Anthrax epizootics in Etosha National Park

by

H. Ebedes
Division of Nature Conservation and Tourism,
S.W.A. Administration*

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* Present address: P/Bag 5020, Stellenbosch, 7600
Cape Province, R.S.A.

ABSTRACT

Anthrax has been recorded in domestic animals, wildlife and humans since early times in South West Africa. Incubation has reduced the incidence in domestic animals, but in recent years anthrax has assumed great importance in Etosha National Park where it was responsible for an estimated 54% of the total recorded mortality. From January 1966 to June 1974 the disease caused the deaths of at least 1 635 animals and affected 10 wildlife species. It was diagnosed in plains zebra, blue wildebeest, springbok, elephant, gemsbok, kudu, ostrich, giraffe, eland and cheetah. Adult male and female plains zebra and blue wildebeest were the most severely affected. The deaths recorded amongst gemsbok and eland were the first records of anthrax in these two species. Most of the animals seem to have a resistance to the disease which is lowered by unknown stress factors. The over-utilized Okaukuejo, Namutoni and Andoni areas are enzootic and contaminated waterholes were the main source of infection. Various control measures are reviewed and although it is doubtful if anthrax can ever be eliminated from the Park, it is suggested that the most effective long-term control measures would be the closure of artificial waterholes in the overcrowded and over-utilized enzootic areas.

1 INTRODUCTION

Anthrax is defined as an acute, febrile, infectious bacterial disease affecting warm-blooded animals and resulting in a fatal septicemia. The disease has a world-wide distribution (Minett, 1952; Klemm and Klemm 1959; Kauker and Zettl 1963; and others). Anthrax is caused by rod-shaped bacteria Bacillus anthracis which are usually found in the blood, fluids and organs of an infected animal. When exposed to air and under the influence of optimum conditions, the bacilli actively form spores which can retain their vitality and virulence in soil, water, vegetation and hides for many years. Spores of B. anthracis preserved on filter paper retained their viability and virulence after storage of 67 years (Novel and Pongratz, 1969). Sporulation takes place when infected fluids exude from the natural body openings and when a carcass is opened and exposed to air. Anthrax is associated with the soil and according to Van Ness (1971) spores vegetate when soil conditions are favourable and bacilli form spores when conditions are satisfactory. Natural infection usually occurs via the digestive system through the ingestion of contaminated food or water.

The disease is diagnosed by the examination and finding of B. anthracis organisms in stained blood smears from an infected carcass and by culture, biochemical, serological and biological tests of suspected material.

In most countries anthrax is a scheduled disease and outbreaks in domestic stock can be controlled by inoculation. In South Africa, legislation provides for the enforcement of quarantine regulations in the infected locality, the proper disposal of the carcass and compulsory inoculation of all animals exposed to the infection. These measures are not always possible when wildlife populations are affected.

In domestic stock the incidence of the disease is well-known and has been reported on extensively. Outbreaks in wildlife have occurred from time to time and it appears as if the disease is assuming greater importance in wildlife populations (Pienaar, 1961 and 1967; Novakovski, Cousin, Kolenosky, Wilton and Choquette, 1963; Moynihan, 1963; Kellogg, Prestwood and Noble 1970; de Vos and Lambrechts,
1972; McConnel, Tustin and de Vos, 1973; Choquette, Broughton, Currier, Cousineau and Novakowski, 1972).

Young (1969) classifies anthrax together with rinderpest as one of the dramatic diseases affecting wild animals in Africa. In one of Africa's largest wildlife reserves, the Kruger National Park, anthrax was responsible for the death of more than one thousand animals during a period of 4 months in 1960 (Pienaar, 1961). Over the past few years since 1965, anthrax has become a significant disease in the Etosha National Park and in this paper the historical background in South West Africa, the epidemiology, incidence, possible transmission of the infection and possible control measures are reviewed.

2 HISTORICAL NOTE ON ANTHRAX IN NORTHERN SOUTH WEST AFRICA

The following brief historical note is an attempt to trace the possible origin of the recent recorded anthrax epizootics in the Etosha National Park. The information which has not been published previously was obtained mainly from the anthrax files of the Division of Veterinary Field Services in Windhoek, reports of the South West Africa Division of Nature Conservation and Tourism, Mandate Reports to the League of Nations and from correspondence and discussions with veterinary and nature conservation colleagues.

2.1 Anthrax in farming areas occupied by Whites

Anthrax occurred in South West Africa in early times (Sander, 1896). During 1879, many Hereros and their livestock, particularly in the northern parts of South West Africa, died after extensive outbreaks of the disease. The year 1879 was commonly known as “Otjindima” — the year of the “anthrax pox”.

During the period of German Colonial Administration (1884—1915), sporadic anthrax outbreaks were recorded in the Karibib, Windhoek, Gobabis, Rehoboth and Gibeon districts in cattle, sheep, pigs and horses (Jacobson, 1907). At the end of 1905 and beginning of 1906, severe outbreaks occurred in cattle and the disease also affected the riding camels of the Schutztruppe (Schneider, pers. comm.). Ostertag (1911) recorded anthrax in ostrich Struthio camelus. According to Kuhn (1907) Europeans and non-Europeans became infected and often died after handling infected skins or eating the meat of animals that died of anthrax. Rickmann (1908) was of the opinion that infected watering-places were responsible for the disease and that it was most prevalent after the first rains. He regarded anthrax as a stationary soil disease limited to certain infected districts and it could also be spread by traffic to adjoining areas.

After World War I (1914—1918), the agricultural and veterinary affairs of the mandated territory of South West Africa were taken over by the government of the Union of South Africa and outbreaks of the disease were recorded in the Windhoek, Warmbad, Keetmanshoop, Rehoboth, Gobabis, Okahandja, Karibib, Omaruru and Otjiwarongo districts with indications of a wider distribution than was previously suspected (Map 1). During 1920, veterinary inspections of farms in the magisterial districts of Windhoek, Gobabis and Okahandja were undertaken by South African veterinarians and, out of a total of 84 farms, 40 were positively infected, 11 were doubtful and 33 were classified as unaffected.

Although sporadic and isolated cases were found in the Grootsfontein area, the earliest recorded major anthrax outbreak in the northern part of SWA occurred in 1920 on the farm “Teufelberg” a few kilometres south of Otjikoto, and approximately 200 kilometres from the former southern boundary of Etosha National Park. From 1940 to 1968 at least 32 outbreaks were reported from Otjiwarongo. Two of these outbreaks, during 1955 and 1960, were on farms bordering on the Etosha National Park.

In the White farming areas of South West Africa anthrax in cattle was brought under control by regular inoculations. Table 1 gives the number of confirmed anthrax outbreaks.

2.2 Anthrax in the Northern Bantu Territories

Sporadic cases of anthrax were previously reported in the Waterberg East Native Reserve and the Ojituuru Native Reserve (now called Hereroland) and a major outbreak was confirmed in 1917. Human cases were frequently treated at the Omakarara Hospital, 24 during 1946, but the severity of the disease in livestock could not be determined because Herero stockowners refused to report the deaths and regarded sudden mortality to be caused by galamsieke or snake-bite. In Ovamboland and southern Angola anthrax outbreaks were recorded for the first time in 1926. Several hundred cattle died in northern Ovamboland during 1926 and 1928 and control measures such as the incineration of infected carcasses and quarantine restrictions were enforced by the Chief Native Commissioner and his staff. Inoculation campaigns were frequently recommended to control the outbreaks, but a shortage of veterinary personnel prevented these from being carried out. During 1939 and 1941 other serious outbreaks occurred in southern Angola and northern Ovamboland and the Chief Native Commissioner estimated that approximately 200 Owambos died of the disease during the latter outbreak.
TABLE 1

Confirmed outbreaks of Anthrax on farms in South West Africa. Information from SWA Division of Veterinary Field Services, Windhoek.

<table>
<thead>
<tr>
<th>Year</th>
<th>1920</th>
<th>1921</th>
<th>1922</th>
<th>1923</th>
<th>1924</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
<th>1928</th>
<th>1929</th>
<th>1930</th>
<th>1931</th>
<th>1932</th>
<th>1933</th>
<th>1934</th>
<th>1935</th>
<th>1936</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>43</td>
<td>83</td>
<td>64</td>
<td>34</td>
<td>38</td>
<td>21</td>
<td>54</td>
<td>70</td>
<td>66</td>
<td>49</td>
<td>64</td>
<td>32</td>
<td>53</td>
<td>50</td>
<td>13</td>
<td>16</td>
<td>49</td>
</tr>
<tr>
<td>Cases</td>
<td>48</td>
<td>28</td>
<td>29</td>
<td>22</td>
<td>28</td>
<td>17</td>
<td>18</td>
<td>27</td>
<td>42</td>
<td>31</td>
<td>37</td>
<td>36</td>
<td>21</td>
<td>36</td>
<td>31</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Cases</td>
<td>27</td>
<td>24</td>
<td>16</td>
<td>7</td>
<td>23</td>
<td>9</td>
<td>23</td>
<td>23</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>15</td>
<td>5</td>
<td>9</td>
<td>13</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Cases</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
</tbody>
</table>

Note: Anthrax outbreaks during World War I
1916-17 Okahandja district
1917 Several (Okahandja, Gobabis, Rehoboth, Waterberg)
(Approximately 10,000 cattle inoculated)
1918-19 Karlheb, Rehoboth, Okahandja and Windhoek
1919 Several (Karlheb, Okahandja, Keetmanshoop, Gobabis, Rehoboth, Warmbad, Windhoek and Waterberg)

No figures are available for the annual livestock mortality caused by anthrax in Owambo, but when once considers the incidence and severity of the disease in humans treated at the various mission hospitals and clinics in the territory from 1926 to 1941, the impression is gained that the disease was widespread. (Table 2).

From 1955 to 1960 and regularly thereafter, intensive inoculation campaigns were carried out in Owambo and the incidence of anthrax in livestock as well as humans decreased dramatically.

Table 2

Number of human Anthrax cases treated at mission hospitals and clinics in Owambo 1926 to 1941.

<table>
<thead>
<tr>
<th>Year</th>
<th>1926</th>
<th>1927</th>
<th>1928</th>
<th>1929</th>
<th>1930</th>
<th>1931</th>
<th>1932</th>
<th>1933</th>
<th>1934</th>
<th>1935</th>
<th>1936</th>
<th>1937</th>
<th>1938</th>
<th>1939</th>
<th>1941</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>35</td>
<td>75</td>
<td>274</td>
<td>56</td>
<td>36</td>
<td>269</td>
<td>116</td>
<td>92</td>
<td>20</td>
<td>50</td>
<td>33</td>
<td>58</td>
<td>41</td>
<td>58</td>
<td>approx. 200</td>
</tr>
<tr>
<td>Deaths</td>
<td>(7 deaths)</td>
<td>(12 deaths)</td>
<td>(5 deaths)</td>
<td></td>
<td>(2 deaths)</td>
<td>(8 deaths)</td>
<td></td>
<td>(3 deaths)</td>
<td></td>
<td>(1 death)</td>
<td></td>
<td>(1 death)</td>
<td>(6 deaths)</td>
<td></td>
<td>(200 deaths)*</td>
</tr>
</tbody>
</table>

* From a report on anthrax by Native Commissioner of Owambo dated 27/4/1941, file 8/3 at SWA Department of Veterinary Field Services.

Anthrax outbreaks were recorded in the Kavango territory and Western Caprivi during 1938.

The first recorded outbreaks of anthrax in Kaokoland occurred during 1953 close to the border of the Etosha National Park. During February and March of 1962 unconfirmed outbreaks of the disease were reported over an extensive area of the south-eastern Kaokoland, but no inoculation campaigns were undertaken.

2.3 Anthrax in wildlife in South West Africa

Up to 1933, anthrax was confirmed in only four Southern African wildlife species (Thomas and Neitz, 1933). These were zebra (Equus burchelli), black wildebeest (Connochaetes gnou), hardebeest (Alcelaphus buselaphus) and springbok (Antidorcas marsupialis). The reason for this limited information on outbreaks is that in the past wild animals did not play a significant role in the economy of the country and mortalities were seldom reported. The first confirmed anthrax case in a wild animal in South West Africa was diagnosed in 1933 by Dr J. Watt in a semi-tame hardebeest from the Gobabis district. Du Toit (1947) believed that hardebeest were responsible for infecting horses with anthrax on a nearby farm.

In June and July of 1942, kudu died of anthrax on farms bordering the Swakop River in the Karibib district. The veterinarian investigating the mortality suspected that biting flies and blood-sucking insects transmitted the infection. Two peculiar features were noted during this outbreak. Firstly, very few anthrax bacilli were found in the bloodsmears taken from the affected animals. This finding has also been described by Kampelmacher and Van Noorle Jansen (1970) and McConnel, Tustin and de Vos (1972). Secondly, only kudu were affected and no cases were recorded in cattle, horses, sheep and goats. Kehoe (1919) noted that during anthrax outbreaks, the disease often affected only one species while animals of other species grazing together on the same veld were not affected.

An outbreak of anthrax during 1945 in a pedigree herd of milk cows in the Ojwaraongo district was traced to two dead kudu that were skinned near the milking stables. In December 1952 anthrax was diagnosed in a blue wildebeest (Connochaetes taurinus) on a farm in the Leonardville district. The previous year several cattle on the farm died of the disease. This was probably the first case ever recorded in blue wildebeest.

During March 1964, two elephants (Loxodonta africana) died near the Odila River close to the Owambo/Angola border. Three Owambos died after eating the meat and several were treated for cutaneous anthrax at a mission clinic. A donkey used for transporting the meat to a nearby Native Kraal also died. Anthrax was confirmed in the elephants and Owambos and one of the elephant carcasses was incinerated. During the same period a sick elephant bull was shot dead near Ombulantu because of suspected anthrax.

Until 1966, no records of mortality were kept in the Etosha National Park and it is therefore difficult to trace the causes of former deaths in wildlife. Most mortalities were considered to be the result of predation by carnivorous animals. Dr P. J. Schoeman (1969, pers. comm.) the Chief Game Warden for South West Africa in the early 1950's never encountered any diseased animals during his stay in the Etosha National Park. Even Foot-and-Mouth Disease, which periodically broke out in Owambo, has never been diagnosed in the Park. The car-
casses of zebra and wildebeest were often found on the Andoni Plain, the edges of the Etosha Salina and in the vicinity of Okondeka and Leebroun, but the causes of these isolated deaths were never properly investigated and no bloodsmears were examined. Anthrax was never suspected. Lungworm infections in wildebeest and heavy parasitism by bots and round worms in zebra were frequently observed in animals shot for rations. An estimated 4 000 to 5 000 blue wildebeest and a few hundred zebra died during 1959 in the region of the Okumu River north-west of the Etosha Salina (de la Bat, pers. comm.). This mass-mortality was investigated by a State Veterinarian and acute salione poisoning caused by the drinking of highly saline water in the pans near the Okumu River was diagnosed (le Riche, 1968, pers. comm.). The most prominent symptoms in the afflicted animals were weakness, paralysis of the hindquarters and watery diarrhoea and the post-mortem lesions showed a gastro-enteritis. Bloodsmears were negative for anthrax.

Towards the end of 1964 several carcasses were found in the Grootvlakte area near Grootdam. There were no indications that predators were responsible for the deaths and because a disease was suspected, bloodsmears were taken and veterinary assistance was sought (Stark, 1967, pers. comm.). The bloodsmears of two zebra, five gemsbok (Oryx gazelle), and an elephant were examined by a State Veterinarian and confirmed to be positive for anthrax (Steenkamp, 1968, pers. comm.). Other fresh elephant carcasses were found during 1965 and 1966 and bloodsmear diagnoses of anthrax were confirmed by bacteriological and biochemical tests.

From the above brief historical review it is evident that anthrax was widespread in the northern part of South West Africa. Anthrax epizootics occurred in livestock in all the areas surrounding the Etosha National Park and there is no reason why the disease should not have occurred enzootically in the Park prior to 1964 when it was diagnosed for the first time. It is possible that the disease was never severe and the occasional mortalities observed from time to time were never investigated properly because anthrax was not suspected.

### 3 EPIZOOTIOLOGY

To appreciate the epizootiology of anthrax in the Etosha National Park, it is necessary to briefly describe the major seasonal wildlife population shifts which are a characteristic feature of the ecology of the Park and also to review some of the changes which may have influenced the severity of anthrax outbreaks.

The area around the Etosha Salina is classified as a Saline Desert with Dwarf Shrub Savanna fringe (Gissel, 1971). Only two climatic seasons are recognized in the Park: a dry and a wet or rainy season. Rainfall figures are given in Table 3. The Park falls in the 100–500 mm arid savanna moisture zone. The rainfall is generally scattered and decreases from east to west. The mean maximum temperature for summer is 32.4°C and for winter 28.4°C. The mean minimum temperature for summer is 17.4°C and winter 6.8°C.

Zebra, blue wildebeest and springbok are the most numerous ungulates in Etosha. The fact that they are migratory was first described by Bigalke (1961). The majority of these animals concentrate around saline permanent waterholes south and east of the Etosha Salina during the dry season. At the onset of the rainy season they migrate to the short annual and micro-perennial grassland west of the Salina which has an abundance of fresh rain water. To a lesser extent they also move to the area around Namutoni Fort (Ebedes, 1970). This movement, away from the tall perennial grasslands to short grasslands, and the utilization of the short grasses during their growing and most nutritious stage is a form of natural rotational grazing practised particularly by zebra (Ebedes, 1969, 1970). The animals return to the dry season grazing grounds when the vegetation deteriorates and temporary rain water pans dry up.

**TABLE 3**

<table>
<thead>
<tr>
<th>Month</th>
<th>Okaakuejo (13 years)</th>
<th>Halali (4 years)</th>
<th>Namutoni (10 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>2.5</td>
<td>2.5</td>
<td>7.9</td>
</tr>
<tr>
<td>November</td>
<td>35.2</td>
<td>82.2</td>
<td>70.0</td>
</tr>
<tr>
<td>December</td>
<td>41.9</td>
<td>47.4</td>
<td>47.4</td>
</tr>
<tr>
<td>January</td>
<td>100.8</td>
<td>140.0</td>
<td>112.7</td>
</tr>
<tr>
<td>February</td>
<td>79.8</td>
<td>74.6</td>
<td>100.9</td>
</tr>
<tr>
<td>March</td>
<td>77.9</td>
<td>104.4</td>
<td>78.3</td>
</tr>
<tr>
<td>April</td>
<td>23.9</td>
<td>21.8</td>
<td>24.5</td>
</tr>
</tbody>
</table>

Prior to 1947 the movement of the animals was unrestricted. In that year however, a portion of the southern portion of the Park was reduced in size and settled by European farmers. During the rainy season several hundreds of zebra, wildebeest, springbok and eland (Taurotragus oryx) moved southward out of the park onto these farms. Stockproof fencing of the farms and general farming activities restricted this movement. A most important event was the erection during 1960–1963, of a 2.59 m high stock- and game-proof Foot and Mouth Disease barrier fence along the eastern and southern boundary. This fence played an even greater role in restricting movement to the south.

From 1956 numerous boreholes with windmills and artesian wells were sunk in various parts of the Park to provide additional watering places for wildlife. Excavations for gravel to improve the tourist roads, were made near the roads to minimise construction costs (Rocher, 1968, pers. comm.), to create more watering places for wildlife-viewing and also to spread the animals over a wider area and to prevent over-concentration at existing natural waterholes (de la Bat, 1970, pers. comm.). During the rainy season, these excavated areas or gravel pits filled with rainwater thus augmenting the naturally-occurring rainwater pans. The word “mini-dam” has been adopted to describe the rain-filled gravel pits. In 1970 there were at least 134 mini-dams in the Okaakuejo area and it is conservatively estimated that when filled with water they could contain 717 747 cubic metres of water. These mini-dams retain water for up to five weeks longer than the small, shallow temporary rainwater pans. They have become favoured drinking places for zebra, wildebeest and gemsbok, probably because they have a lower salinity than that of natural waterholes. (Plate 1).

By restricting the southbound annual animal migration through fencing and creating additional watering points in the traditional wet season grazing areas west of the Salina and around Namutoni, large numbers of animals remained here for longer periods than in previous years. The result is evident in over-utilization of the vegetation with characteristic invasion of weeds, bare patches and bush encroachment by plants.
Map 2: Map of Etosha National Park showing distribution of zebra
such as slapdoring (*Acacia nebrownii*), mopane (*Colophospermum mopane*) and gabbabos (*Caitrophactes alexandri*) on the plains. A similar situation has been reported by Pienaar (1967) in parts of the Kruger National Park where uncovered gravel pits, which act as unwanted water reservoirs in traditional summer grazing areas, have led to continued grazing pressure, overtrampling and range regression.

These over-utilized areas in the Etosha National Park have become enzootic for anthrax. The Pafuri area in the northern Kruger National Park, which has periodic anthrax epizootics, is also overgrazed (Pienaar, 1967; de Vos, 1971, pers. comm.). Similarly, the severely over-utilized parts of the Waterberg East Native Reserve (Hereroland West) along the Omuramba Omatako, are enzootic for anthrax. The 1963 anthrax epizootic in white-tailed deer (*Odocoileus virginianus*) on Beulah Island, Arkansas, SA, was associated with a high deer population and low food supply (Kellogg, Prestwood and Noble, 1970).

Anthrax outbreaks are often associated with contaminated soil and water (Rickman, 1908; Kehoe, 1919; Viljoen, Curson and Fourie, 1928; Minett and Dhanda, 1941; Davies, 1960; Pienaar, 1961 and 1967; Wilson and Miles, 1966; Van Ness, 1959 a. and b., 1969 and 1971; Choquette, 1970; and Merchant and Packer, 1971). Calcareous soils and shallow loams on calcite associated with hardpan calcite outcrops are the dominant geological features in the enzootic areas of Etosha (Verster, pers. comm.). The organic material, nutrients and minerals accumulated in the pans and mini-dams during the rainy season together with mean mid-summer water temperatures of 27°C and pH of 7.5 are factors which contribute to the formation of the anthrax “incubator areas” described by Van Ness (1971). Sporulation and germination of the anthrax organisms takes place under optimum temperature and moisture conditions (Davies, 1960).

Contaminated waters were suspected as the source of a severe outbreak in the Okaukuejo area during the 1969 rainy season. Water, mud and soil samples were collected from natural pans and mini-dams for cultural, biochemical and biological tests at the Veterinary Diagnostic Laboratory in Windhoek. Sixteen of the 23 mini-dams (70%) and 11 of the 24 natural pans (46%) tested were found to be contaminated with virulent anthrax organisms (Bergmann, pers. comm.). Two years later, in 1971, 85% of the mini-dams and 80% of the pans tested were positive for anthrax. Similarly, in the Namutoni area and on Andonivlakte, anthrax mortality was associated with mini-dams infected with *B. anthracis*. After disinfection and closure of a large mini-dam on Chudobvlakte, the incidence of anthrax in the Namutoni area dropped dramatically and similarly the disinfection of the mini-dam on Andoni resulted in a decreased mortality.

Apart from the un-aesthetic appearance of the mini-dams which scar the landscape, there are a number of noteworthy differences between natural pans and mini-dams. These are summarised in Table 4. Notwithstanding these differences, it is evident that mini-dams are potential anthrax “incubator areas”.

The confirmation that a large number of mini-dams were contaminated with *B. anthracis* is significant in that susceptible animals could become infected from more sources and over a wider area than was previously the case when only natural pans were infected. Before the mini-dams existed, the animals moved away as soon as the natural pans had dried up. However, the mini-dams retain water longer than the pans, the animals remain in the area for longer periods and those susceptible are therefore, more likely to become afflicted.
3.1 Namutoni area

The first serious recorded outbreak in the Etosha National Park occurred in the Namutoni area during the 1968 rainy season. At least 240 animals died of suspected anthrax and were incinerated from 9th January to 16th April. The outbreak had probably been raging for a few weeks before the disease was first suspected and diagnosed. Exceptionally good rains had fallen in the area and 2 147 zebra, 1 204 blue wildebeest and 962 springbok concentrated within 10 km east and west of Namutoni Fort. Fisher (quoted by Bigalke, 1961) recorded that the animals moved away from Namutoni at the start of the rainy season. Similarly, Shortridge (1934) noted that thousands of zebra assembled at the Namutoni fountain in the dry season. The fact that thousands of animals were found near Namutoni in the rainy season is contrary to former distribution patterns. A possible reason for these concentrations is the large number of mini-dams which have been constructed in the area during the 1960's. As soon as the disease was diagnosed routine anthrax patrols were started and an average of 3 carcasses, mainly zebra and wildebeest, were found daily and incinerated. The majority of deaths occurred on Chudob/Atlant and the airfield. Towards the middle of February the area was severely overgrazed and by the middle of April the open waters had dried up and the majority of the animals moved away with consequent decrease in mortality. The source of the 1968 outbreaks was traced to infected mini-dams and particularly a large mini-dam on Chudob/Atlant next to the main road. After this mini-dam was disinfected with the quaternary ammonium compound “Sanocept” (Agriutra) and chloride of lime and bulldozed closed there was a marked decrease in the incidence and only sporadic cases were found from 1969 to 1973. This situation continued until the rainy season of 1973/1974 when a further outbreak occurred. The

Plate 2: Vultures at carcass of zebra that died of anthrax.
source of infection was traced to a new mini-dam that had been constructed near the previous one on Chudobvlakte. The soil in the Namutoni area is shallow calcareous clay with moderate drainage. The vegetation here is short grassland with shrublets and consists mainly of short annual and micro-perennial grasses: Enneapogon desveauxii (E. brachystachys), Eragrostis annulata, E. nindensis (E. demudata), Tragus berteroniana, Willkommia sarmentosa, Eragrostis echinochloidea, Monolotum luderitzianum, Odyssea paucnervis, Sporobolus pyramidalis, S. saltus and S. cornandelliana; and small karoo-like shrubs such as Cyathula horeomenis, Aizoon sp., Sericorema sericea, Salsola tuberculata and Eriophagus pubescens; and many kinds of weeds such as Hirperticum gazzanioides, Tribulus zeyheri, Holotropium lineatum, H. ovalifolium, Acroteme inflata, Geigeria odontoptera, Eracastrum arabicum and others.

3.2 Okauguejo area

This is the most severely affected enzootic anthrax area in the Etosha National Park and extends over some 1 100 km². The majority of zebra, blue wildebeest and springbok in the Park congregate here during the rainy season and up to 10 000 zebra, 3 000 blue wildebeest and more than 5 000 springbok have been counted by aerial surveys during the 1968 and 1969 rainy season.

Anthrax was diagnosed in the Okaukejo area for the first time in 1964 and outbreaks have occurred annually ever since. The most seriously affected area was the triangular one bounded by Okondeka, Adamax and Okaukejo and the Grootvlakte. The majority of pans and mini-dams are contaminated by B. anthracis.

The salinity of the soil decreases westwards from the Etosha Salina and the general geology is shallow alkaline soils associated with calcrete. The vegetation is characterised by large expanses of annual and micro-perennial grasslands, the species composition being almost the same as in the Namutoni area, and halophytic shrub savannas consisting mainly of the following: Cyathula horeomenis, Leucophaera bainesis, Petalidium engelerianum, Lescas pechuelii, Monochroma australis, M. genistifolium, Salsola tuberculata, Sueda articulata and the sedge Setaria dioica (near the Salina); interspersed with Colophospermum mopane woodland, Acacia deitensis woodland, A. reflaxis woodland, Acacia nebrownii/Catophractes alexandri, and shrub Colophospermum mopane woodlands.

Natural rainwater pans (sometimes called vlei's) are found scattered over the lower-lying areas of the plains and savannas. When filled with water these pans abound with amphibia, crustacea and insects.

The following vegetation types are usually found in or around the pans: Algae (during rainy season); Grasses: Cymodon dactylon, Diplachne fusca, Chloris virgata, Eragrostis mirandula, E. rotifer, E. echinochloidea, E. glandulostipata, Echinochloa colona, Setaria verticillata, Cyperus esculentus, Marsilea ephippocarpa; Weeds: Senecio schinzii, Geigeria ornatica, Crotalaria argyrea, Sesbania macowaniana, Gossypium triphyllum, Eracastrum arabicum, Sesamum triphyllum; Abuton angustulata; Trees and shrubs: Acacia hebecrada, A. reflaxis, A. mellifera var. deitensis, Combretum imberbe, Colophospermum mopane, Ziziphus mucronata, A. nebrownii, Diospyros hystrix, Maytenus senegalensis, Catophractes alexandri and others.
3.3 Andoniwvlakte area

Approximately one-third of Andoniwvlakte, (5 500 ha) falls in the Etosha National Park. The rest is in Ovambo. The boundary was fenced during 1973 and prior to that animals freely moved into Ovambo. The vegetation on this halophytic grassland is dominated almost exclusively by Sporobolus spicatus. Odyssea paucinervis grows around the waterholes and along the margin of the Salina. There are occasional patches of annuals such as Chloris virgata, Diplachne fusca, Dactylisium aegyptium and Eragospre porosa.

The soil is a sandy-clay loam and is poorly drained. After heavy precipitation the entire plain becomes waterlogged.

Up to 6 000 zebra, 4 000 blue wildebeest, 1 500 springbok and hundreds of gemsbok and ostriches concentrate in this vital area of the Park towards the end of the dry season. In normal rainfall years the plains animals start immigrating and arriving on Andoniwvlakte from the middle of June. By October the vegetation shows signs of severe overutilization. The animals remain here until the start of the rainy season (December, January) and then move mainly in a westerly direction along the northern edge of Etosha Salina to the Okaukuejo area and to a lesser degree southwards towards Namutoni (Ebedes, 1970). During the rainy season Andoniwvlakte is almost completely deserted by animals.

Two waterholes occur on Andoni, Andoni artesian borehole which feeds a large pan and a large mini-dam near the main road to the north-west of Andoni waterhole. Because the Andoni water is saline (pH 8.9) animals prefer drinking from the mini-dam (pH 7.6) for as long as this water is available. Both waterholes have been found to be contaminated with B. anthracis and severe anthrax mortality, up to six cases per day, has been recorded. During October 1966 an elephant bull that died of anthrax was found in the Andoni waterhole. Dead zebra and wildebeest have frequently been found in or near the water.

4 INCIDENCE OF ANTHRAX AND SPECIES AFFECTED

From July 1967 to June 1974 a minimum total of 2 801 carcasses were found of which 1 526 were diagnosed as confirmed or suspected anthrax cases. (Table 5). Anthrax accounted for 54% of the total recorded mortality.

This total cannot be considered accurate and could possibly be doubled because of the carcasses not found, and in the case of old dehydrated carcasses bloodsmeares were unreliable for an accurate diagnosis. The majority of female zebra and blue wildebeest that died were either pregnant or suckling young. The young usually fell prey to scavengers or died of starvation. Initially the severity of the disease was not realised and frequently no regular anthrax patrols could be undertaken because of a shortage of field personnel.

The monthly incidence shows that maximum intensity occurred during and towards the end of the rainy season, February to April (Figure 1). A similar tendency exists on farms in South West Africa with exception of a high incidence in October (Figure 2). According to Viljoen et al (1928) anthrax in South Africa occurred during both wet and dry seasons. In the Kruger National Park epizootics occurred towards the end of the dry season (de Vos, 1971, pers. comm.) and in North America outbreaks usually followed warm rainy periods (Saulmon, 1972, pers. comm.). Minett (1952) found that the incidence of anthrax in Europe reached its lowest point six months after the peak.

Figure 1: Monthly trend of anthrax in Etosha National Park, SWA. July 1966 - June 1974.

Figure 2: Monthly incidence of anthrax mortality recorded on farms in SWA (1922 - 1968). Total of 658 outbreaks.

Anthrax mortality was recorded in the following species:

4.1 Zebra

Anthrax in zebra has been recorded by Viljoen et al (1928), Pienaar (1961), Lobry (1964), Netz (1966) in Southern Africa and by Schindler, Sachs, Hilton and Watson (1969) in Tanzania. Zebra are the most numerous large mammal species in Etosha (estimated population in 1968 approximately 15 000) and are the most frequently affected by anthrax. The incidence of the disease in zebra in the Etosha National Park is the highest recorded in Southern Africa. When the small number of animals affected is considered in relation to the population, however, it is evident that they are relatively resistant. This could be due to a natural or acquired immunity. Indirect F.A. tests on a small sample of zebra from the enzootic Okaukuejo area as well as the anthrax-free Ovijovasandu area show that from the age of three months an immunity is pre-
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4.2 Blue wildebeest

The blue wildebeest was the second most severely affected species. During 1972 - 1973 more wildebeest carcasses than zebra carcasses were found (Table 5). An equal number of bulls and cows were affected and as in the case of zebra there was no difference between the sexes (Table 5). Adults were mainly affected although several cases in calves and yearlings were found.

Until 1952 the disease had not been diagnosed in this species (vide supra Historical Note) and no cases were recorded during 3 epizootics in the Kruger National Park (Pienaar, 1967). The disease has been reported in East Africa by Lory (1964) and Young (quoted by Schindler et al, 1969) and severe outbreaks have occurred in Tanzania (Gainer 1972, pers. comm.).

Territorial bulls died during the dry season in the enzootic areas after the cow/calf herds had left these areas. Bulls were sometimes found dead in their hollowed-out resting places. On four occasions bulls were found in extremis and two attempts to treat them with antibiotics were unsuccessful.

Etosha National Park is the only sanctuary for blue wildebeest in South West Africa. The large herds which used to roam the plains of Ovamblo do not exist anymore. In 1958 there were as many wildebeest as zebra in Etosha (Bigalke, pers. comm.). In 1968 there were approximately 5 000. The wildebeest population in Etosha is gradually decreasing and notwithstanding heavy poaching pressure in the past the role played by anthrax in hastening this decline should not be underestimated. According to de la Bat (pers. comm.) wildebeest migrated annually to Lake Oponono in Southern Ovamblo. This migration has been proved by the writer with marked animals. Poaching activities in Ovamblo have no doubt decimated the large herds there and few animals have survived.

An unusual finding in a few bloodsabs taken from wildebeest and springbok carcasses suspected of anthrax, was the isolation of Pseudomonas aeruginosa. Septicaemia and death caused by this bacteria has not been recorded previously in wildlife in Southern Africa.

4.3 Springbok

Relatively few springbok died of anthrax although they are numerous in the enzootic areas during the rainy season. More male carcasses were recorded than females. The species appears to be highly resistant to the disease and two factors may in addition play a role: carcasses are not easily located and they are rapidly eaten by scavengers. It has also been observed that springbok do not drink as readily during the rainy season.

4.4 Elephant

Elephant move away from the enzootic areas during the rainy season and anthrax was only recorded during the dry season. A good deal of thorn bush, including thesparding Acacia nebrovallii is eaten and it is possible that the sharp thorns injure the mucous lining of the mouth, throat, oesophagus and stomach thus aiding the invasion of organisms. Spreeu (quoted by Kehoe, 1919) noted a similar condition in cattle fed on prickly pears. Deaths caused by anthrax have been recorded in the Kruger National Park (Pienaar, 1967) and in Kenya and Tanzania (Lobry, 1964).

Elephant are widely distributed and the furthest ranging mammals in the Park. Isolated deaths have been recorded throughout the Park. Most of the carcasses were found in the vicinity of waterholes. During 1969 - 1970 at least 10 elephant died of anthrax. More male carcasses were found than female carcasses. An interesting observation was that when an elephant died of anthrax near a waterhole, other elephants deserted the area and did not return to drink from that particular waterhole for several weeks.

4.5 Gemsbok

Gemsbok have a wide distribution in the Park and appear to have a strong resistance to anthrax. The disease was not previously diagnosed in this species. They seldom drink water during the rainy season and most of the deaths were recorded in the Okaukuejo area during the dry season. Gemsbok have been seen to chew dry bones and a strong possibility exists that they become infected through eating contaminated bones.

4.6 Kudu and giraffe

Both species are more numerous in the Namutoni area than in the Okaukuejo area. During the rainy season they move away from the enzootic Okaukuejo area, but are found not far from the Namutoni enzootic area. Contrary to the high incidence of anthrax recorded in kudu by Pienaar (1961) very few cases were recorded in Etosha. Both species are browsers and frequent the more dense and bushy areas away from the roads where carcasses cannot be located easily.

4.7 Eland

During the rainy seasons of 1967 to 1971 large herds totalling up to 1 000 eland entered the enzootic Okaukuejo area and were found mainly on Grootvlakte. Although they drank from contaminated pans they appear to be resistant to the disease as only three cases were recorded. These are the first known recorded cases for this species.

4.8 Ostrich

Birds are generally regarded as naturally resistant to anthrax because of their high body temperatures (Pasteur, quoted by Klemm and Klemm, 1959). Anthrax is rare in birds of prey although sporadic cases have been recorded in zoological gardens (Keymer, 1972). The disease has, however, been recorded in ostrich by Henning (1894), Ostertag (1911) and Theiler (1912). Five cases were confirmed in Etosha. The disease was not encountered in ostrich in the Kruger National Park (Pienaar, 1967).
4.9 Carnivorous animals

Anthrax has been recorded in captive and free-living carnivorous mammals (Henning, 1956; Leistner and Schumann, 1956; Kronbergen, 1958; Pienaar, 1961 and 1967; Moynihan, 1963; Neitz, 1965; Thornton, 1968; Anon, 1971; and Lyon, 1973).

In Etosha, lion (Panthera leo), spotted hyaena (Crocuta crocuta), brown hyaena (Hyaena brunnea), and black-backed jackal (Canis mesomelas) often feed on anthrax carcases, but are highly resistant as no cases have been recorded. One suspected case in a spotted hyaena could not be confirmed. Over a six-day period a pride of 21 lions was followed and kept under observation after they had fed on two anthrax carcases, but no signs of illness were seen. Lions were frequently found at carcases initially suspected to have been killed by them, but later confirmed to be anthrax. On several occasions lions were indeed found to have killed animals which were weakened by anthrax.

Two suspected anthrax cases were recorded in female cheetah. During the early 1960s, cheetahs were not as uncommon in the Park (Rocher, pers. comm.) as they are in recent times. They appear to be vulnerable to the disease and one can only speculate if diseases such as anthrax did not play a role in diminishing their numbers.

Until June 1974 anthrax had not been confirmed in the following species:
Lion
Leopard (Panthera pardus)
Black-backd jackal
Spotted hyaena
Brown hyaena
The smaller cats
Ratel (Mellivora capensis)
Bat-eared fox (Otocyon megalotis)
Mountain zebra (Equus zebra hartmannae)
Warthog (Phacochoerus aethiopicus)
Black rhino (Diceros bicornis)
Grey Duiker (Sylvicapra grimmia)
Steenbok (Raphicerus campestris)
Damara dikidik (Madoqua kirki)
Black-faced impala (Aepyceros melampus petersi)
Introduced into Namutoni area 1968 and Otjozandu area 1969 and 1971)
Roan antelope (Hippotragus equinus)
(Introduced into Otjozandu area in 1970)
Red hartebeest

5 SOURCE OF INFECTION AND TRANSMISSION OF ANTHRAX

Post mortem examinations performed on the fresh carcases of 5 zebra and 3 blue wildebeest in the Okaukuejo area (Ebedes, 1971, unpbl. ms.), generally revealed all or some of the characteristic lesions described by Henning (1956). The pharyngeal and peri-pharyngeal region and particularly the lymph glands such as the submandibular and subpharyngeal showed marked congestion, oedema and necrosis. Histopathologically, severe necrosis was seen in the submandibular and subpharyngeal lymph glands and to a lesser extent in the bronchial lymph glands (McConnel, 1971, pers. comm.). In the lymph glands showing necrosis there were large numbers of B. anthracis organisms. McConnel was of the opinion that a primary pharyngitis was present before the systemic disease occurred. B. anthracis was isolated from oesophageal swabs of 4 animals, from the rumen and abomasum contents of 2 blue wildebeest and from grass in the mouth and stomach of one zebra. The findings strongly suggest that the portal of entry into the body by B. anthracis was through the mucous of the mouth or pharyngeal region. The usual portal of entry is through the digestive tract and transmission is per os (Henning, 1956; van der Hoeden, 1964; Lincoln, Walker, Klein and Haines, 1964; Wilson and Miles, 1966; and others). Experimentally, anthrax has been transmitted to susceptible laboratory animals by the inhalation of spores (Barnes, 1947; Ross, 1957; Gleiser, Berdjas, Hartman and Goethenou, 1963; and others). Anthrax organisms can be spread in many ways and some of the possible methods of transmission are briefly reviewed.

5.1 Soil and water

The association between anthrax and soil and water is well recognised and has been extensively documented in the literature (Rickman, 1908; Kehoe, 1919; Viljoen et al., 1928; Minett and Dhanda, 1941; Pienaar, 1961 and 1967; Kellogg et al., 1970; Van Ness, 1959, 1959 and 1971; and others). Viljoen et al. (1928) were of the opinion that flooding during the summer months (rainy season) was responsible for the increased prevalence of the disease in South Africa.

The enzootic areas in the Park are characterised by being flat with lower-lying fountains, pans, mini-dams and umrumbas. Spores from infected carcases, soil and vegetation are carried by surface drainage and the pans and mini-dams are continuously contaminated from surrounding infected areas. Samples of water, mud and soil from suspected natural and artificial waterholes have been regularly tested during both wet and dry seasons and found to be contaminated with anthrax organisms (Bergmann, pers. comm.). Spores are constantly taken up by animals drinking water and pass through the digestive tract of resistant animals without causing the disease. Spore-rich faeces could contaminate soil and vegetation over a wide area. Water can become infected and reinfected by animals either defaecating in or near waterholes. However, anthrax organisms could not be isolated from a small number of faeces samples collected from fresh carcases.

Animals that are fond of wallowing in mud, such as buffalo, elephant and warthog could be responsible for transferring infected mud and contaminating pans (Pienaar, 1967). In the Park, zebra and wildebeest frequently walk into the water, often up to the underside of their bellies to drink, and could transport spores on their hair and hooves. In order to establish if the mud on the hooves and hair above the hooves was contaminated, 118 mud and hair samples were collected from dead and immobilized zebra and wildebeest in the enzootic Okaukuejo area. The samples were cultured in Windhoek and 3 of the 118 samples (2.64%) were found to be positive for anthrax (Bergmann, pers. comm.). From this small sample which should be repeated, it does not seem as if the mechanical transmission of spores by animals is significant.

5.2 Animals associated with carcases

The following animals are usually associated with anthrax carcases and through their close contact with the carcass can be considered to be potential transmitters of B. anthracis from infected to other infected or non-infected areas.
5.2.1 Birds

Kehoe (1919) and Viljoen, Curson and Fourie (1928) expressed the opinion that vultures and jackal could be considered possible agents in disseminating the infection. In the Kruger National Park, vultures were considered to be chiefly responsible for transmitting the infection from dead animals to watering places (Pienaar, 1967; Young, 1970; and de Vos, 1973). This seems to be the case in the Etosha National Park as well. After feeding, vultures and marabou storks often fly to the nearest waterhole to drink and bathe.

Anthrax spores were isolated from the excreta of vultures (Bullock, 1956) and in the Kruger National Park infected faces were another means by which water and grazing was contaminated (Pienaar, 1967). In the Park three vultures feeding on an anthrax carcass were shot dead and anthrax organisms were isolated from the beak, mouth, oesophagus, cloaca and neck feathers, but not from the rectum, duodenum or faeces.

Of the four species of vultures in Etosha the white-backed (Gyps africanus) are abundant, the Cape vultures (G. carunculatus) and lappet-faced vultures (Torgos tracheliotes) are common and the white-headed vulture (Aegypius occipitalis) are rare. Lappet-faced vultures are invariably found at the carcasses of young or small animals (e.g. springbok, lambs and zebra foals). Up to 185 vultures have been counted at zebra and wildebeest carcasses and over 250 have been seen at an elephant carcass. During a severe anthrax outbreak in 1969 more than 800 vultures were counted on one day in the Okaukuejo area. In the dry season, fewer vultures were seen at carcasses either because they were breeding or because there were fewer anthrax carcasses available for them to feed on or both.

During March and April 1969 and April 1972, 67 vultures and one marabou stork were captured and marked near Okonjekela and on Groottvlakte to determine their movements in and away from the enzootic areas (Ebedes, 1973) (Plate 2). The marked vultures were frequently found at anthrax and other carcasses in the Okaukuejo and Ombika areas and also in the Halali area (45 km), Namutoni area and on An donivlakte (125 km), and a farm in the Kamanjab area south of Etosha (130 km). In the Kruger National Park, marked white-backed vultures were recorded 75 km away from the marking site (Kemp, 1969). From the foregoing it is evident that vultures range over extensive areas and can transmit infection to areas far-removed from the original infected carcass. The marked marabou stork was found at anthrax carcasses on Groottvlakte, and was regularly seen at Grootfontein for 6 weeks after it was marked.

Other birds which might be associated with the transmitting of the infection are black crows (Corvus capensis), pied crows (G. albus), tawny eagle (Aquila rapax) and yellow-billed kite (Milvus aegyptius).

5.2.2 Carnivorous mammals

The possible role played by the spectrum of carnivorous mammals in spreading anthrax in the Park has not been fully investigated. Lions and hyenas often dismember an intact carcass and carry pieces of meat, skin and limbs for a considerable distance from the carcass. Anthrax organisms are spread in this manner and also on the hair of the head and front legs of the animals to nearby waterholes. Lions sometimes drag carcasses to the shade of nearby trees and bushes and the soil and vegetation along the dragpath must be presumed to be infected in this manner. Faeces samples were collected from 18 different lions and 6 black-backed jackals after they had previously been seen feeding on anthrax carcasses. The samples were cultured but no B. anthracis could be isolated. This would suggest that the bacilli and/or spores are destroyed by the gastric juices or competitive organisms in the intestinal tract. Choquehuet (1973) however, states that spores are not destroyed by gastric juice. Hair collected from around the mouth of a black-backed jackal shot shortly after it was seen actively feeding on an anthrax carcass was cultured and found negative (Bergmann, pers. comm.). Kranenbeld and Mansoor (1941) were able to culture B. anthracis from the faeces of carnivorous animals fed on infected meat and Bullock (1956) succeeded in isolating anthrax from dog faeces. After a lapse of eight years, virulent spores were cultured from a sample of faeces collected from a dog fed on anthrax spores (Morris, 1920).

5.3 Non-biting insects

Anthrax bacilli were isolated from faeces and regurgitated material of house flies (Musca domestica) (Stockman, 1911). Stein and Helwig (1953), Stein (1943) and Sen and Minett (1943) reported that non-biting and non-bloodsucking flies may play a role in anthrax transmission. In the Kruger National Park blowflies were responsible for contaminating vegetation browsed by kudu and nyala and the high mortality particularly in kudu was ascribed to their eating the contaminated leaves (Pienaar 1967 and de Vos, 1973). Anthrax bacilli were cultured from suspensions of blowflies, Lucilia cuprina, Chrysomya marginalis and C. albiceps, caught at an infected zebra carcass in the Park (Bergmann, pers. comm.). Although blowflies here are not as numerous as they are in the Kruger National Park they could play a significant role in infecting vegetation.

5.4 Biting insects

Biting insects have been held responsible for the transmission of anthrax. Mitzmain (1914) experimentally transmitted anthrax from infected to healthy guinea pigs with Stomoxys calcitrans and Tabanus striatus. Nieschulz (1928) proved the transmission of anthrax by Tabanus rubidus. T. striatus, Chrysops flavicans and Stomoxys calcitrans. Kranenbeld and Mansoor (1939) isolated anthrax bacilli from the faeces, gut content and proboscises of Tabanus rubidus that had fed on animals infected with anthrax. De Villiers (1943) suspected that bloodsucking insects such as horse flies were responsible for transmitting the disease to kudus in the Karibib district in South West Africa. Tabanus spp. (horse fly) were incriminated as transmitters of anthrax to horses in Prince Edward Island and Quebec Province, Canada (Moynihan, 1963). According to Pienaar (1967) bloodsucking insects such as Tabanus, Hippoboscus and Stomoxys spp. played a minor role in outbreaks in the Kruger National Park. Bloodsucking vectors (diptera) are regarded by Kolonin (1969) to be the principle transmitters of the disease in the forested areas of Russia. Stable flies Stomoxys calcitrans and horse flies Tabanus spp. are common in the Park and could be responsible for the transmission of some cases of anthrax although this is considered to be doubtful.

Pure cultures of B. anthracis were obtained from two engorged female ticks Rhipicephalus evertsi, collected from a fresh zebra carcass, but the significance of this finding in the transmission of the disease is not known.
5.5 Bones

Osteophagy (or bone-eating) caused by possible aphanophasorosis has been seen in giraffe, gemsbok, elephant and ostrich in Etosha. Bones lying around in the veld may be contaminated with spores and this is a possible source of infection. Clark (1938) was of the opinion that osteophagy was an important factor in causing the disease in cattle. Pienaar (1967) did not regard osteophagy as significant during epizootics and in Etosha it is felt that only isolated cases are caused by this method.

5.6 Water birds

During the rainy season many species of migrant water birds settle on some of the infected pans and mini-dams in the enzootic areas. When the water dries up temporarily or permanently, the birds move to other waterholes in the Park or outside the Park. An Egyptian goose (Alopochen aegyptiacus) was shot dead on an infected pan near Okondeka and anthrax organisms were isolated from bacteriological swabs taken from the inside of the beak and gizzard. Based on only one case it seems as if water birds could play a role in transmission of infection from one waterhole to another. In Canada, B. anthracis spores were isolated from the cloaca of gulls Larus argentatus which had recently fed on the carcasses of bisons (Bison bison) (Choquette, 1970).

5.7 Wind

Strong easterly and north-easterly winds blow in Etosha during the dry season and whirlwinds which are particularly severe from August to October could be regarded as possible disseminators of spores over extensive areas.

6 METHODS OF CONTROL

The effective anthrax control measures usually implemented on farms are difficult in a game reserve like the size of the Etosha National Park. A start to control the disease was however, made in 1968 when Nature Conservators were issued with field microscopes and instructed to take bloodstains from all carcasses found and to diagnose and incinerate the spot on all anthrax carcasses to prevent the further spread of infection. Diagnosis was based on the finding of typical B. anthracis in methanol-fixed bloodstains smeared with concentrated Giemsa. Blood swabs of some suspected cases were sent to the Veterinary Diagnostic Centre in Windhoek for cultural examination and guinea pig inoculations.

As soon as impending epizootics were anticipated by an early diagnosis in the enzootic areas, daily anthrax road patrols were undertaken. On the open plains, the sighting of descending vultures or vultures on the ground usually indicated the location of carcasses. Great difficulties were however, experienced in locating carcasses in bushy areas and in areas where there were no roads. Occasional aerial surveys showed that many carcasses were not or could not be spotted by personnel patrolling the area. In the Kruger National Park and North-Western Territories, Canada, light aircraft and helicopters were used to locate carcasses and to trace possible contaminated waterholes (Choquette et al., 1972; and de Vos, 1973).

Incineration was done with dry wood logs and old motor oil. Sometimes carcasses, particularly those of fat zebra, had to be burnt more than once. Elephant carcasses were sometimes incinerated five times to ensure that all the carcass material had been burnt to ash. Because of the hard ground formations in the Okaakoje and Namutoni areas, carcasses could not be buried and at no stage was this disposal method contemplated. Although the soil on the Andoni Vlakte is soft and burial possible, the area becomes waterlogged during the rainy season and seepage and contaminating of underground waters could present serious problems.

In the Kruger National Park, the grazing in severely affected areas was burnt to eliminate possible sources of infection and to facilitate the finding of carcasses (Pienaar, 1967). This method was not applicable in the Park for several reasons: the main outbreaks occurred during the rainy season when the grass was green; the sparse vegetation could not be burnt easily (in the Kruger National Park outbreaks occurred during the dry season in woodlands areas) and infected water mainly and not vegetation was the source of infection. In the past, fire probably helped to control anthrax, but in recent times, fire would cause more damage than good if the veld was burnt during the dry season. Before firebreaks were made in the Andoni area, veldfires from Ovambio frequently swept over the grassland. How these fires affected the large herds congregating in the area has not been recorded, but they most probably moved out of the Park.

During the 1962 outbreak in Wood Buffalo Park, Canada, when 281 of 1 300 bison died within a month in a 700 square mile area, the surviving bison were driven from the infected area to a holding zone and a small portion (15%) of the infected area was burnt (Moyinihan, 1963; and Choquette et al., 1972). Forcing animals to leave enzootic areas in the Park or keeping them out of these areas by unnatural methods such as fencing would greatly interfere with their seasonal migrating patterns.

Disinfectants such as "Tetramine" (di-decyl dimethyl ammoniumbromide) and "Hyamine 2389" (alkyltrimethyl ammonium chloride) were successively used in the Kruger National Park for the sterilization of contaminated waterholes (Pienaar, 1961, 1967). At a later stage "T 400", (an organic tin complex combined with a quaternary ammonium compound, Gold Reef Chemical Co.) was used (de Vos, 1971 pers. comm.). After the 1968 and 1969 epizootics in the Park serious consideration was given to the possibility of using disinfectants to sterilize contaminated waterholes.

Field trials with four disinfectants, Sanosept (a quaternary ammonium compound, Agricola), Iosan (a "named" iodine product, A. S. Ruffel), T 400 and chloride of lime (Klipfontein Organic Products) were undertaken in the Park. Water samples were tested before and after disinfection. Chloride of lime was found to be the most effective and least expensive of the four products. Bergmann (pers. comm.) found that Sanosept and T 400 at a concentration of 1:100 destroyed anthrax spores in vitro after 60 minutes contact. Although chlorine is more active in an acid medium, Tilley and Chapin (quoted by Sykes, 1965) found that 10 p.p.m. available chlorine at pH 8 destroyed all anthrax spores after 30 minutes contact (Table 6) and 0.005 % chlorine destroyed all spores within six hours (Hailer and Heicken, 1950). Using electron microscopy, Trzhetskaya and Kulikovsky (1969) demonstrated that 0.55 % active chlorine caused cavolization of the sporoplasma of virulent B. anthracis spores. Cameron (pers. comm.) found no sporidal effect with 5 p.p.m. chloride of lime after 24 hours. Using 17 p.p.m. chlorine, Hamman (pers. comm.) found that all bacteria in water were destroyed after 48 hours and the water remained sterile for 3 days. Similar results were reported by Bergmann (pers. comm.). Hamman
found that disinfection with chlorine at a cost of 0.5 cents /m³ was the most inexpensive disinfectant to use, but that effective chlorination of mini-dams and pans was difficult because the organic matter depressed the bactericidal efficiency of chlorine and also because of the physical difficulties in ensuring adequate mixing and penetration of the chlorine. Natural pans have a higher organic content than mini-dams (Verster, pers. comm.) and chlorination would therefore be more effective if applied to mini-dams. Andoni mini-dam was periodically disinfected with chlorate of lime and Sanoscept and dramatic decreases in anthrax mortality were noted. Hamman (1972, pers. comm.) tested several other disinfectants on water obtained from contaminated waterholes in the Park. Although the experiments were not specifically against B. anthracis the following results are of interest:

Aluminium sulphate: Treatment with 50, 100, 150 and 200 p.p.m. lowered the pH from 7.5 to 6.95, but there was no decrease in the bacterial counts.

Flocculant: Treatment with 20 and 40 p.p.m. caused no decrease in bacterial numbers.

Lime Treatment: with 50, 100, 150, 200, 300 and 400 p.p.m. increased the pH to 9.5, but the bacterial content was not affected, and 500 p.p.m. would raise the pH to 11.0 and sterilize the water but this would be unsafe and unsuitable for animal use.

Copper (CuSO₄ 5H₂O): Treatment with 1 and 2 p.p.m. reduced the bacterial counts, but failed to sterilize.

Silver (AgNO₃): 1 and 2 p.p.m. reduced the bacterial counts, but did not sterilize.

Chlorine: At 17 p.p.m. all bacteria destroyed.

During January – April 1972 all the mini-dams and pans in the enzootic Okavango area excluding the Grootvlakte area and a large shallow pan north of the Okondeka – Adamax road, were disinfected with Sanoscept and T 400. The volume of water was estimated and concentrations varied from 1:10 00 to 1:30 000. The results of bacteriological tests on the disinfected waters were confusing and many of the samples were still positive for B. anthracis 24 and 72 hours after disinfection. Sanoscept and T 400 in concentrations of up to 1:5 000 were effective in most cases.

The following year (1973) most of the water and mud samples collected from previously contaminated waterholes in the Okavango enzootic area were found to be negative for anthrax and there was a corresponding decrease in mortality (See Table 5). 1973 was a particularly dry year. Zebra and wildebeest remained on Andonivlakte during January and February and 70 cases of anthrax were reported there. Very few carcasses were found in the Okavango area during March and April when a high incidence was usually experienced in previous years.

During 1972 two of the most suspect mini-dams were partially closed and during 1973 most of the larger mini-dams in the Okavango area were partially closed with a bulldozer and a road grader. The beginning of 1974 was characterised by exceptionally good rainfall throughout the Park. The incidence of anthrax in the Okavango area reached the lowest level recorded since 1967, and the most of the anthrax cases were recorded in the Namutoni area. Disinfection and closure of mini-dams may have been responsible for this decrease in the Okavango area and a new mini-dam in the Namutoni area for the increase there.

It is difficult to assess the effect of the 1972 disinfection programme. Vegetative organisms of B. anthracis are destroyed by many disinfectants. The quaternary ammonium compounds which were mainly used are however not sporidical (Sykes, 1965), and these compounds are therefore, only effective against the vegetative stages. Under optimum conditions, contaminated waterholes are natural bacterial in cubators where continual germination and sporulation takes place. The quaternaries can therefore, effectively destroy bacilli during the germinating stages. The quaternaries are surface active and when attached to spores are capable of destroying the bacilli as soon as spores start germinating, Under adverse conditions (for the spore) no germination takes place and in time the quaternaries lose their effectiveness. For sterilization with quaternaries disinfection must be applied when spores are germinating. Precisely at what stage germination occurs under natural conditions is not known and several disinfections will have to be undertaken at frequent intervals to ensure sterilization.

Virulent spores have been found up to 1 m deep in the dry mud of a mini-dam. For effective disinfection, the water and mud must be stirred thoroughly with waterpumps to ensure diffusion and contact at all depths and over the entire area. The contamination of waterholes is usually gross. As waterlevels recede, conditions become unfavourable and sporulation takes place with deposition of spores along the beds of the waterholes. It is therefore, essential to disinfect when they are filled to capacity and also to ensure that the sides are disinfected.

There are two other unknown factors in the sterilization of waterholes in wildlife reserves. Firstly, the effect of the disinfectant on the rumenial and intestinal flora. Observations in the Kruger National Park (Pienaar, 1967) and in the Etosha National Park suggest that the quaternary ammonium products are not harmful or toxic, yet continual intake over long periods may eventually prove to be toxic to the animals drinking the water. Secondly, disinfection of waterholes destroys all forms of lower life including crustaceans, amphipods (tadpoles) and insects. The significance of these in natural food chains, ecological associations and the niche they occupy, is poorly understood. Sterilization of waterholes may be beneficial in destroying pathogenic bacteria, but on the other hand may cause unknown and longlasting damage and should not be undertaken unless all possible consequences and undesirable effects to the animals that drink the water and that live in the water, have been carefully considered. These aspects need further investigation.

### Table 6

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<th>pH</th>
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The mass vaccination of bison herds to control anthrax outbreaks in the enzootic Canadian North-western Territories was undertaken in 1965, 1966 and 1970 (Choquette et al. 1972). Helicopters were used to herd the animals into corrals and from these they were forced into a compartimental crate for vaccination and branding. The protection afforded by the vaccination could not be evaluated because no anthrax deaths were subsequently recorded in either the vaccinated or non-vaccinated animals (Choquette, 1970). Choquette however, felt that the vaccination of a large number of susceptible animals could lessen the possibility of epizootics.

In the Park, zebra intended for export were captured with the “Oelofse plastic-net corral method” (Oelofse, 1969) and vaccinated with Onderstepoort spleen vaccine in a similar way to that described above (Unpublished report, 1971). Techniques for the mass inoculation of corralled herd animals have been described by Young (1972 and 1973).

The inoculation of free-ranging roan antelope by firing vaccine filled disposable projectile syringes from a helicopter, was perfected by de Vos, van Rooyen and Klopper (1973) in the Kruger National Park. Each animal received 1.25 ml of the Onderstepoort spleen vaccine (12.5 million spores per dose). The inoculated animals were marked simultaneously with an alcoholic based gentian violet dye contained in a rubber compartment fitted to the syringe needle. The all inclusive cost per animal was R14.96 and R28.10 for the inoculation campaigns of 1971 and 1972. The aerial inoculation of roan antelope was resorted to as a desperate measure to save a dwindling herd in danger of being exterminated by anthrax.

It is gratifying to know that wild animals can be successfully, albeit expensively, protected by means of inoculation. All animals captured in the Park for marking purposes were routinely inoculated. The protection afforded by the vaccine, however, is not life long and only lasts a year (Stern, 1939). This was proved in the Park by the deaths of two zebra from anthrax approximately one and two years after they were in oculated and marked for a migration study.

Bergmann (1973, pers. comm.) succeeded in producing an oral vaccine that protected guine pig from repeated challenges with virulent anthrax spores. The vaccine has not yet been evaluated on other species.

7 DISCUSSION AND CONCLUSION

It is only in recent years that anthrax has been observed to be an important cause of mortality in the Park. The vegetation in the enzootic areas has also deteriorated and there seems to be an association between the two conditions which the following discussion may help to elucidate.

Before the establishment of additional waterholes such as boreholes and mini-dams, the area north of Okaukuejo was traditionally visited by migrating zebra, wildebeest and springbok for short periods during the rainy season. Some of the migrating animals, however, settled permanently in the area and utilized whatever grazing was left after the migrating herds had moved out of the area. Because the mini-dams retained rainwater for longer periods than the natural pans, animals remained in the area for longer than was previously the case thus causing further damage to the vegetation. The Namutoni area, with its abundant permanent fountains was traditionally grazed during the dry season.

According to Prof. Volk (pers. comm.) who has studied grazing conditions in South West Africa for more than 30 years, continual and severe grazing pressures favour the growth and survival of hardy grasses and inedible weeds characteristically found on the poorly aerated alkaline soils in the enzootic Okaukuejo and Namutoni areas. Good rainfall has not had an influence in improving the vegetation on the overgrazed plains, yet considerable improvement in the quality, quantity and composition of the vegetation is evident in protected experimental exclosure plots.

A relationship exists between the over-concentration of plains animals in certain areas of the Park causing degraded and over-utilized vegetation and anthrax epizootics. Over-grazed conditions in the enzootic Pafuri area of the Kruger National Park have been described by Pienaar (1967) and Kellogg. Prestwood and Noble (1970) described an anthrax epizootic on deteriorated range conditions where the deer population had exceeded the carrying capacity. It would seem that anthrax in wildlife operates to control over-population in what could appropriately be called “slum areas”. In domestic stock anthrax occurs under similar conditions of over-crowding and range degeneration. This is particularly the case in some of the Bantu areas where pasture management is not practiced. Inoculation of domestic stock has effectively controlled anthrax mortality, yet little has been done to implement management practices aimed at improving the habitat. Pienaar (1967) regards anthrax in the Kruger National Park as having a cyclical nature and it would seem that major epizooties occur there every 9 to 10 years. These outbreaks could possibly be associated with the periodic build-up of populations in over-utilized habitats.

In the enzootic areas of the Park, the majority of supposedly susceptible animals constantly ingest anthrax organisms, yet only a small percentage of the populations are affected and die. The writer is of the opinion that through constant association with virulent anthrax organisms, the animals have over the ages built up an immunity to the disease. Preliminary serological studies on a limited number of zebra have confirmed this immunity status and similar immunity can be expected in other species. Young animals are not affected by the disease and are most probably protected by a congenital passive immunity. The stress factors responsible for precipitating the breakdown of immunity in certain adult animals of both sexes is not well understood but poor nutrition or a deficiency of certain essential vitamins or minerals in the diet are possible predisposing factors which lower the natural resistance to the disease. These aspects need further investigation.

The incineration of infected carcasses and the sterilization of contaminated or suspected contaminated waterholes are temporary control measures which cannot effectively eliminate or control the disease permanently. In an area as vast as the Park and with limited field personnel, it is virtually impossible and merely wishful thinking to attempt to locate and incinerate every anthrax carcass to prevent the spread of infection. A shortage of dry wood in the Okaukuejo area presents a further limiting factor for this control procedure and the same may apply to other enzootic areas in the Park in future. It is also ecologically incorrect to gather wood in the Park for incineration.

The sterilization of contaminated permanent waterholes such as Andoni, to prevent mass mortality has been successfully used in the past. However, the sterilization of temporary water supplies such as natural rainwater pans and mini-dams cannot be recommended because the effects on the ecology and the possible toxic effects on animals drinking the water have not been evaluated yet. Sterilization is only temporary because the annual flooding of low-lying areas, seepage in waterlogged areas and re-contamination from surrounding areas will
always ensure the survival of spores. Furthermore, in time spores may develop a resistance to disinfectants, but even if this were not the case it is virtually impossible to sterilise the soil surrounding the waterholes.

Introducing avirulent spores into the water supplies in the form of oral vaccines may have some merit if bulk quantities of these vaccines could be produced economically. However, if one accepts that animals in enzootic areas already have an immunity, and that an artificially induced immunity is not permanent, then this control measure does not have a practical long-term application in the Park. When highly susceptible and rare species are threatened by anthrax, they can be rounded up for mass-immunisation or individually inoculated.

Climatic and geological conditions such as alkaline soils and water, temperature and organic material favour the perpetuation of anthrax organisms and the formation of incubator areas. It is doubtful if the disease can ever be eliminated, but anthrax mortality has been reduced by the mechanical closure of mini-dams and a small but noticeable improvement in the vegetation has been seen in the Adamax, Natco and Grünewald areas after the boreholes were closed for several years.

The long-term control of the disease in the Park should be directed primarily towards improving the quality of the vegetation by preventing over-concentration and by eliminating the existing contaminated artificial water supplies in enzootic areas. These procedures can be effectively implemented by closure of the man-made mini-dams and boreholes. This will prevent overcrowding and force the migrating animals to move out of the enzootic areas. The future control of anthrax will therefore, have to be based on sound management procedures.

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