could survive in the polluted waters. In the early 1930s after the Skukuza Rest Camp was opened to the public, visitors lodged complaints about the condition of the water. Stevenson-Hamilton and the Board of Trustees annually addressed representations to the Department of Mining to combat pollution by means of legislation. However, nothing was done because "die mynbedrywighede 'n aantal mense se lewensinkomste verteenwoordig, en hulle dit nie kan bekostig om anti-besoedelingwerke aan te lê nie."* On the 15th March 1933 a water expert from Muizenberg, Mr. F.B. Jeary, obtained permission from the Board of Trustees to make a survey of the micro-fauna and flora in the waters of the Sabie. His startling report indicated that micro-organisms in the Sabie River were totally *non-existent*. Boreholes had to supply Skukuza with water, and the pollution of the river continued unhindered until the end of the Second World War.

At that stage other users outside the park, especially farmers, vehemently complained about the pollution and after more than 20 years the Mining Department eventually took measures to stop the pollution. Another amazing fact is that the Sabie has recovered and cleansed itself to such an extent that today, 40 years after pollution of the river was forbidden, it is unquestionably one of the biologically richest river systems in South Africa. It is significant, however, that during a survey made by a hydrologist in the late 1960s there were still mercury deposits to be found in the deep bottom silt of the Sabie.

History usually repeats itself and in January 1981 the Olifants River was

*"...the mining industries represent the earnings of a number of people, and they cannot afford to pay for anti-pollutant measures."

polluted by acid deposits from the Bosveld fertiliser installation at Phalaborwa, which resulted in enormous numbers of fish being killed. A year later, on the 17th January 1983, an even greater disaster struck the Olifants River when a massive silt-laden flood from the overgrazed Lebowa was deposited in the river. The silt content of the water was so high that almost all life in the water was obliterated, and millions of fish of all kinds succumbed along the complete length of the river. Surveys which were later conducted showed that the number of fresh water fish species has declined from 32 in 1966 to 12. In October 1983 the Sand River was seriously polluted when a number of diesel container trucks were derailed on a railway bridge near Rolle.

Cases of pollution (by insecticides) have also occurred in the Letaba River, and the Crocodile River can no longer be considered a natural system because the river bed is extensively contaminated by water hyacinth (*Eichhornia crassipes* (Mart.) Solms-Laub.), lantana (*Lantana camara* L.), Indian lilac (*Melia azedarach* L.) and other pest plants, and polluted with sewerage and industrial effluent. The same condition prevails in the Komati River which is the only natural habitat in South Africa of the rare Lomati bream (*Astatotilapia brevis*). The drying up of the Luvuvhu River along almost the complete length of the Pafuri flood-plain, during the dry season of 1984, not only had a detrimental effect on the riparian vegetation, but preliminary surveys also show that the crocodile and hippo populations in the river had decreased sharply.

It is therefore, abundantly evident that not only the progressive desiccation of the once perennial rivers of the KNP, but also the ever-increasing danger of pollution are placing a very heavy responsibility on the National Parks Board of Trustees, as the country's highest nature conservation authority, to preserve for posterity, at least representative specimens of these rivers' unique (and irreplaceable) water life. This should be undertaken in situations where they will be safeguarded against these menaces. The only solution to this problem is to build dams with capacities large enough to outlast prolonged droughts in tributaries of rivers which have their sources within the park. These dams must all contain fish ladders, should be provided with sluices for draining and should, as far as possible be indemnified against the dangers of eutrofication.

Examples of such dams already completed are the Pionier, Hlanganini, Stapelkop, Reënvoël, Gudzane, Mtshawu, Stolsnek, Newu and Berg-en-dal dams, as well as the emergency water impoundments at Skukuza. Other dams such as a series of weirs in the Sabie and other rivers are in an advanced planning stage. These weirs will provide additional habitat to hippo and certain fish species and will be designed to limit the possibility of silting up. It will be possible to pump water by means of well-camouflaged pipe lines from these weirs to selected points many kilometres upstream, thus creating a circulation of flowing water in the "perennial" river until a natural flow regime is resumed. A system of this nature will safeguard from extinction those forms of waterlife dependent on running, oxygen-rich water.

3.3 The dry rainfall cycle: 1926-1933

On the 31st May 1926, Minister P.G.W. Grobler piloted the National Parks

Act through Parliament of the Union of South Africa. The old Sabi and Shingwedzi reserves were at last consolidated as the Kruger National Park — after many years of trial and tribulation.

At a Board Meeting of the Trustees on 10th March 1927, one of the members, Dr. G. Preller proposed that, in the light of the remarks made by the Acting Warden, Captain Howe, in his Annual Report, the possibility of sinking a number of boreholes to provide water for game during droughts should be considered. In June 1927 Colonel Stevenson-Hamilton informed the Board of Trustees, however, that in his opinion, boreholes, at that stage, were not yet required.

This matter was raised again at a Board Meeting on 23rd February 1929 when Dr. G. Preller again proposed that a number of boreholes be drilled to provide water for animals in the park during dry periods to prevent them from leaving the park to look for water. The Acting Warden (Captain Howe) and Mr. Hockley (Board Member) reported that surveys made by engineers showed that it was not practicable to sink boreholes in the park. The Board of Trustees, however, decided that water *must* be preserved and the Warden was instructed to make a survey of suitable dam sites in spruits.

In 1929 Stevenson-Hamilton circulated a memorandum to his game rangers, stating that "The bad drought of the past few years has brought home the fact that in order to encourage the game to remain in the Park, and to ensure a better distribution of waterholes and feeding grounds, it is necessary to increase the number of waterholes artificially if necessary. Will you please make a survey of your sections and look for likely spots on the normally dry river beds. They should be from 5 to 8 miles apart. Places should not be chosen too near the borders to be accessible to poachers." After he had received the rangers' reports, Colonel Stevenson-Hamilton wrote as follows to the Secretary of the Board:

"I have now been able to get the opinions of the rangers of the various sections regarding what is, in the opinion of each, the best method of increasing the water supply in some of the more arid areas, and thereby encouraging the spread of the animals and so far as possible checking emigration, especially into Portuguese territory. At present there are large tracts which during the winter are quite devoid of all except insect life, but which are often except for lack of water quite suitable to carry large numbers of antelope of most species, and this throws an undue pressure upon the pasture in the better watered areas, besides causing many animals to trek east and west out of the Park altogether."

Four general methods were suggested:

- a) The building of concrete dams across suitable points in the dry water-courses.
- b) Dams formed of wire netting.
- c) The sowing of Kalahari tsamma melon (*Citrullus lanatus* (Thunb.)) seed.
- d) The enlargement of pans and "soils".

Some 50 lbs. of tsamma melon seed were obtained and sowed in dry, sandy patches as an experiment. Fortunately it was a failure, because the tsamma is not a plant species occurring naturally in the park. The Warden also recommended that a dam-scraper be bought with which he wanted to enlarge

veld pans and build smaller earth dams. The dam-scraper was bought in 1930, but it was little used.

Stevenson-Hamilton wrote the following in the 1930 Annual Report: "The first two months of the year were rather dry, February being a very hot month. Heavy rains fell in March and April. Thereafter there was complete drought until the beginning of November." In the 1931 Annual Report he continued: "1931 was a dry year and only about 14½ inches of rain fell at 'Reserve' (Skukuza) during the 12 months. On the other hand abnormally heavy rains fell in the early part of July."

During that year history was made when the well-known *Ntomene waterholes* along the old Delagoa Bay transport road finally dried up. It was a cause of deep concern for the park's authorities who decided to build the KNP's *first concrete dam* at that locality. The dam was built by Captain M. Rowland-Jones, the then Tourist Officer at Pretoriuskop, and completed early in 1932. The Warden informed the Board of Trustees that a further 45 suitable dam sites had been selected in the park. Dr. G. Preller, however, still thought that windmills and troughs would be a better solution.

The year 1932 was an exceptionally dry year, and the Warden reported the following: "This was a year of extreme drought, the seventh in succession, in which dry conditions have been prevalent. Native crops failed throughout, even in the western border area where this is unusual. There was very little grass by the end of June, and as yet no winter rains fell, pasture ceased to exist in many parts; this, with the drying up of all water holes, drove the game away from what are usually favourite spots. No. 5 Section (Satara) for instance was relatively denuded of game during the latter part of the dry season. There were fairly good "first rains" in December ... and the veld improved to the end of the year."

In the meantime the Warden appealed to the Board of Trustees for funds for a series of boreholes at places where in the immediate past there had been water available to the game. The Board of Trustees gave its attention to the matter, and Mr. F.B. (Bertram) Jeary of Muizenberg, in particular, worked hard to raise money for the project. After a survey made in 1931 the Department of Irrigation tabled a report in which they expressed their conviction that boreholes could be sunk successfully in the park. Eventually more than £2 500 (R5 000) was raised for the borehole programme, and the Government donated two boreholes. The Board of Trustees decided to limit boreholes to the southern part of the KNP for the time being, and Mr. W.H. Rood recommended that retaining dams be built in the tributaries of the Mbyamiti near Kemp's cottage. (A series of small dams were eventually constructed in the Mhulu Spruit in 1949-1950 by Ranger H. Kirkman and Mr. Roets.) The drilling programme commenced in October 1933 and after sinking a successful hole for the Pretoriuskop Rest Camp, other holes were sunk at places such as Komapite near Skip Mountain, Randspruit (to replace the sluggish spring), Gomondwane (to take the place of the waterholes at Sardelli), Skukuza Kopjes (to replace another sluggish spring), Hlam-bamaduba (to stabilise the well-known water-hole at the Hlam-bamaduba-Mbyamiti confluence which dried up in 1932), and Manzi-mahle on the Skukuza-Tshokwane road where the water had dried up in 1932. Ranger L.B.

Steyn of Tshokwane built an earth dam at Kumane. Leeupan was enlarged and made deeper.

Colonel Stevenson-Hamilton reported further on the year 1933: "1933 was the eighth year of drought conditions: so far as the earlier part is concerned, heavy rain having fallen only for a few days in the beginning of January and again at the beginning of March. The southern portions suffered most; north of the Letaba conditions were rather better, and they improved still more towards the north, so that No. 8 Section (Punda Maria) held good pasture all through the winter. On the other hand south of the Olifants river, especially in parts of Nos 4 and 5 Sections (Tshokwane and Satara) water became so scarce towards the end of the winter that all the animals tended to congregate near the few permanent supplies, *with the result that every particle of pasture was eaten off for many miles around*; the veld resembled a roadway and the animals *had to trek to find food*".

3.4 The wet rainfall cycle: 1934-1942

In general, 1934 was a favourable rain year for the park (according to the Warden's Report), and the water drilling programme could be continued uninterrupted. A successful hole was sunk about 5 km from the then Rabelais Gate. The drillers also tried repeatedly to sink a successful hole next to the Makonkolweni which had been a running spruit in bygone years (land surveyor Vos's diary), but to no avail. Dry holes were sunk next to the Saliji Spruit, but at Mabye-bye between Bangu and Gudzane, but at Mareya between Kumane and Satara, successful boreholes were sunk. It is still not clear why they drilled at the latter sites. The successful boreholes were equipped with concrete reservoirs which fed ball-valve regulated troughs. Two earth dams were also erected in the Shitsakane Spruit at Satara, and in the Sweni near the main road drift. Unfortunately both were washed away.

Mrs. Eileen Orpen, who in later years became a great benefactress to the park, in 1934 bought the farm Chalons and donated it to the park. She bought the farm because it had a large permanent waterhole in the upper reaches of the Shisakashangondzo Spruit, which did not dry up even during the great drought of 1926-1933.

That waterhole contained ample water until the late 1950s, but finally dried up, together with other perennial pools, in the severe drought of the 1960s. The Shisakashangondzo Dam was consequently built in 1958. This dam later silted up and had to be replaced by a series of boreholes such as Hamerkop, Eileen and Houtboschrand.

The year 1935 was another dry year (in the wet cycle) and the Warden reported that: "The rainfall was poor, especially in the three northern sections. *Pools which had always hitherto been believed permanent* were completely dried up by the end of the winter. The drought continued till nearly end of December and combined with the great heat experienced in the last 3 months of the year caused all signs of grass in some areas to disappear. Some unseasonable rain fell in May and June which had the effect of damaging the newly made roads..."

The drilling programme was continued and the last boreholes in the series were completed at Gudzane, Bangu, Shivulani, Ngwenyene, Malopene

North and the Malopene Gate. During the winter season of bygone years there had been water available at the first five sites.

The Kumane earth dam was completed and work started on the Mazithi Dam. Stevenson-Hamilton made the following remarks on the artificial water supply up to that stage:

“It was a rather remarkable point however, and emphasizing the innate conservatism of wild game, that while so long as no water was obtainable elsewhere the boreholes were freely used, as soon as a local shower happened to provide even small puddles in the sputts the animals preferred to drink at the old places to which from long usage they were accustomed, although a more plentiful supply was often to be had at the boreholes.”

The year 1936 had another good rainy season and little was done to supplement the artificial water situation. An engineer from the Irrigation Department, a certain Mr Lingnau, spent eight weeks in the park looking for suitable dam sites. He recommended six sites for earth dams — in the Fayi Spruit, Mazithi (already completed), Mavumbye Spruit, Mooiplaas Flats and the upper reaches of the Shishsa.

In 1937 Ranger Tomlinson built a small earth dam in the Mooiplaas Vlei which is still standing today. He also constructed a second earth dam in the Dzombo Spruit. At the same time he discovered that the water table in the drainage zones of the northern basalt flats was very high at certain places. That was probably the factor instigating the extensive series of wells dug by Ranger W. Lamont in later years, in this area. The Folly Dam at Pretoriuskop was also completed.

The year 1937 was an exceptionally wet year and copious rains fell over the entire park in spring. During January, February and March over 610 mm (24 inches) of rain were recorded at Skukuza, while in February alone some 381 mm (15 inches) fell within a few days.

The northern section had little more than the normal rain. The autumn was less favourable although good rains fell in the northern region in December.

Both the Kumane and Mazithi dams broke during floods, but were soon repaired.

The year 1938 was yet another year of excellent rainfall especially in the southern part of the park, and general summer rains resulted in excellent grazing conditions in the whole area. Mr. W. Lamont, Camp Manager of the tourist staff at Shingwedzi, was appointed as ranger in charge of well and dam construction. He soon started digging wells in the northern Lebombo Plains at marshy spots or in vleis where the water table was extremely high, and where in the past, permanent drinking water was supplied from wallows, pans or seeps. The small earth dam at Punda Maria was made deeper and enlarged.

The year 1939 is known as one of the best rain years in recorded history. Stevenson-Hamilton wrote in his Warden's Report for the KNP: “Rainfall records kept at Skukuza since 1907, show 1939 to have received the second heaviest rainfall of any year since that date.” (The highest rainfall ever recorded in a single year was 1 710,7 mm in 1924-1925 which transformed the Punda Maria area into a marshland. The lowest rainfall totals were recorded

during the great drought of 1963/1964 at Shangoni (186,0 mm) and Shingwedzi (197,0 mm)). "The veld continued to be green through most of the winter, and grazing never ceased to be abundant. When the heavy February rains commenced, the rivers and spruits had not fully subsided after the floods of December 1938. In consequence, all rose to unprecedented heights, and great damage was done.

Along the Olifants and Crocodile rivers for instance, large fig trees, which must, some of them, have been 100 years old, were uprooted and carried away. The general appearance of the banks along both the above rivers was greatly altered, wide expanses of bare sand appearing in places of dense tree fringes.

Practically all Park stations were cut off from the outside world during a considerable portion of February. Skukuza was practically marooned for a fortnight, owing not only to collapse of all road communication, but to the interruption of the Selati and main railway lines, and the breakdown of telegraphic and telephonic intercourse." The Olifants River only became passable in May and continued flowing. "...two feet or more above normal during the whole winter, and the Crocodile River likewise never sank to its usual winter level."

Meanwhile Ranger Lamont proceeded to dig wells on the northern Lebombo Flats. Windmills were erected at Stangene, Babalala, Nwarihlangani South, Nkulumbene North, Nwashitsumbe North, Dzombyane, Mashikiri, Masandje, Nkovakulu and Kloppefontein.

The years 1940 to 1942 also formed part of the wet rainfall cycle, although Colonel Stevenson-Hamilton recorded (Warden's Report for the KNP) that 1941 was one of the driest years that he could remember. Severe frost was also experienced during June and July, and temperatures as low as -13,3 °C (8°F) were recorded. The frost caused extensive damage to trees. (The previous frost of this nature was recorded in 1920.) During the last six weeks of 1941 conditions improved, and heavy rain fell in, especially, the Letaba district.

The years 1940-1942 were relatively unproductive as far as the water-for-game project was concerned. This could be ascribed mainly to a lack of funds because of the war. However, a new concrete dam at Pretoriuskop was completed in 1942, and had to supply water to the rest camp and wildlife in the immediate vicinity of the camp.

3.5 The dry rainfall cycle: 1943-1951

Colonel Stevenson-Hamilton described 1944 as "...the most severe drought which has occurred for many years past; in some of the sections it even exceeded the worst experienced in the period 1925-1935, when the animal population of the Park suffered so seriously, through death or emigration. In 1944 it was not, however, universal, and affected in the highest degree the southern and eastern portions." Pretoriuskop, Punda Maria and Shangoni (in the north and west) "...came off better, though even with them rainfall was poor." At Letaba Section "...practically no rain fell for a period of 8 months." "Fortunately a series of local thunderstorms during November saved the veld from disaster at the last moment, and most sections having had their turn of these storms, it had by the end of the month improved everywhere.

Pretoriuskop had from the beginning good and sufficient spring rains, and correspondingly *a large migration of game* to that area took place.”

In October 1944 construction on the Orpen Dam near Tshokwane was started with funds donated by Mrs. Eileen Orpen. Ranger T. James built a small concrete dam in the Mlambane Spruit.

In 1945 Colonel Stevenson-Hamilton wrote the following in his last Annual Report before his retirement in April 1946: “The drought was as severe as in 1944, and Letaba had the lowest recorded rainfall on its records. Fortunately rain fell fairly generally in October and this, by bringing up young grass on the eve of the calving and lambing season, saved the situation so far as the herbivorous animals were concerned. Prior to that rain some of the older animals, especially impala, were dying from poverty.”

“In 1925, just before the proclamation of the Kruger National Park I hazarded the number of herbivorous animals, from and including impala upwards, as perhaps 130 000. Today, notwithstanding setbacks due to long years of drought, I should suppose we have double that number usually in the Park or say one animal to 100 morgen...” The latest census total (1984) for these animals was 242 293 which is roughly the same number estimated by Stevenson-Hamilton in 1945. Elephant, buffalo and rhino are present in far greater numbers. The number of wildebeest and possibly also waterbuck, reedbuck and tsessebe could be lower than in 1945 on account of droughts and habitat changes.

In 1945 concrete dams were built in the Isweni River (washed away in the 1970s), and at Tsange in the Tsange Spruit.

The year 1946 can be considered as the beginning of a new era as well as a new phase in the water-for-game programme in the Kruger National Park. In April 1946 Colonel J.A.B. Sandenbergh succeeded Colonel Stevenson-Hamilton as Warden. Sandenbergh was a dynamic person and took on the challenge of the water supply programme with great enthusiasm.

In Colonel Sandenbergh's first Annual Report (1946) he said:

“From the information at my disposal it is apparent that year by year the supply of natural water for game has diminished and today the position is that approximately one third of the park cannot be fully grazed. As the park is roughly 8 000 square miles in extent, this means that at least 2 000 square miles of good grazing is not supporting the wild life it could support if perennial water was established within grazing range of these areas. It would appear that if matters are left as they are, and water continues drying at the rate known in living memory, there will be an ever increasingly large area unsuitable for grazing because of lack of water within range of the grazing areas.

The result will be that the game will concentrate, throughout the year, on areas adjacent to the perennial rivers, overgrazing will result, erosion will follow and inevitably disaster will overtake the wild life. The *rehabilitation* of our water, if I may call it that, is a vast undertaking which will necessitate the expenditure of many tens of thousand of pounds. It will be futile for me to attempt to prepare any plans for this purpose as it is obviously only within the scope of experts in soil and water conservation.”

Both Stevenson-Hamilton and Sandenbergh were mistaken in their conviction that all grazing in the park should necessarily be available to herbivores throughout the year. "Summer grazing" invariably benefits from being rested during the winter months, so that the winter grazing can recover in the rainy season when "veld waters" and pans make the "summer grazing" accessible. It is important, though, that permanent natural water away from the perennial rivers — *i.e.* permanent pools in seasonal rivers, springs, vleis and marshes — that supply additional drinking water during the winter months, are not allowed to disappear or diminish in supply. The water stabilisation programme since 1946 has had this aim in mind.

A commission appointed by the Soil and Water Conservation Board in 1947 conducted an extensive survey of the water conditions in the park. The commission compiled a report, and the financial implications of the report, if put into execution amounted to £27 000 (R54 000).

In 1949 Colonel Sandenbergh inaugurated his extensive water-for-game fund with the approval of the Board of Trustees. He personally promoted the cause throughout the country and raised more than £15,000 (R30 000) in the process. He subsequently reported to the Board of Trustees:

"The preliminary Geophysics Survey has been carried out and it is hoped to make great strides in the provision of water for our wild life next year. I think 1950, with the water points we shall establish during that year, will go down in the history of the park as one of the milestones of the park's history."

As was expected, the water purveying programme progressed with rapid strides during 1950. Fifty-one boreholes were sunk during that year (especially in the northern and central districts), but only 46 yielded water. In October of the same year the Irrigation Department and Geological Survey investigated the feasibility of further exploiting surface run off in the area south of the Olifants River.

The Warden remarked on this in his Annual Report (1950): "This report is at present being considered, and it is hoped to start work early in the new year. This work, in the main, will be the construction of large dams which will ensure a constant supply (*sic*) of water in areas where such a supply is considered necessary."

Meanwhile the park was in the grip of a severe drought (1943-1951) and numerous critical situations were pointed out which in later years received attention. Perennial springs such as Shilalane and Josiah finally dried up during this drought period (although both started flowing again during the wet rainfall cycle of 1971-1978). The large waterholes in the Mphongolo and Phugwane also dried up, and the game had to rely on water dug from the sandy river beds and the springs at Malahlapanga and Mafayeni. The well-known Kloppefontein which had been a permanent water source throughout the history of the park, as well as during the previous century, also dried up. In the Shisha only the Muwawi waterhole held water and during the dry season the game practically trampled each other in order to quench their thirst.

In 1951 eight successful boreholes were sunk, and the Mlondozi Dam was completed.

3.6 *The wet rainfall cycle: 1952-1960*

In 1952 two boreholes were added to the 54 which were sunk during the previous year. The total of 56 successful boreholes completed the borehole programme for the time being.

It was noticeable that the majority of boreholes were sunk on or near sites where, until quite recently, permanent surface water had been available to game during the dry winter months. The following boreholes, completed during this programme, are worth mentioning: Kirkman, Rhizazene, Nwanedzi East, Ngirivane, Mavumbye, Nsemane, Red Gortzen, Malopanyane, Makhadzi, the series of Shawu windmills, Nalatsi, Dzombo West, Dzombo East, Mooiplaas, Mahlati, Tsumane, Ndlofine, Nkulumbeni South, Shingomene, Nwashitsumbe, Magamba, Boyela, Papanyane, Nwarihlangani North, Shisha West, Dotholi, Bubube West, Nkulumbeni Central, Nwamba, Nkokodzi, Klopferfontein, Mahembane and Tsumanene.

The dam construction programme also progressed well during 1952 and the following concrete dams were completed: Gudzane, Lindanda, Ngotsa, Nguweni, Bangu No. 1, Bangu No. 2, Isweni, Nwanedzi and the Nwanedzi Weir at the WNLA camp.

Although further dam sites in the park were investigated in 1953, no new constructions were undertaken. Mr. L.B. Steyn, the Senior Game Ranger at Tshokwane, took over as Warden from Sandenbergh in 1953.

During 1954 two earth dams were built — one at the Naphe Spring and the other at Matukwala in the Punda Maria Section. A series of earth retaining walls were also built in the upper reaches of the Mtshawu Spruit just below the Shabeni Hill.

At a Board Meeting of Trustees held on the 29th September 1955 the opinion was expressed that the Board spent too little money on the water-for-game programme, and that land-owners to the west of the park spend large amounts of money on dams, thus luring great numbers of game from the park for hunting and other purposes. The consensus of opinion was that more water in the form of dams or boreholes should be made available in the vicinity of the western boundary. The Board of Trustees decided on the following:

“That the provision of an adequate supply of water for game along the western boundary of the Kruger National Park be expedited as far as possible as a measure of prime importance to retain the game within the Park's boundaries and that the Director be authorised to obtain the services of private persons or bodies for the selection of suitable sites for dams and boreholes should it be found that the Irrigation Department and Geological Survey cannot come to the Board's assistance when their services are required.”

During 1955 two concrete dams were built — the Mbyamiti Dam, to replace the waterholes that had dried up there, and the Phugwane Dam to supplement the Nsuzeni, Mafanele and Ntorekwani waterholes that were no longer perennial.

In 1955 construction was started on the Klopferfontein Dam, which was

completed in January 1956 replacing the now defunct Klopperfontein Spring.

Giving effect to a decision taken by the Board of Trustees in 1955, the Ngwenyeni Dam in the Nwaswitsontso River was completed during 1956. A few earth dams were also built: at Lipape, Mhlanganzwane, Bubube and Vutomi.

A consulting engineer, Mr. J. Dommissie, was requested by the Board of Trustees to investigate the windmill system in the park. In an extensive report he recommended that borehole water should be used more productively and be stored. A few of his recommendations, such as the so-called "pit dams", created great problems in later years (1960-1961) during an anthrax epidemic.

More earth dams were built in 1957: at Lipape and Pswaeni on the western boundary, and at Panamana in the Crocodile Bridge Section.

The Shisakashangodzo Dam in the largest tributary of the Timbavati River was completed in 1958 and served as a supplement to the waterholes on the former farms Chalons and Houtboschrand.

In 1959-1960 two gauging-weirs were built by the Department of Water Affairs in the Mbyamiti and Nwanedzi rivers. Two more were subsequently built in the Tsende and Shisha rivers.

In 1959 fencing of the park's southern and western borders with game fencing was commenced to limit the dissemination of contagious stock diseases such as foot-and-mouth from the park. The work was undertaken by the Division of Field Services of the Department of Veterinary Services, and the fence along the Crocodile River (the so-called Snyman fence) was the first to be completed (in 1959). The fences along the western boundary, and the Luvuvhu boundaries of the park were completed during 1960-1961 and 1962 respectively. Fencing the western boundary had serious implications for game populations in, especially, the central part of the park. The game was unable to reach their traditional summer grazing to the west of Kingfisher Spruit, and the traditional winter watering sites in the Sand River in the Sabie-Sand block was also fenced out. As a partial solution to this unfortunate situation two concrete dams were built in 1960 in the Tswiriri and Nwanitsana spruits to the east of these traditional dry season watering sites.

• 3.7 *The dry rainfall cycle: 1961-1970*

The period from 1961-1970 — with the exception of the 1966-1967 rainy season — was conspicuous for a series of exceptionally dry years, and culminated in 1970 in the driest environmental conditions (in that part of the Lowveld) in living memory. In 1960, 1961, 1962 and again in 1970 the KNP was harassed, in addition, by serious anthrax epidemics in the region north of the Letaba River.

Concrete floors had to be provided at all the "pit dams" at windmills in the anthrax endemic area. In 1961 park officials tried to alleviate the pressure on the newly-erected western boundary fence by a milling mass of thirsty migratory game herds by sinking a number of boreholes at Shiyanamane, Vlakgesicht, Nwatindlopfu, Ngwamutsatsa and Kolwane. The Shiyanamane borehole at Batavia was sunk in order to retain the only herd of roan antelope in the central district of the park. In the dry season they traditionally watered

at a natural waterhole on the adjacent farm, Brasilië. Before the roan could discover their new drinking site in the park, an elephant broke the fence. Practically the whole herd slipped through the gap to Brasilië and never returned. This was one of the detrimental consequences of fencing the western boundary. In the final analysis, however, it was remarkable how rapidly the migrating game (blue wildebeest and zebra) adapted to the unfamiliar obstruction across their traditional migration routes, although in 1962 water had to be transported to suitable drinking sites such as the Tswiriri and Nwatindlopfu dams.

In 1961 an intensive drilling programme was commenced to further lessen the detrimental effects of the prolonged drought by supplying additional artificial water at or near sites where natural waters were progressively drying up. The drilling programme was continued throughout the subsequent wet rainfall cycle at sites that had been carefully selected during the preceding drought. The programme was concluded in the early 1980s after at least 270 additional drinking sites from boreholes had been provided. Many of the drinking sites are fed by more than one borehole, and, at present two or even three windmills supply water to game at a number of these localities. A new programme was also introduced whereby concrete reservoirs, three metres in height, were being constructed at all the watering points to provide water to one or two drinking troughs by means of a ball-valve system. A double set of troughs, placed apart, are being erected at all the stronger boreholes to limit competition between dominant species, such as elephant and buffalo, and other game. During this dry cycle the dam constructing programme was continued, and the following earth and concrete dams were completed: Shimangwanene, Mpenza, Hlamalala, Shitlave, Manyeleti, Transport Dam, Air Force Dam, Stangene, Hlamfu (Grootvlei), Shawu, Hlanganini (concrete), Manzimahle, Shilolweni and Mestel.

The favourable reaction of a wide variety of game species to the extensive water stabilisation programme since 1960 was most gratifying and informative. Noteworthy, in this respect, is the remarkable increase in the numbers of some less prolific and rare species such as sable antelope, in especially, the Phalaborwa, Mahlangene, Shingwedzi and Vlakteplaas sections (their numbers have more than doubled since the 1960s) and tsessebe in all their favoured habitats in the northern sections. This phenomenon is clearly reflected in the census data of the past few years.

One can safely assume that the recolonisation of white rhino *Ceratotherium simum* in the park since 1961 would not have been nearly so successful had it not been for the water stabilisation programme in their chosen settlement areas in the Pretoriuskop, Stolsnek, Malelane and Crocodile Bridge sections, in particular.

Towards the end of 1969 a new phase was entered in the water-provision programme of the KNP when work was started on a weir in one of the large "perennial" rivers, the Letaba River. This river stopped flowing early during the winter months, and the situation gradually deteriorated until the hippo population congregating in the remaining pools suffered severely. Large concentrations of game trampled the river banks to dust, and the riparian vegetation and waterlife in general suffered greatly. A donation by an American financier, Charles Engelhard, made it possible to initiate a scheme

to stabilise the perennial rivers in the KNP by means of a series of weirs. The Engelhard Dam (at present the largest in the park) was the first in a series of such dams to be constructed. The dam was completed towards the end of 1970 and was fitted with a fish ladder.

To appreciate the conditions at the end of the dry cycle of 1961-1970, and to understand the rationale of the further development of the Board's water stabilisation programme especially in the larger seasonal rivers and "perennial" rivers, it is necessary to take note of the Nature Conservator's Report at the end of 1970. "The present review period was featured by an unparalleled drought, a serious disease epidemic (anthrax) among the game herds of the Kruger Park and extensive administrative turbulence..."

In nature conservation circles 1970 will be remembered as the blackest year in the history of the Kruger National Park. The serious water shortage envisaged in the previous report, as a result of the insufficient summer rains of 1969-1970, soon became reality and the situation gradually became critical. The Letaba ceased flowing in January 1970, and the Sand River in March. The Luvuvhu stopped flowing later in the winter, while the Olifants and Crocodile rivers were reduced to mere trickles (in some places they flowed under the sand). Even the Sabie River dropped to its lowest level in living memory, as the dry season progressed. The drought steadily worsened and the permanent waterholes in most of the seasonal rivers disappeared one after the other. When the first spring rains brought relief there were only four dams in the park that had not dried up completely — the Transport Dam in the south, the Shilolweni and Mlondozi dams in the central district, and the Hlanganini in the Letaba District.

Long-established water holes in the large seasonal rivers such as the Mbyamiti, Nwaswitsontso, Nwanedzi, Timbavati, Tsende, Makhadzi, Dzombo, Mphongolo, Phugwane, Shisha, and the whole western section of the Shingwedzi dried up almost entirely. It naturally put an additional strain on the artificial water system of the park, and at many places water had to be pumped, with engines running continuously, from an early stage in the dry season in order to supply water to the thirsty animals. *A number of boreholes were unable to cope and either dried up or weakened to the extent that they became virtually useless.* Many well known springs also dried up (i.e. Shahlulu, Shinonyane, Tambye, Makangela, Masanje, Magovane, Shipudze, Nwatingala and others), although a few of the strongest ones such as Nyamari, Mvubu, Mafayeni, Malahlapanga, Shipale, Tshalungwa (very weak), Tsange and Malonga yielded water throughout the drought and saved scores of animals from death by thirst. The Tshalungwa which used to be a strong spring deteriorated to a pool the size of a washbasin and could only provide water to birds and small game. During the later winter months a bulldozer was used successfully to uncover water under the sand in some of the large seasonal rivers such as the Mbyamiti, Nwaswitsontso, Nwanedzi, Timbavati, Shingwedzi and Mphongolo. In the Tsende and Dzombo spruits, however, no success was achieved by this method and when long established waterholes such as the Nyavutsi and Shipandane dried up, the game was forced to search elsewhere for water. Hundreds of waterbuck along the Dzombo crossed the eastern boundary to Moçambique and very few of them, as well as other game that migrated eastward, returned.

The massive game concentrations at the available drinking sites and waterholes trampled the surrounding veld extensively, and later the animals were forced to cover increasing distances between food and water. By the end of the dry season these harsh conditions claimed the lives of many young and decrepit animals, and predators feasted on the large numbers of weakened animals.

Hippo probably suffered the most, and as their natural shelters and pools dried up or were depleted by other thirsty animals (especially large herds of elephant), their habitat conditions deteriorated to stinking mud puddles. For miles around the last remaining mud holes there was no grazing, and the hippos eventually weakened to a state where they were unable to leave their shelters. They stoically awaited death, too weak to rise. The hippo population in especially the Letaba River was hard hit by the drought, and along the lower reach of the Olifants River more than 150 hippo died of exposure and starvation. Large numbers of much weakened game such as warthog, kudu, impala, bushbuck *Tragelaphus scriptus* and buffalo succumbed during a freezing spell accompanying the first spring rains during October in the southern and central districts. When conditions were at their worst, relief was at hand, and the first good spring rain was followed by copious showers in the new year (1971). After good rains in its catchment area, the Letaba River commenced flowing again on the 23rd December 1970, and flood water eventually also reached the newly completed Engelhard Dam. The "historic" day on which the dam overflowed for the first time was the 9th January 1971.

It was conspicuous that throughout the dry cycle of 1961-70, old, established pools dried up and others silted up because of weakened flow of the rivers. A few examples worth mentioning are the large Mbangari and Hlangeni hippo pools in the Timbavati which housed large herds of 20 and more hippos until the mid-1960's, and where none are now to be found.

Colonel Stevenson-Hamilton built himself a lookout in a tree near a large waterhole in the Nwaswitshaka Spruit at the Nhlanganini mouth. In the early 1960s fish could still be netted there, but that waterhole, as well as the one near the mouth of the Nwatimhiri Spruit have silted up permanently. Similar phenomena occurred in the Mbyamiti, Nwaswitsontso, Shingwedzi, Phugwane and Mphongolo rivers.

Despite of the depressing economic conditions of 1970 the Olifants-Satara pipeline (with subsidiary pipelines feeding drinking troughs for game), and earth dams in the Mtshawu, Nyamundwa and Mareya spruits were completed.

3.8 *The wet rainfall cycle: 1971-1978 and thereafter*

Excluding the 1972-1973 rainy season, the remainder of the period 1971-1978 was marked by exceptionally prolific rains, cyclonic conditions, a general revival of the flow patterns of perennial rivers and springs, and the re-establishment of a wide spectrum of permanent waterholes in the larger seasonal rivers and spruits.

The general impression was that the propitious environmental conditions of a past age had returned. This seemed to apply also to the renewed vigour of the vegetation. If Hall's (1976) histogrammatic representation of dendro-

chronological data obtained from a single, very old yellowwood tree is accepted, and his findings can be verified, then 1971 was, possibly the beginning of a new long term era of above-average rainfall which will probably end towards the middle of the 21st Century. Furthermore, if the flow of perennial rivers and the general water distribution of the 1971-1978 period are compared with conditions which prevailed in the previous century, then the similarities are indeed remarkable. Perennial rivers maintained their flow throughout the dry season and almost forgotten springs started flowing again. The springs in question here are Shilalani, Shahulu, Shinonyane, Makangela, Josiah, Magovane, Thambyi, Dzundwini, Mahembane, Tsila-vila, Baobab Hill, Malituve, Mashikiri, Masanje, Shibangwanene, Nwatingala and Fihlamanzi. A number of spruits, especially those draining the basalts of the Lebombo Flats, started flowing throughout the year, as was the case in the previous century. Crystal clear streams were a general sight in this region. Important spruits in this category were sections of the Shisha, Gadzingwe, Dzombo, Nyavutsi, Shihloka, Dzombyane, sections of the Mbyashishe, Shawu, Makhadzi, Mfulene, Nkadze, Shitaburi, Sakashaingwe, Ninene, Bangu, Hlahleni, Wadrif Spruit, Shitsogweni, Ngotsa (below the Nyamari Spring), Shipembane, Nwatingala, Mavumbye, Gudzane, Nwanedzi, Kambana (Satara), lower reaches of the Sweni, Pelwane, Nhlorwane, Munywini (eastern boundary), Mlondozi and tributaries, Mativuhlungu, Nhlowa, Nyamundwa, Mtshawu, Phabeni, Mestel, Fayi, Nsikazi, Ntomene, Nhlowe, Mlambane, Mangake and Mtjulu. Even the Nwaswitshaka occasionally flowed for months on end. Leeupan, Machayi and other large pans again held water throughout the year.

This utopian state was brought to an end with the onset of the next dry cycle in 1979. The first three years of this cycle were relatively mild when compared with previous dry periods, and could have been included in the preceding cycle, especially if the favourable environmental conditions which persisted are taken into consideration. It is remarkable that the Mavumbye Spruit flowed uninterruptedly until 1982, and even in that very dry year kept the Gudzane Dam full. This phenomenon underlines the fact that the favourable environmental conditions of a wet cycle, are often perpetuated during the first few years of the succeeding dry period. The detrimental effect on animal populations which attain peak levels during favourable environmental conditions can therefore be catastrophic if the droughts are protracted and take on the dimensions of the 1961-1970 period.

Particularly wet rainfall cycles such as that of 1971-1979 do not always have only favourable effects on the plant and animal life of a particular area. The altered (denser) habitat conditions had a remarkably detrimental effect on certain prey species because it exacerbated predation pressure. It was during this period that there was a dramatic decline in blue wildebeest and zebra populations, especially in the central part of the Kruger National Park. A similar drastic decline in the numbers of both these species was also experienced during a previous wet climatic cycle 1933-1934.

In anticipation of the next dry cycle (which made itself felt in 1982) the water stabilising programme was continued without interruption during the wet cycle of 1971-1979, and the authorities attempted to forestall the problems experienced during the preceding drought.

During 1971 the cyclones Caroline (January) and Eugenie (March) hit the KNP but did not cause extensive damage. Earth dams were completed in the Newu, Stolsnek and Mpondo spruits (the latter because of the weakening of Gaisenga, a permanent waterhole in the Bumi which dried up for the first time during the 1982-1984 drought).

A large concrete dam was built at Sirheni in the Mphongolo River to provide water when the large waterholes such as Ngwendu, Shibaueni, Mbomene, Dzundula and Mavatsane in this system dry up, as they did in the 1940s and 1960s. Construction of a new weir in the Letaba River at Shimuweni was also started.

During 1972, which was a relatively dry year, earth dams were built in the Mashengane Spruit (Sable), and in the Nkulumbeni north of Shingomeni (Langtoon). The Shimuweni Weir in the Letaba was completed, and work was started on a third weir in this river at Mingerhout (just west of the old low-water bridge). The Wik-en-weeg Dam in the Phugwane was built to provide water when the river's permanent pools such as the Zari, Dhili, Maswitakali, Mashadya and Mfetu dry up (which has happened repeatedly).

In 1973 earth dams were built in the Kokodzi (Krapkuil), Mashokwe (Rooibosrand), Manzemba (Biesiesvlei) and Dzombo spruits (Ganspan). The Mingerhout Weir in the Letaba was completed and a fourth weir, the Black Heron, was started. Work on the large Kanniedood Dam, east of Shingwedzi, was also commenced to provide water when "permanent" waterholes such as Mbohle, Mahlambangwenya and Nyarini in that part of the Shingwedzi dried up. Both concrete dams were completed in 1974. Another earth dam was built in the Maswitakali Spruit, a tributary of the Phugwane (Mooigesig Dam).

The year 1975 was marked by an historical event — the eastern boundary was fenced off with elephant-proof fencing as a result of deteriorating international relations with Moçambique. With the completion of this task in 1976, the KNP was fenced in completely (with the exception of the northern boundary along the Limpopo, which was fenced in 1980). The game within the park was now completely dependent for survival on local natural resources including those which are man made. Mass migration to escape natural catastrophes such as droughts and extensive veld fires is now impossible.

Despite the effort needed to fence off the eastern boundary, construction of the large Pionier Dam in the Tsende River was started in 1975. This dam provides water for a strategic area of the KNP when its large natural pools such as those at Shipandane, Mooiplaas Mouth, Mabohlelene and Eendrag dry up as they did in 1970. The dam also serves as a safe, unpolluted refuge for many fish species in the Letaba System, and has been provided with a fish ladder.

The cyclone Danae hit the park in January 1976. Except for heavy downpours of rain, it caused no damage. The Pionier Dam was completed and another earth dam was built in the Shipikane (Stapelkop) near Joubert's grave, where there had been a popular hunter's camp in the previous century.

During the first week in February 1977 the cyclone Emily, struck the KNP

with devastating force and caused extensive damage, especially in the northern section. A number of dams could not cope with the violence of the floods, and the Wik-en-weeg in the Phugwane, the newly completed Pionier Dam in the Tsende and the Black Heron Weir in the Letaba burst. The dam walls at Kanniedood, Shimuweni, Mingerhout and Engelhard were also damaged.

The flood damage caused by this cyclone was a near lethal blow to the water-provision scheme, and for the next three years (until 1981) no new projects could be undertaken. All available funds and manpower had to be diverted to repairing the flood damage. However, the windmill programme was completed at about that time, and no additional boreholes to provide water for additional game will probably be required.

The water provision scheme was continued in 1981. An earth dam was built in the Mulalane Spruit (Reënvoëldam), and work was started on the Silwervis Dam west of Tsange, in the Shingwedzi River. This large dam will provide water for the large herds of game in the area (especially elephant and buffalo) when the western series of waterholes in the Shingwedzi — the Nkayeni, Shikokola and Makete-kete — dry up as they did in 1970. It is also a valuable refuge for rare fish species (such as the papermouth, *Barbus mattozi* Guimaraeus) of the Shingwedzi River.

The Silwervis Dam was completed in 1982. During 1983 and 1984 no large dams were constructed because the leeway in the reservoir and trough programme supplying the windmill network of the park had to be made up. The cyclones Domoina (5th February 1984) and Imboa (18th February 1984) both hit the southern part of the park, but caused no damage worth mentioning.

The 1984-1985 rainy season was exceptionally profuse and widespread for a year included in a dry cycle and brought great benefit to grazing conditions and raised the level of "perennial" rivers that had become critically low, especially in the northern part of the park. More than 80 hippo succumbed in the Luvuvhu River at Pafuri, and the crocodile population decreased drastically.

Plans to commence building the Groblershoop Dam in the Timbavati River during 1986 were under way at the time of writing. Since the 1960's this river has not been the reliable water source that it had been in the past. The Groblershoop Dam is being built at Mbangari, where, until the mid-1960's, there had been a large and deep hippo pool. The dam will also replace the other large silted-up waterholes in the Timbavati, such as those at the present picnic spot, Nwatingala Mouth and Hlangene Mouth.

4. Conclusion

If one pages back through the history of the artificial water-for-game programme in the KNP, one is apt to recall the words of the present Chief Director, Mr. A.M. Brynard, when he said, in 1969:

"The first phase commenced at the end of 1929 when a careful start was made, under difficult circumstances, with the water supply programme. Many unknown factors retarded the programme, and although it progressed slowly,

new methods were continuously tested — methods which formed the foundation of subsequent water programmes.

The second phase came into being when Colonel Sandenbergh took over in 1946 as Warden of the Kruger National Park from the late Colonel Stevenson-Hamilton. A sudden revival in the water supply programme took place, and Board funds, as well as money collected by the public were spent to improve the situation, especially by means of boreholes.

The third phase covers the period from 1953 to 1960. During this phase (before the fencing-off of the western boundary) relatively little was done, except for a few dams that were built. The idea was voiced by some that there had been no further need for water for game.

The fourth phase started in 1960. From 1960 the programme progressed well and from then until the end of 1969, an amount of about R269 000 was spent on water for game. Without fear of contradiction one can assume that during the last eight years of this phase, more money was spent on water for game than during the preceeding 31 years since 1929.

The end of 1968 brought us to a brand new phase (the fifth) namely the strengthening of the water position in our major rivers and their large tributaries." (The programme for this phase was sanctioned in August 1969 by the Board of Trustees, and was again amended in 1985 as requested by the Head: Wildlife Management.) "If this phase can be executed successfully, as planned, it will necessarily outshine the work done during the previous four phases, and the money spent."

Mr. Brynard's words were prophetic. Phase five has not yet been completed, and since 1969, millions of rands have been spent (*one* concrete dam today costs some R500 000, or more, if escalation of costs and erosion of the Rand's value are taken into consideration). It is foreseen that the reservoir and trough programme, and the satisfactory stabilisation of water in the larger "perennial" and seasonal rivers will take at least another 10 years to complete.

The author foresees a sixth phase which will entail consolidation and elimination of the mistakes made in the past. This phase will be backed by greater expertise originating in knowledge of long-term and short-term climate cycles determining rainfall patterns in the Lowveld, the carrying capacity of the fenced-in area, and the particular needs of its legions of inhabitants. It will probably imply that certain boreholes (for example those in the traditional summer grazing areas) will be removed, and that some dams which were built in the past will serve no further purpose and will be drained, if necessary.

Whichever way phases five and six will develop, the Chief Director can again be cited: "Nobody should be allowed to look down with scorn upon the achievements of the past. Every borehole drilled, every windmill erected, every wheelbarrow of concrete, and every bucketful of soil were accompanied by hard labour, more often than not, under difficult circumstances, many hours of planning and often meagre funds that were needed in many places at the same time. The Kruger National Park and its animals can look back gratefully to what had been done for them."

An awareness of the cyclic nature of the rainfall pattern (at least in Africa) is as old as mankind (*cf.* Joseph's interpretation of Pharaoh's dream of the "seven years of great plenty and seven years of famine" in the Bible — Genesis 41 : 17-57). The powers determining these oscillations in the rainfall pattern are hard to explain. Dyer (1975) searched for a correlation between rainfall cycles and the number of perceptible sun-spots.

If the existence of long-term dry and wet climatic cycles can be confirmed, they might be seen as natural regulating mechanisms.

Prolonged droughts and famine have, from the earliest times, caused conflict situations which have given rise to wars, instability and population crashes. Climate plays a crucial role in the survival possibilities of the world's ecosystems, and necessarily, of man himself, too. Until such time as man is capable of developing the technology of weather modification to such a sophisticated level that he can manipulate rainfall at will, it is of paramount importance that the nature conservationist takes careful note of short-term and possible long-term rainfall patterns so that he may formulate responsible and future-directed conservation strategies for conservation areas placed in his care.

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