THE EPIDEMIOLOGY/ECOLOGY OF ANTHRAX

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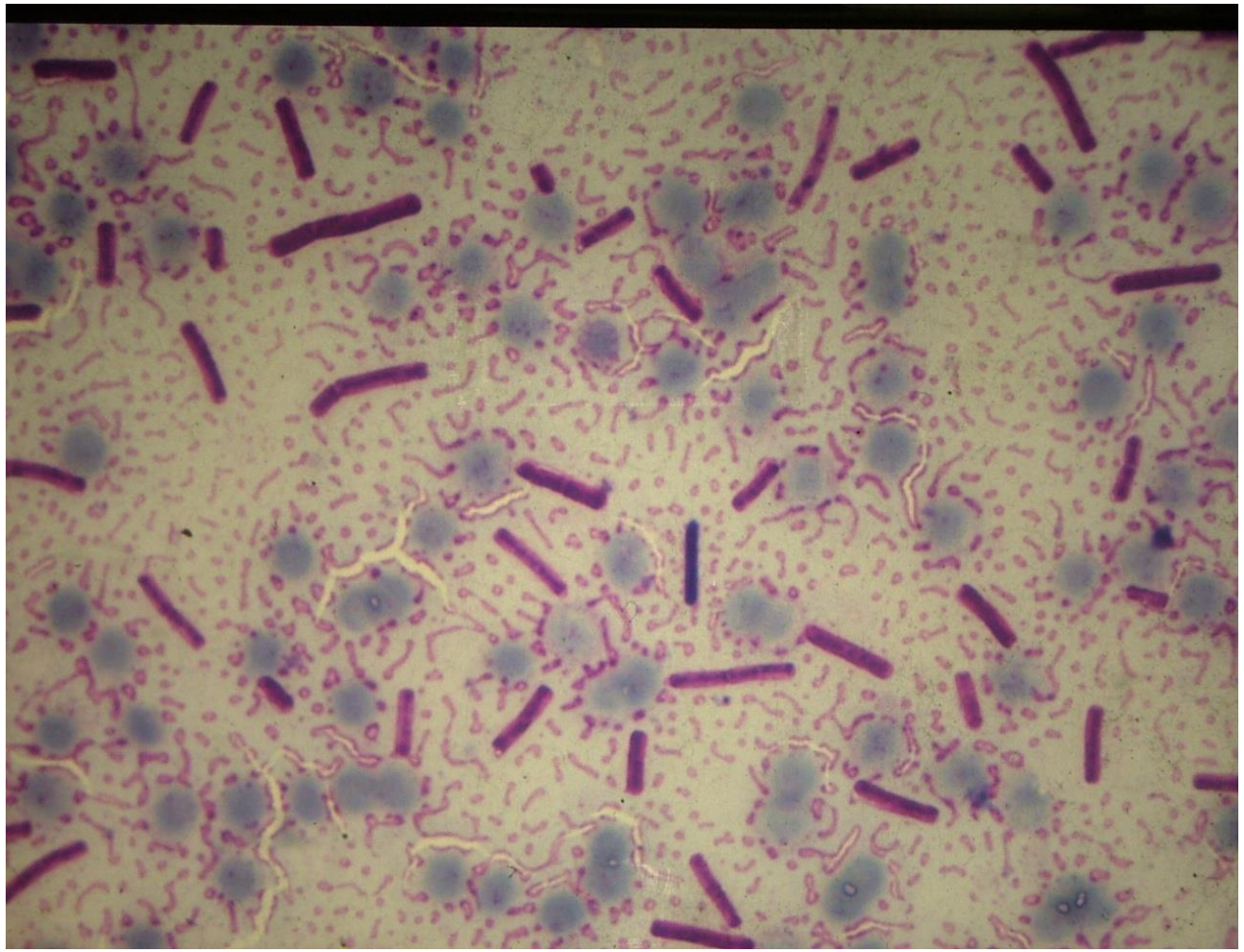
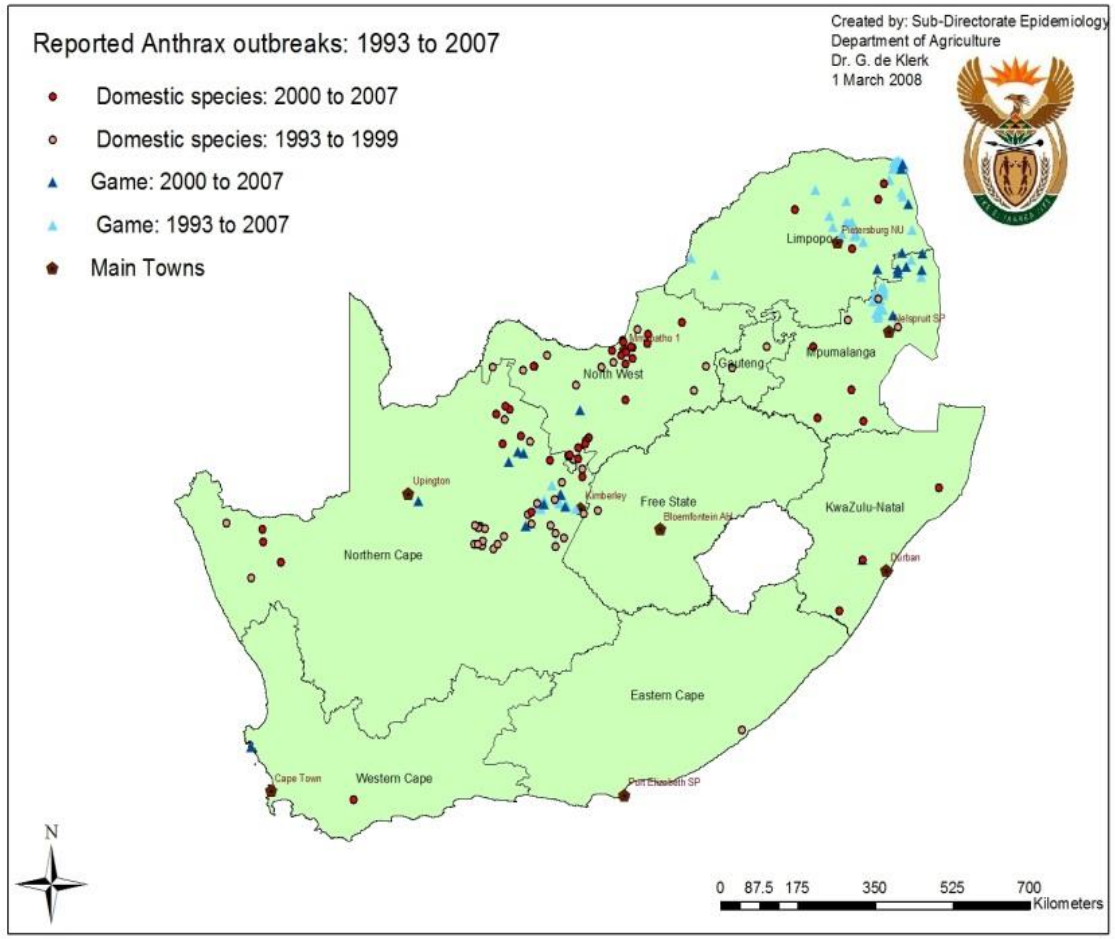
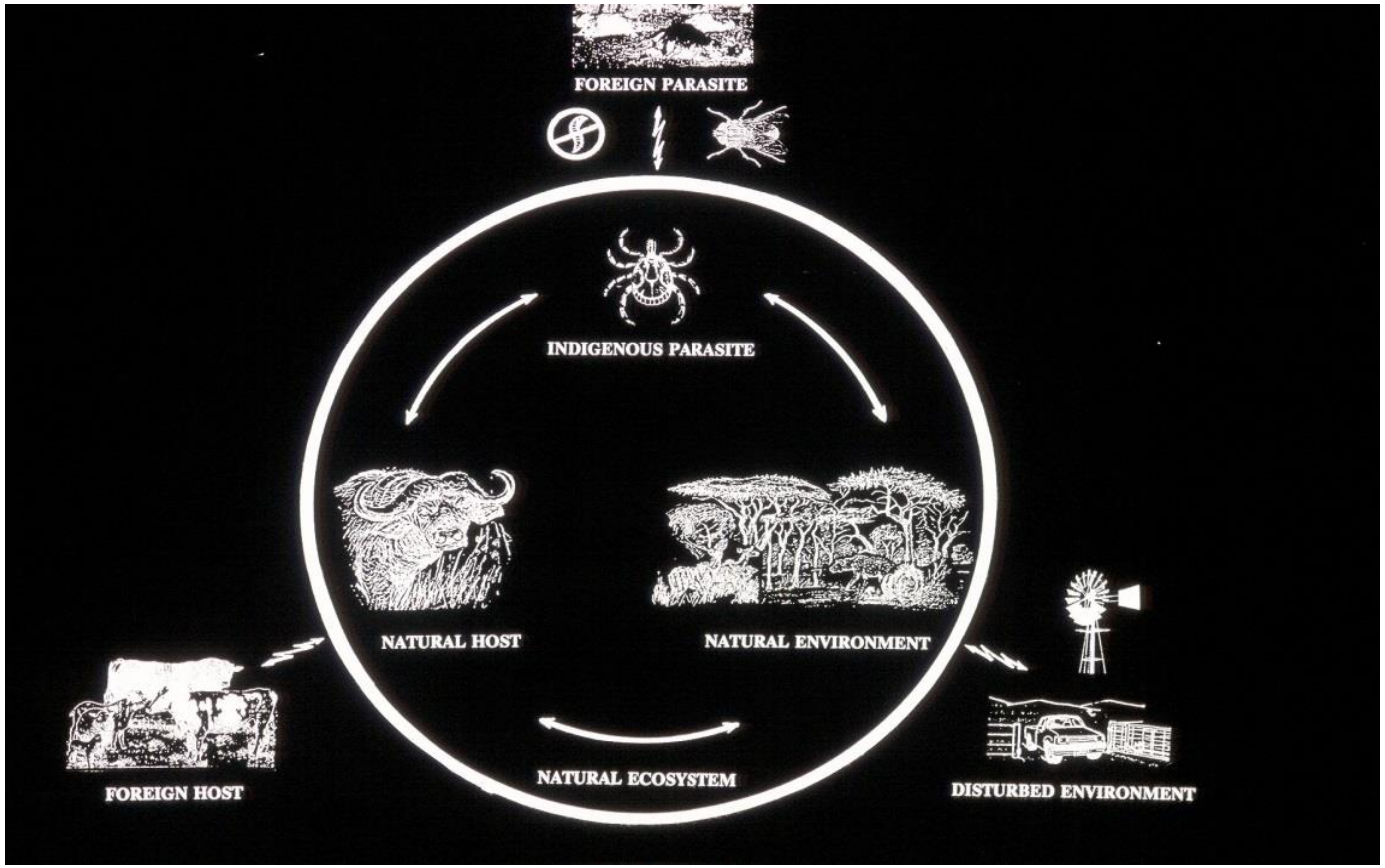


Eco-historical perspective



- Early **African settlers** encountered and became familiar with anthrax (“kwatsi”) in N. Cape where early **adventurers and travelers** encountered it.
- Isolation of anthrax from bone from archaeological digging in Pafuri, KNP, proves existence at least **250 years** back. This includes Soutpansberg area
- Spread into rest of country equaled commercial farming and. Height of outbreak in 1923 (60000 deaths recorded).
- Vaccination provided control of anthrax in commercial farming areas.
- From 1980: Increase in anthrax outbreaks epidemics parallel with increase in **game ranching** in N. Cape.
- Persistence of outbreaks point to two **endemic areas** in RSA: KNP and N. Cape.
- Rest of RSA show **sporadic point outbreaks**.
- Genotype grouping of anthrax isolates proves anthrax to be **indigenous** to southern Africa.

Attributes of indigenous diseases



"**Indigenous disease**" implies co-evolution of disease with host/s and environment leading to: symbiosis and inter/dependency as a natural and interacting element of the ecology of the area, typically reaching a dynamic balance. Foreign influences can affect the balance.

ANTHRAX CYCLE

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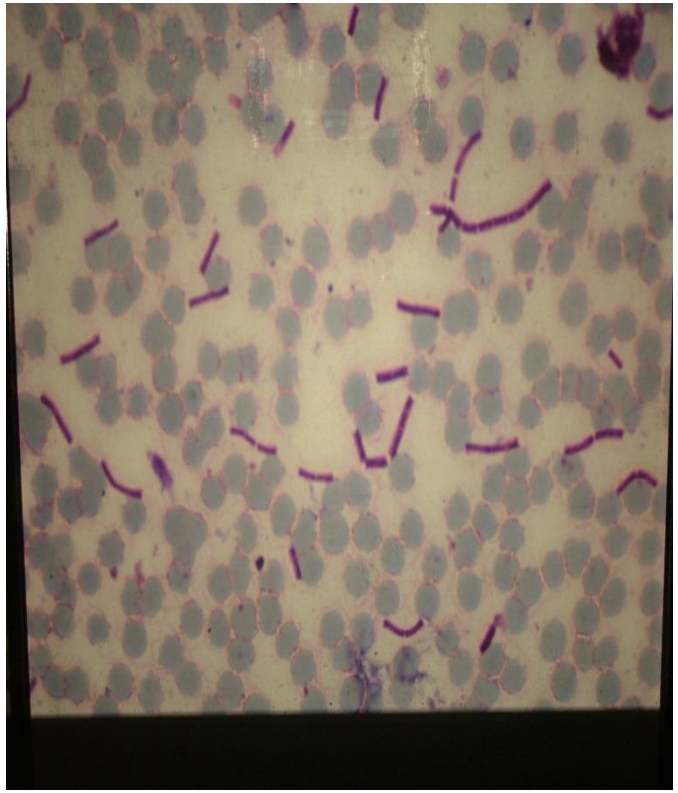


Anthrax cycle consists of:

1. A biotic growth phase in a susceptible animal, where vegetative growth takes place, causing terminally a rapidly fatal septicaemia, resulting in sudden death; and

2. an abiotic dormant phase, which starts with a transition into a very resistant spore form at the height of the growth phase under aerobic conditions and is carried passively and purely mechanical in carcass rests, soil, water and insects.

Anthrax has to kill its host in order to survive!

Start of an outbreak.

- Records show sporadic point outbreaks progressing to cyclic (5 to 10 years) epidemics when the necessary driving forces are present. Point (isolated) outbreaks probably occur more regularly.
- Between outbreaks the organisms survive as resistant spores in soil, water and carcass rests. Also known as the abiotic phase. No growth during the abiotic phase.
- *B anthracis* is non-invasive and needs lesions to enter body; such as provided by course grazing/browsing in late winter/early summer.
- Spores revert to vegetative form, multiplies and results in death of animal. Also known as the biotic phase.
- Just before and at death of the host the relative fragile vegetative bacilli change to resistant spores.

Factors determining the outcome of an anthrax outbreak in the Ghaap region.

The index (initial) case either:

1. **Remains isolated, involving only one or a few animals (point outbreak).**

- or -

2. **Progresses to a full-scale epidemic; if the necessary driving forces are present!**

The following driving forces for an epidemic were recognized for the Ghaap region: These should all be present in an above critical threshold.

1. **Temporal considerations.**
2. **Hosts.**
3. **Scavengers.**
4. **Blowflies.**
5. **Biting flies (*Hippoboscids*).**
6. **Actions or inactions of man.**

Dissemination and transmission by water, insects, scavengers and predation.

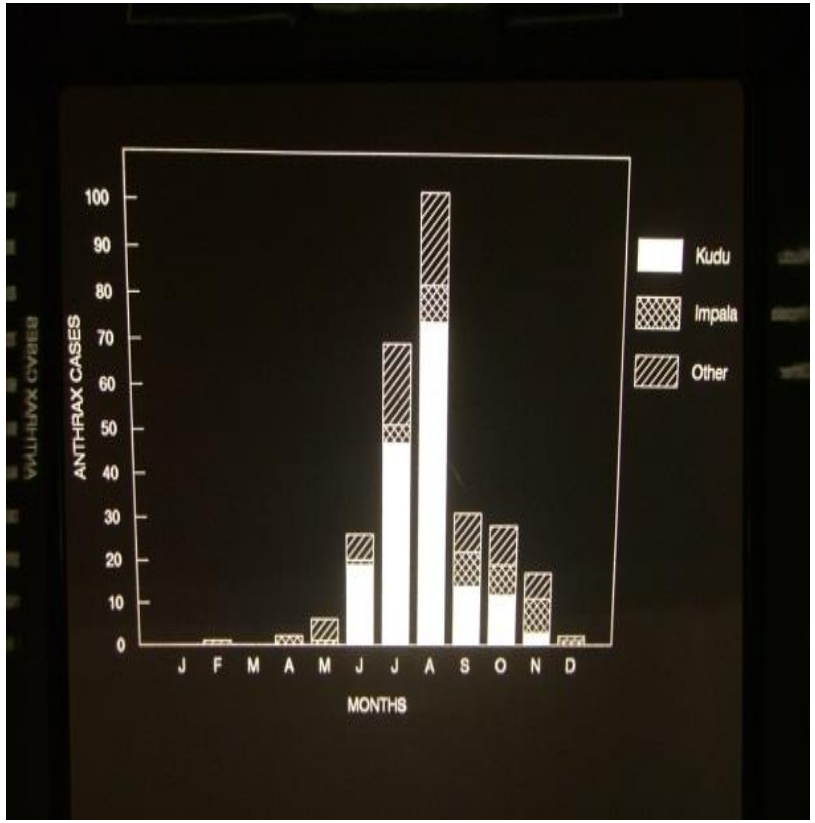
Water runoff.

Anthrax spores are washed down drainage channels and end up in:-

- Flowing river systems where the spores are eliminated.
- Low-lying poorly drained, or stagnant areas, such as flood plains where spores accumulate; the so-called “concentrator areas”.

Temporal patterns of anthrax outbreaks.

Kruger National Park.



- In Kruger all epidemics limited to late winter – early summer months. Rain stops outbreak.
- In the N. Cape epidemics occur in summer months. Two possible explanations:-

  1. Moisture and warm weather probably triggers drastic population increases of biting flies (*Hippobosca*), the major transmitters of anthrax.

  Hippoboscids are also more active in warm sunny weather.

  2. Heavy rains accumulate in shallow depressions or "anthrax concentrator areas". Animals grazing close or drinking from these areas would be at risk of picking up anthrax.

  3. *B anthracis* is non-invasive and needs lesions to enter body; such a provided by course grazing/browsing in late winter/early summer.

Role of scavengers.

- Before death and at height of growth, while still under aerobic conditions, some of the vegetative organisms change into resistant spores and are circulated through the body.
- Scavengers open up carcasses and further growth and spore formation take place in exposed body fluids.
- Spores are very resistant and can survive for many years outside animal.
- Vegetative form fragile and dies out in unopened carcass and on desiccation.

Vultures as scavengers and disseminators of anthrax

- Vultures most successful scavengers of all. Keen eyesight.
- Not only open up carcasses, which facilitates spore development, but also carry infective material over long distances.
- Carry yet curtail anthrax by cleaning up a soft-skinned carcass in a short while before further growth and sporulation in soft tissues can take place.
- Vegetative form eliminated by digestive system, but spores unharmed.

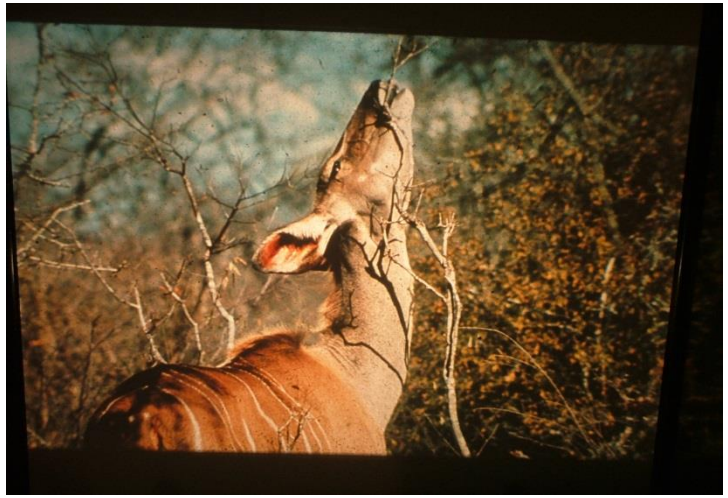
The role of scavengers in the epidemiology of anthrax in the Northern Cape region

- During the domestic livestock era most large predators, mammalian scavengers and vultures were eliminated from the N. Cape.
- The pied crow has entered this unoccupied niche and are very effective in locating carcasses. They cannot open carcasses, but take out the upper eyes. All carcasses encountered were intact, but with the upper eyes removed.

Blowflies as carriers of anthrax

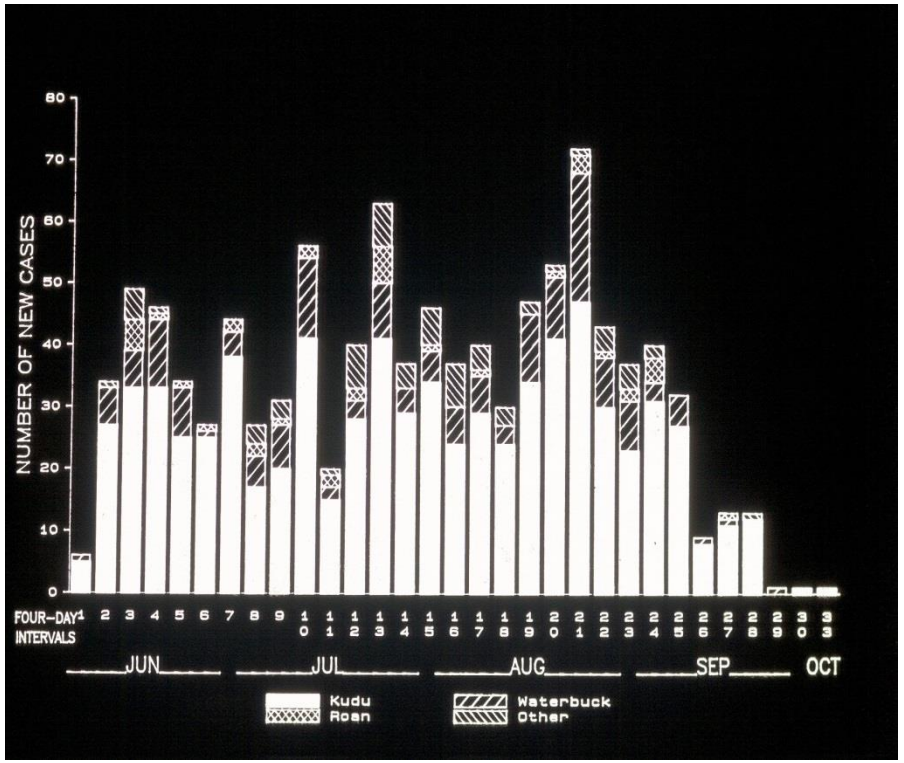
- **Blowflies feed off body fluids of opened carcass.**
- **They then deposit vomit and discard droplets on nearby vegetation.**
- **They may remain carriers the rest of their lives.**

Anthrax – blowfly – kudu interaction



- Blowflies **contaminate nearby vegetation** by depositing vomit and discard droplets, preferably 1 – 2 m from ground level. This is also the preferred feeding height of kudus.
- This is the reason why browsers, especially kudus, are more **vulnerable** to anthrax than grazers.
- This **anthrax – blowfly – kudu transmission cycle** is considered the major driving force of epidemics in the Kruger Park.
- In the N Cape ecosystem **blowflies**, are also considered important and the reason why kudus are considered the the principle host of anthrax. However, biting flies also play a major role.

Anthrax – blowfly- kudu interaction



- **Anthrax - blowfly – kudu interaction responsible for kudus making up 75% of all anthrax carcasses during epidemics.**
- **Kudus therefore maintenance host of anthrax in the Kruger.**
- **All other deaths incidental.**
- **Disease density dependent in kudus. Less than 20% killed during epidemic, and mainly older animals.**

Biting flies as transmitters of anthrax

- **Hippoboscids were found to be superabundant in the N Cape.**
- **Hippoboscids are relatively large (1cm), being able to ingest a relatively large volume of blood, but also to deliver a correspondingly large inoculum.**
- **For large herbivores the terminal blood count of anthrax bacilli is about 10^7 - $10^{8.}$ Only 100 spores needed to infect impala.**
- **Cumulative effect of large numbers.**
- ***B. anthracis* were isolated from all pooled samples of hippoboscid heads. Ratio of vegetative bacilli to spores found to be about 100:1.**
- **Isolations increased in proportion to the stage of the outbreak on a farm.**

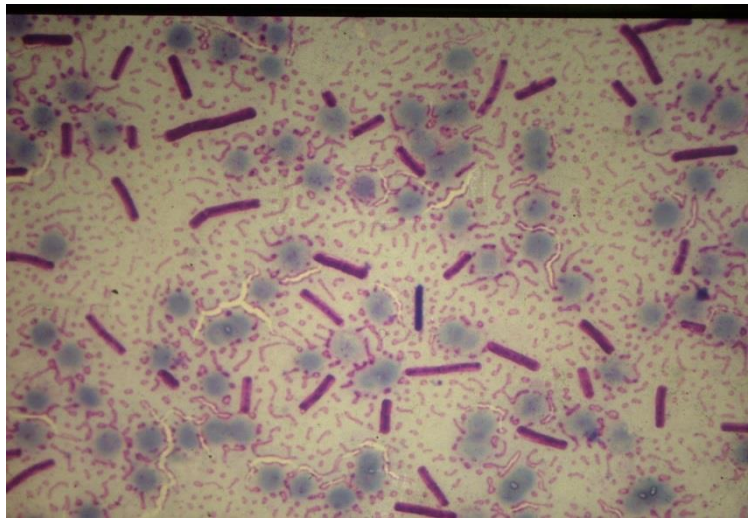
Biting flies as transmitters of anthrax

- Flies tend to **cluster** in perineal region, axilla and neck.
- Typical **anthrax swellings** are also found in those areas.
- **Preferred hosts** are the larger animals such as kudu, zebra and wildebeest, accounting for their high mortality.
- Flies build up in numbers in **summer** and bite more particularly in sunny weather.
- It was observed that flies swarm on **sick and debilitated animals**.
- Flies normally remain for long periods on hosts, but will **change hosts** where animals congregate. They will stay and presumably feed on a dead host for a while, but will move off in pursuit of a new host. This explains why so many free-flying flies are encountered during the peak of an epidemic.

Hosts as a driving force.

- The first requirement for a point outbreak to proceed to a full-scale epidemic, is susceptible and vulnerable hosts in densities above a certain critical threshold.
- Indications of overstocking and over utilization of habitat were evident for the N Cape. This is ascribed to poor wildlife management and supervision; (and difficulty to obtain hunting permits from the Dept of Nature Conservation?).
- As in Kruger, kudus seem to be the principal or amplifier host for anthrax in the N Cape. This is due to the combined effect of both blowfly and biting fly modes of transmission. With inadequate fencing kudus also roam virtually at will to infect other areas.
- Other large herbivores such as zebra and wildebeest also high on the mortality and vulnerability list. This is ascribed to the activity of biting flies. It differs from Kruger where biting flies were found to be of little significance.
- Difficulty to vaccinate free ranging wild animals is a complicating factor.

Terminal blood smear counts



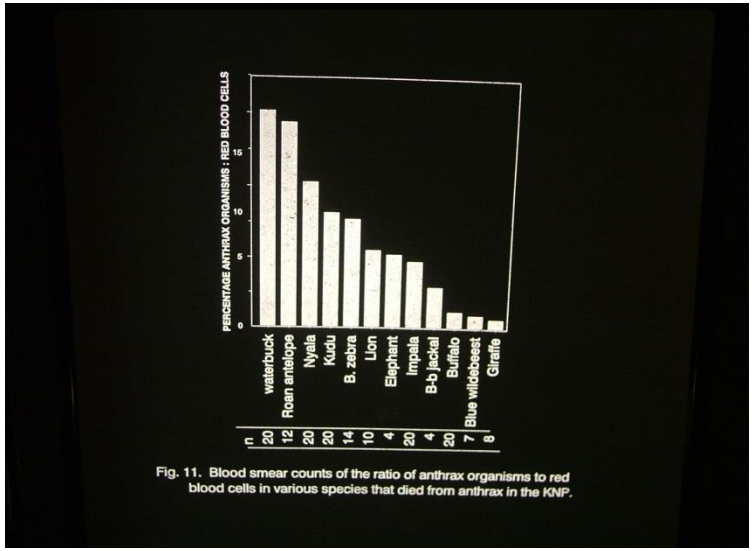


Fig. 11. Blood smear counts of the ratio of anthrax organisms to red blood cells in various species that died from anthrax in the KNP.

Host species can be grouped into two categories:

1. **Those with low terminal counts: Species resistant to infection, but highly susceptible to the effects of the toxin.**
2. **Those with high terminal counts: Species highly susceptible to infection, but resistant to the effects of the toxin.**

Species differences to anthrax.

Kudu:

Expected terminal count (high).
Susceptibility (high).
Vulnerability (high).
Resistance to toxin (high).
Potential spore crop (high).
Thin skinned.
Maintenance/amplifier host.

Buffalo:

Expected terminal count (low).
Susceptibility (medium).
Vulnerability: (low to medium).
Resistance to toxin (high).
Potential spore crop (low).
Thick skinned.
Incidental host.

Species differences to anthrax.

Zebra:

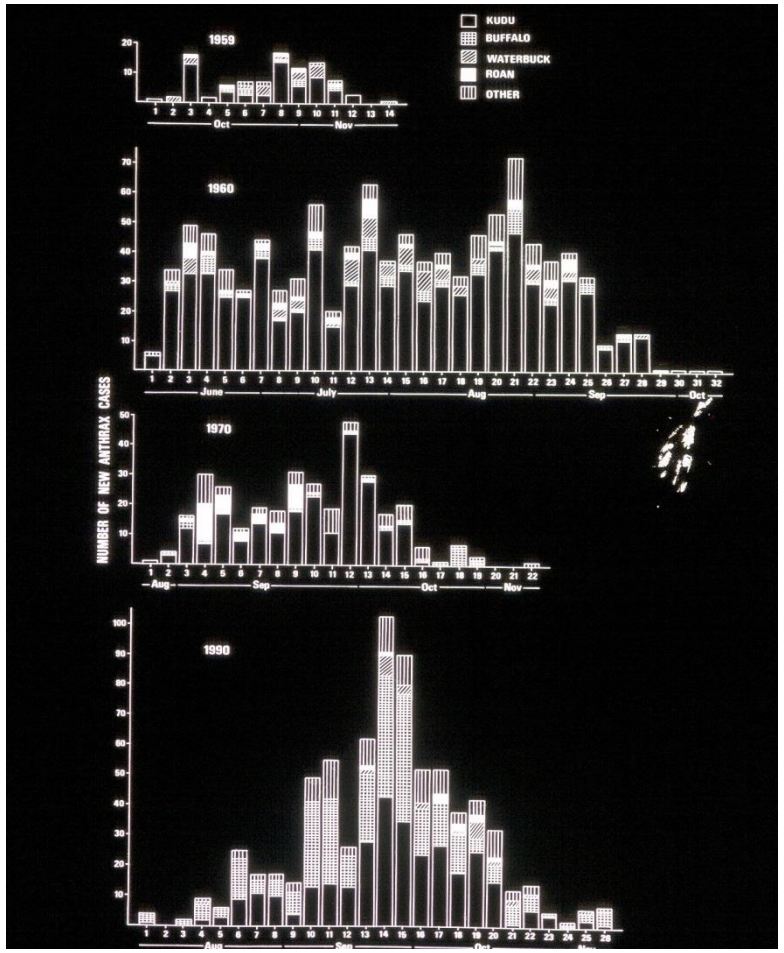
- **Expected terminal count (low to medium).**
- **Susceptibity (medium).**
- **Vulnerability (low – KNP); (high due to biting flies – N Cape) Some resistance to toxin (oedema).**

- **Incidental host.**

Lion:

- **Susceptible.**
- **Highly vulnerable due to predatory and scavenging habits.**
- **Very variable terminal counts.**
- **Resistance to toxin.**
- **Incidental host.**

Species vulnerability



% Vulnerability assessed as %deaths/%availability X 100.

Kudus in both N Cape and KNP most vulnerable.

Kudus also most deaths in epidemic = maintenance host.

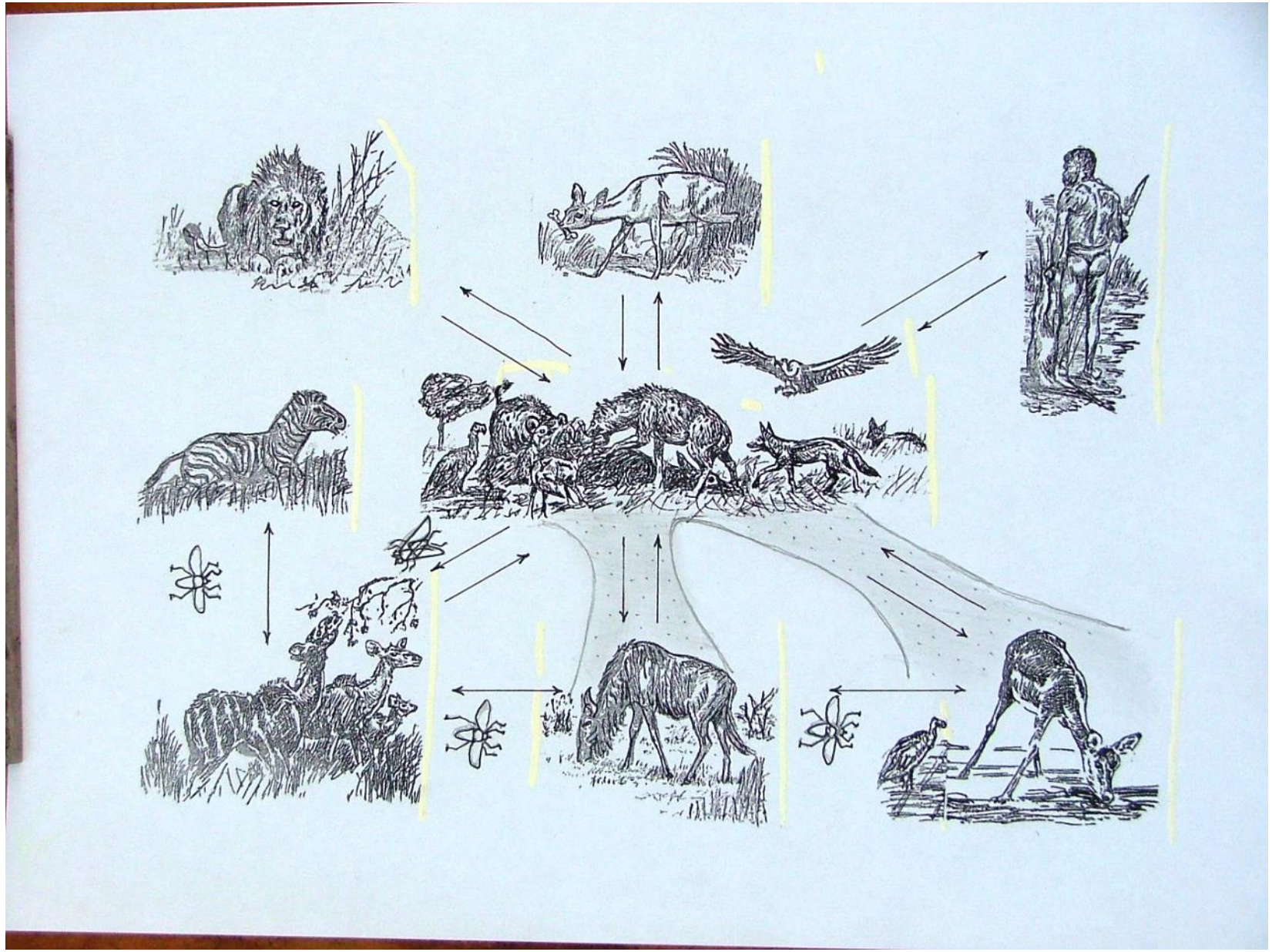
Inverted U shaped epidemic curve = density dependent (20% deaths).

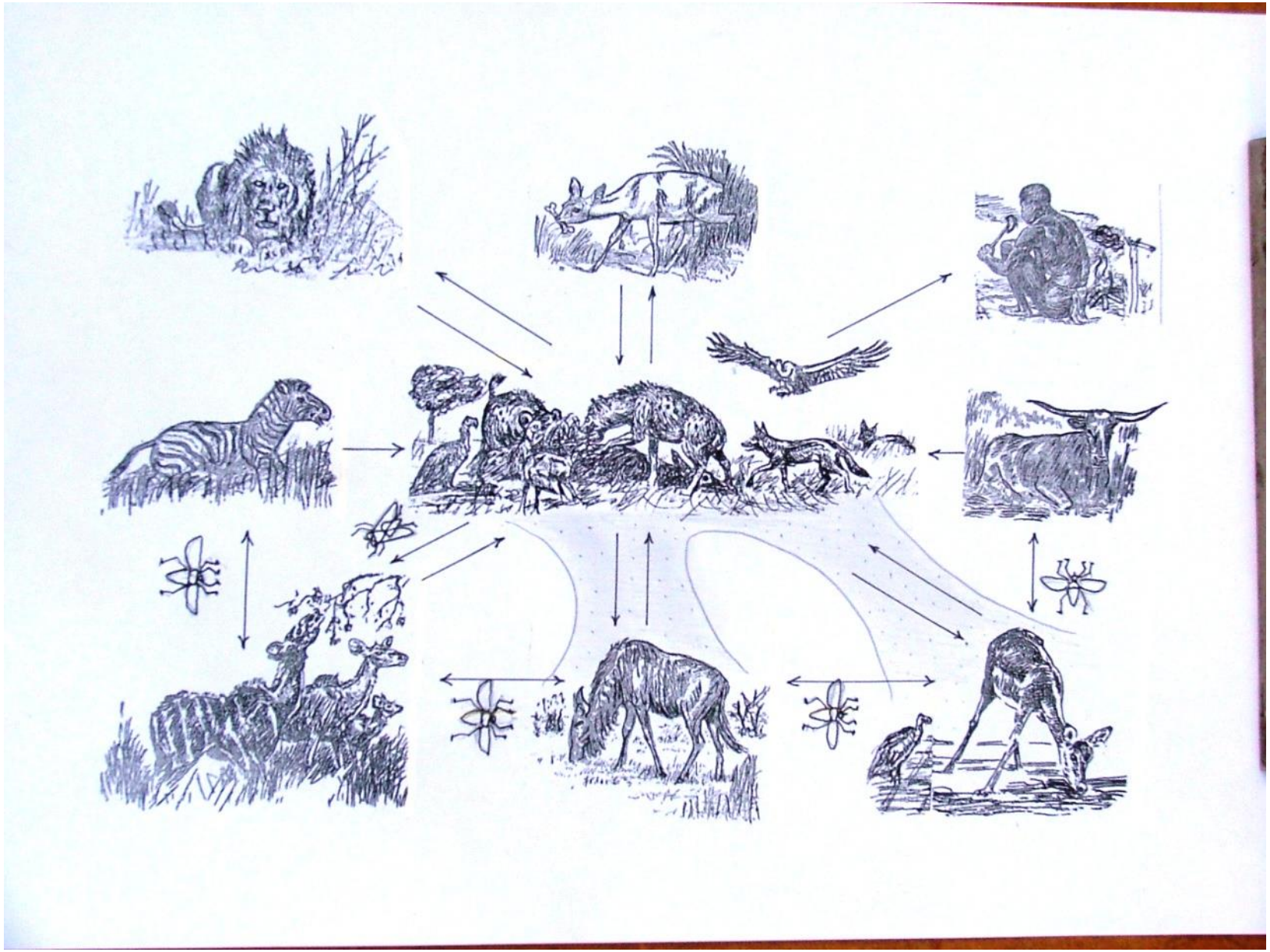
Actions/inactions of man, determining the outcome of anthrax epidemics.

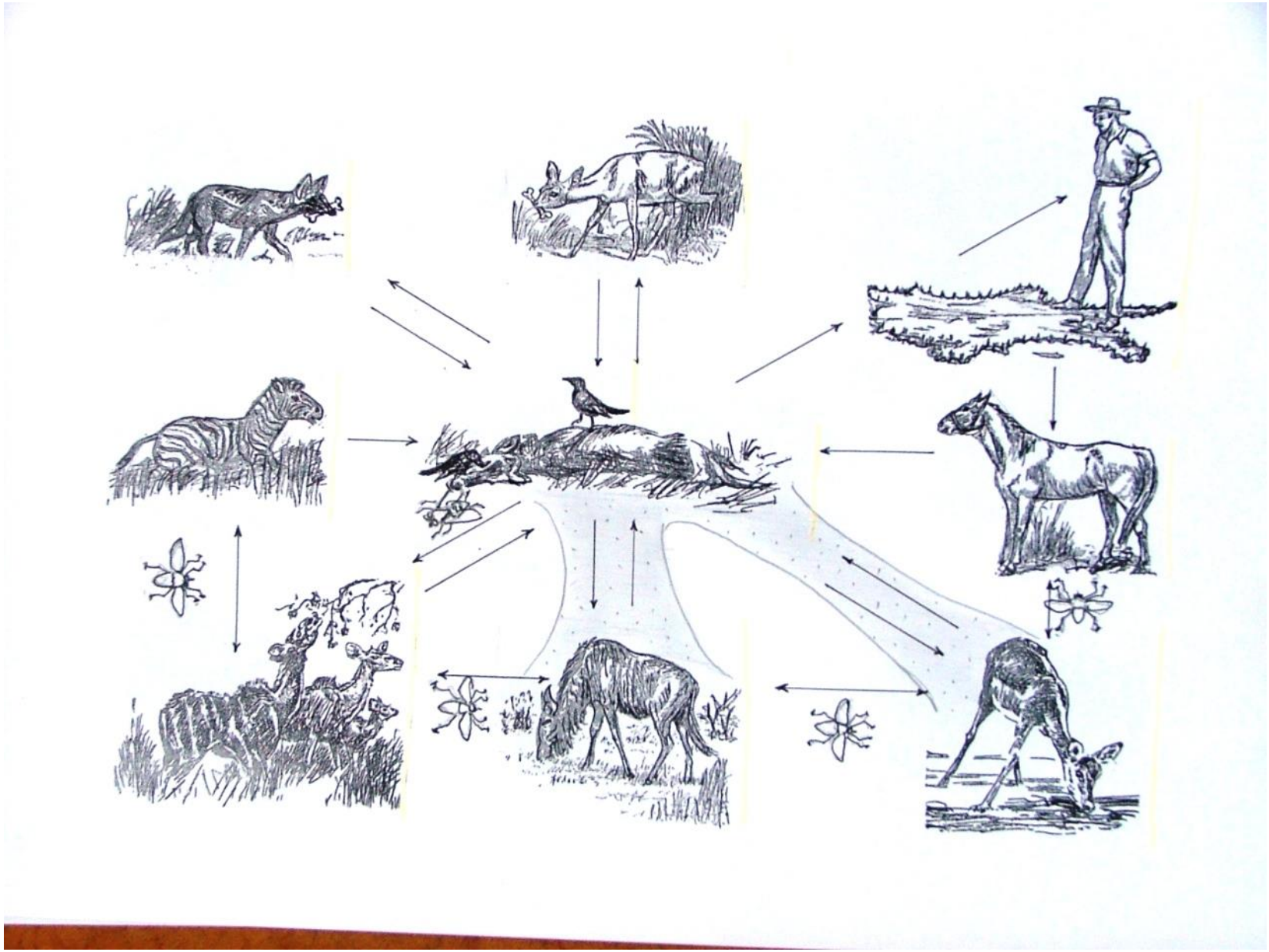
- **Professional wildlife management strategies are lacking on most of the game ranches. This is leading to failure to identify anthrax risk factors and act prophylactically and to manage an outbreak. These are *inter alia*:-**
  - **Poor surveillance before and during an outbreak.**
  - **Failure to report suspect cases.**
  - **Failure to control numbers, leading to overstocking, overutilization and stress.**
  - **Ineffective fences and failure to be able to quarantine effectively.**
  - **Inability and a failure to vaccinate free-ranging wildlife.**
- **Veterinary regulatory measures were drawn up and aimed at livestock and are inadequate for wildlife. This will have to adapt to the fast expanding wildlife situation.**

Final thoughts from experience in KNP and N Cape

- Anthrax is endemic and indigenous to the RSA.
- The focal endemic areas in the RSA are the N Cape and the northern KNP (Pafuri area). The endemic situation in both areas is maintained by an abiotc– biotic cycle.
- The anthrax cycle in its natural habitat, such as the Kruger Park, is fully integrated and in symbiosis with the other elements of the ecosystem.
- Anthrax can survive abiotically as dormant spores over very long periods (hundreds of years).
- Epidemic outbreaks are initiated and propagated by a combination of availability of hosts, stress and successful dissemination/transmission of anthrax spores.
- The actions of man affects the course of outbreaks.







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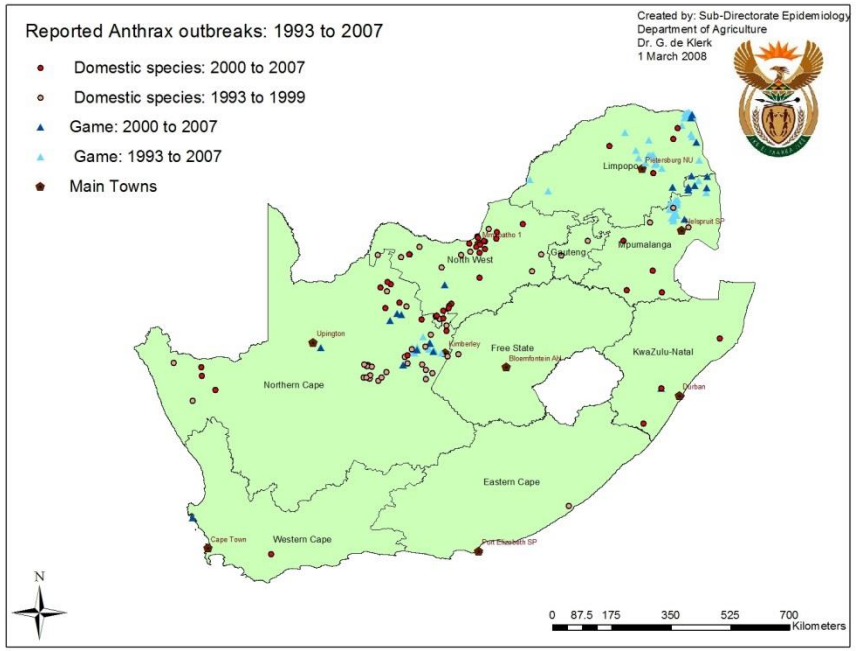
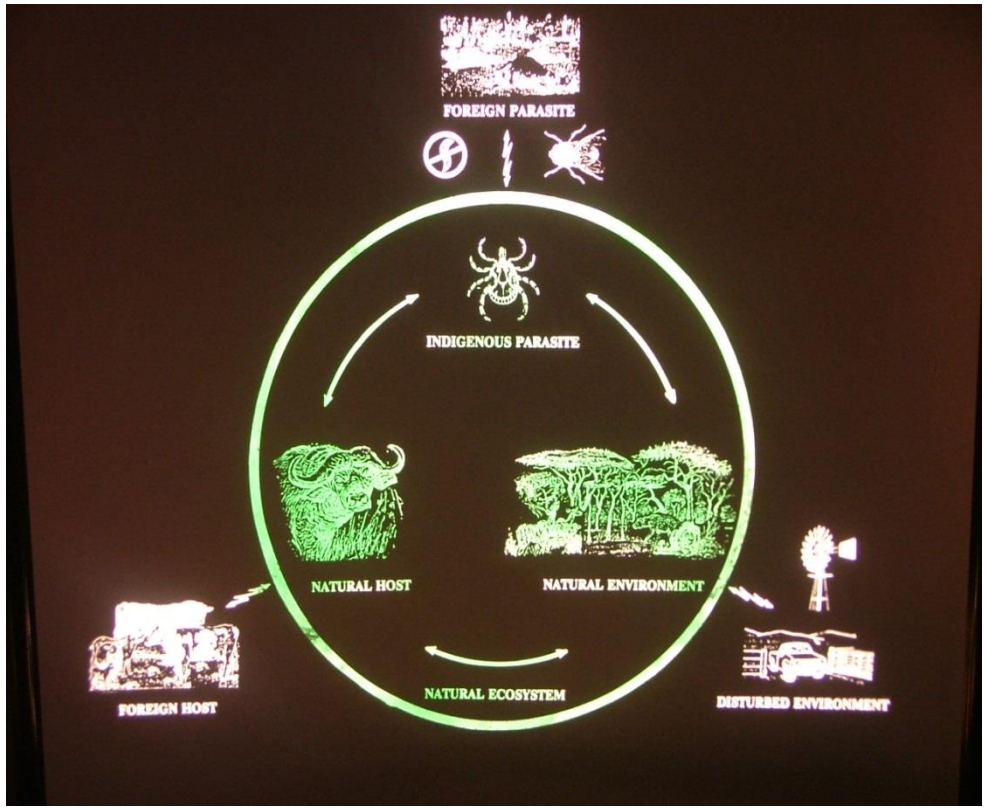
The significance of this must be judged against the fact that in 1923 about 30 000 to 60 000 animals died of anthrax in South Africa, and that in the “Cape of Good Hope” 1333 outbreaks of anthrax were recorded for the years 1923/24. It is argued that the Rondebosch scenario cannot be seen in isolation and that more such burial pits probably exist.

Historical perspective



- Early **African settlers** familiar with anthrax (“kwatsi”).
- 1880-1980: **Commercial farming** and vaccination provided complete control of anthrax in region.
- From 1980: Increase in anthrax outbreaks epidemics parallel with increase in **game ranching.**
- Persistence of outbreaks point to two **endemic areas** in S.A.: Pafuri and N. Cape.
- **Genotype grouping** of anthrax isolates (N. Cape isolates included) proves anthrax to be indigenous to southern Africa. Corroborated by ecological evidence in Kruger Park.

Implications of being endemic and indigenous



- It means that anthrax cycled as an integral part and was in dynamic balance with the other elements of the pristine N. Cape ecosystem.
- The natural anthrax cycle which existed in the pristine era was virtually eliminated during the commercial livestock farming era.
- Due to dramatic increase in game ranching the cycle was revived, albeit in a somewhat changed format.
- Endemicity due to stagnation and persistence of anthrax cycles in the region.

Physiographical features conducive to endemicity

- The Ghaap plateau and lower lying flats are bisected by a few shallow drainage channels, but are mostly flat and poorly drained with numerous shallow pans.
- This is a stagnant situation and ideally suited as filter and catchment for spores which are liberated from carcasses, forming “anthrax concentrator areas” .
- The soils of the Ghaap region are predominantly calcareous, which is necessary for spore preservation.
- Phosphorus deficiency in the region cause osteophagia in herbivores, which make them extremely vulnerable to anthrax.
- The dense bush nature of the vegetation makes it extremely difficulty, if not impossible, to locate most carcass remnants (such as bone). Percentage of carcasses found during outbreak very low.

The role of scavengers in the epidemiology of anthrax in a pristine area such as Kruger Park.

- Scavengers, especially vultures, are extremely effective in locating and opening up carcasses while still fresh. Virtually all carcasses encountered during anthrax outbreaks were opened by scavengers. This ensures the development of a good spore crop.
- Scavengers can also carry infective material over long distances, to contaminate especially watering places.
- Opened carcasses provide opportunity for blowflies to feed and disseminate infective material.
- It is assumed that the same situation occurred in the N Cape in its pristine era when scavengers and large predators still roamed the fields.

The role of scavengers in the epidemiology of anthrax in the Ghaap region

- During the domestic livestock era most large predators, mammalian scavengers and vultures were eliminated from the N. Cape.
- The pied crow has entered this unoccupied niche and are very effective in locating carcasses. They cannot open carcasses, but take out the upper eyes. All carcasses encountered were intact, but with the upper eyes removed.
- Spore crop is dependent on spores developing before death in the body and from blood seepages from the body openings and eye socket. From the soil underneath old carcasses counts of *B. anthracis* spores ranged from 12500 to 202500/gm of soil.
- Evidence of small scavengers, such as jackal, carrying around remnants of carcasses were seen.

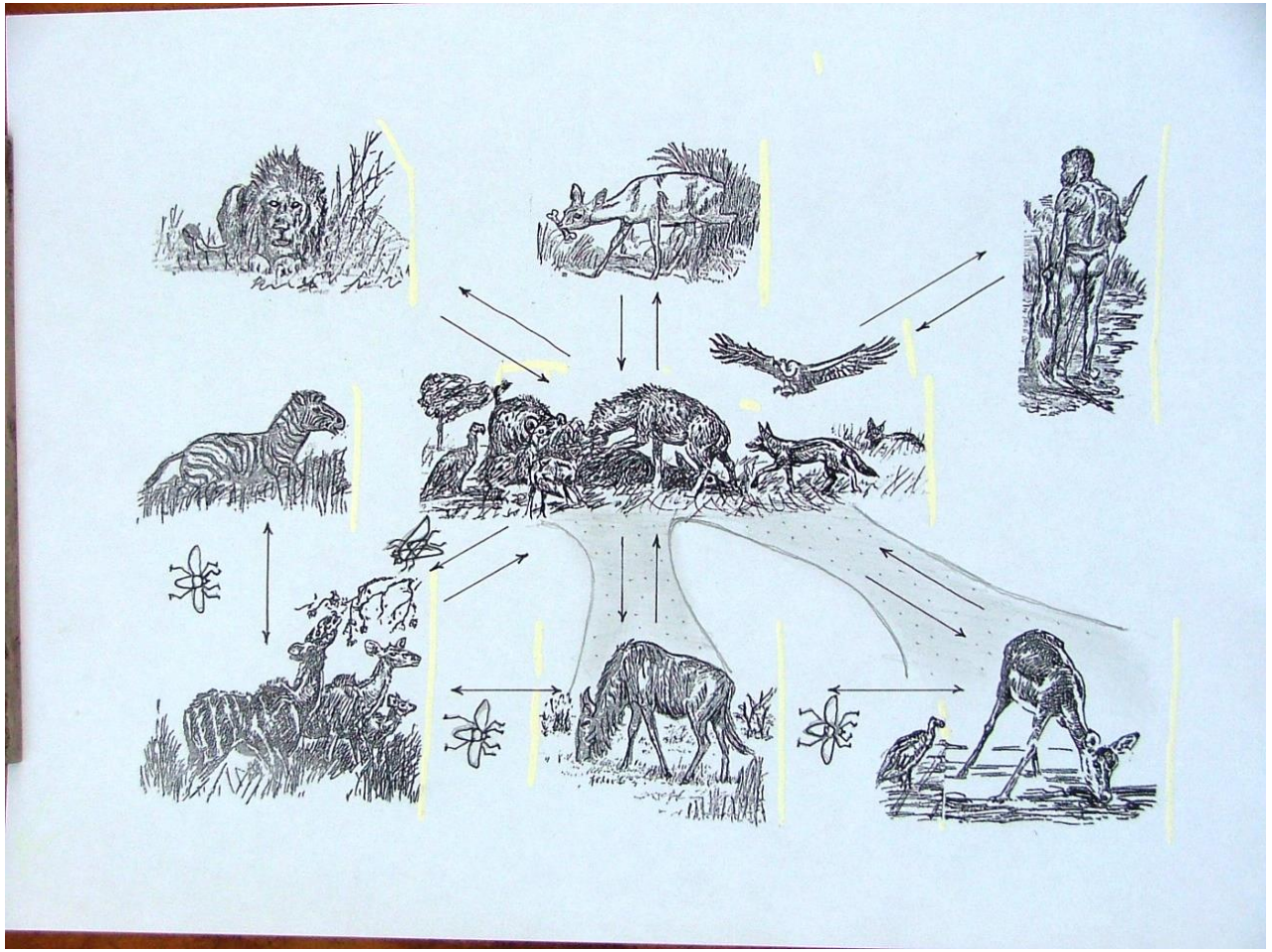
Blowflies as disseminators of anthrax in the Ghaap region

- **Crows take out the upper eyes of all carcasses found. Blowflies feed on blood from the eye socket and on on body fluids of opened carcass or seepages from body orifices and eye socket.**
- **They then deposit vomit and discard droplets on nearby vegetation.**
- ***B.anthracis* isolated from leaf droplets in vicinity of anthrax carcass.**

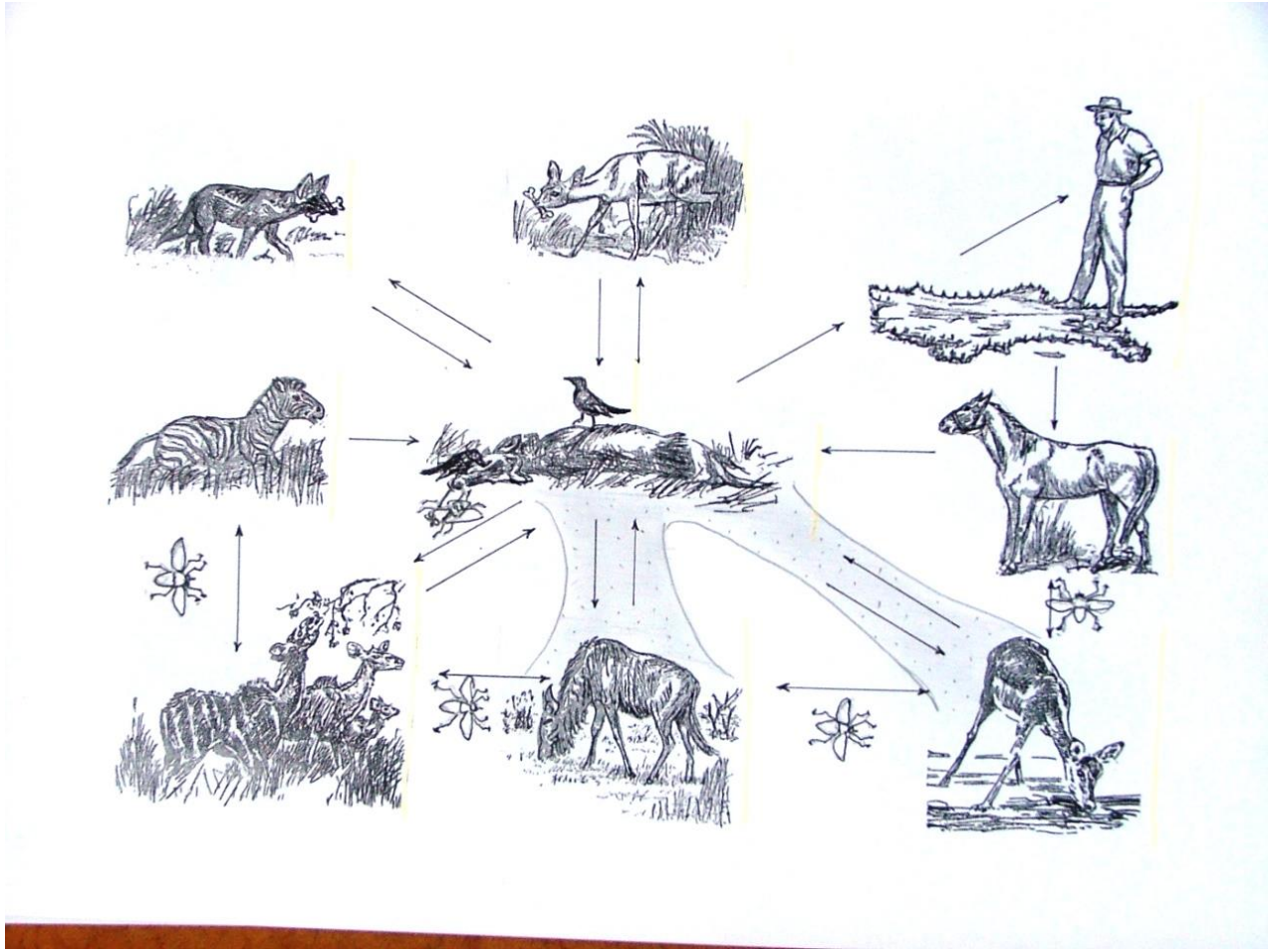
Actions/inactions of man, determining the outcome of anthrax epidemics.

- **Professional wildlife management** strategies are lacking on most of the game ranches. This is leading to failure to identify anthrax risk factors and act prophylactically and failure to manage an outbreak. These are *inter alia*:-
  - **Poor surveillance** before and during an outbreak.
  - **Failure to report** suspect cases.
  - **Failure to control numbers**, leading to overstocking, overutilization and stress.
  - **Ineffective fences** and failure to be able to quarantine effectively.
  - Inability and a **failure to vaccinate** free-ranging wildlife.
- **Veterinary regulatory measures** were drawn up and aimed at livestock and are inadequate for wildlife. This will have to adapt to the fast expanding wildlife situation.

Reconstruction of the anthrax cycle during the pristine era of the Ghaap region



Current anthrax cycle in the Ghaap region



Final thoughts

- That anthrax is endemic and indigenous to the Ghaap region.
- That the endemic anthrax situation is maintained by stagnancy and an inability to rid the environment of anthrax spores and infective material.
- That cyclic epidemics are propagated by high population densities and superabundance of blowflies and biting flies.
- That professional wildlife management is lacking on most of the game ranches. If the satus quo in this respect is maintained it is expected that the present anthrax situation will persist for the foreseeable future. It may even get worse as more game ranches are developed.
- That the situation can be managed and major epidemics prevented by applying effective game ranch management principles.
- That veterinary regulatory measures, presently aimed at livestock, will have to adapt to the fast expanding wildlife situation.

ANTHRAX CYCLE

Driving forces for abiotic and biotic phases of cycle

Dormant phase

- **Vegetative bacilli, which caused death of host, sporulate to form resistant spores in presence of oxygen.**
- **Spore crop larger in freshly opened carcasses.**
- **Spores are disseminated by water runoff, insects, scavengers and man.**
- **Spores are washed down drainage channels and end up in flowing river where spores are eliminated,**
- **or in low-lying poorly drained “concentrator areas”.**
- **No indication of spontaneous growth in soil.**
- **Calciferous nature of soil conducive to spore survival.**
- **Spore survival excellent in carcass remnants, especially bone. Phosphate deficiency leading to pica.**

Driving forces for point outbreak to develop into epidemic.

- **First case/s (point outbreak) - conversion of abiotic to biotic.**
- **Climate and rainfall. Kruger: Late winter. N. Cape: Summer.**
- **Overstocking of hosts, especially kudus – critical density level necessary.**
- **(Super)abundance of biting flies a major role in N. Cape. Not significant in Kruger.**
- **High scavenger activity and early opening of carcasses. Mammalian scavengers and vultures in Kruger; crows in N. Cape.**
- **Dissemination and spread to browsers (especially kudu) by blowflies. Major role in Kruger. Also important in N. Cape.**
- **Spread to watering points by scavengers and vultures. Only Kruger. Crows not considered significant.**
- **Human interference – only N. Cape.**

  Farms reverting from livestock to game farming. Dense shrub habitat. Weekend/holiday farmers. Wildlife management procedures lacking.

  Infrastructure equally lacking, such as fences not being kudu proof. Poor supervision and surveillance. Mortalities not reported – scared of consequences. Bush slaughtering. Reluctance to issue permits for hunting by Conservation.