THE ROYAL (DICK) SCHOOL OF VETERINARY STUDIES

University of Edinburgh
Veterinary Expedition To Swaziland
1986

UNIVERSITY OF EDINBURGH

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VETERINARY EXPEDITION TO SWAZILAND

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"We have nothing to offer but blood, toil, ticks and sweat"
(With apologies to the late Sir Winston Churchill)

Contents

Foreword

In 1966, a team of recent graduates from Edinburgh University's Royal (Dick) Veterinary School organised an expedition to Uganda to carry out some research in collaboration with the East African Trypanosomiasis Research Organisation. This expedition created a healthy precedent, and expeditions from the (Dick) Vet. as it is affectionately known have gone out to various parts of the globe more or less continuously since then.

The return of Peter Wedderburn and Tim Jagger in April 1986 from Swaziland thus marked the twentieth anniversary of successful (Dick) Vet. expeditions. Their visit to Swaziland to carry out research on ticks and tick-borne diseases of cattle was one of the smaller expeditions but because of their close involvement with the Swaziland veterinary authorities who gave Peter and Tim their full support, a prodigious amount of work was achieved and the results should be of great value to Swaziland in their commitment to rationalise their programme of tick and tick-borne disease control.

Many people both in Swaziland and elsewhere cooperated constructively toward the successful execution of the expedition; they are acknowledged separately in this report but a particular tribute is due to Dr. Nick Gumede, the Director of Veterinary Services, who supported the expedition from the outset and to Dr. Brendan McCartan, Senior Veterinary Investigation Officer, who took Peter and Tim under his wing and joined in whole- heartedly in the work of the expedition.

I commend readers to this report which contains much of scientific and general interest.

A. G. HUNTER
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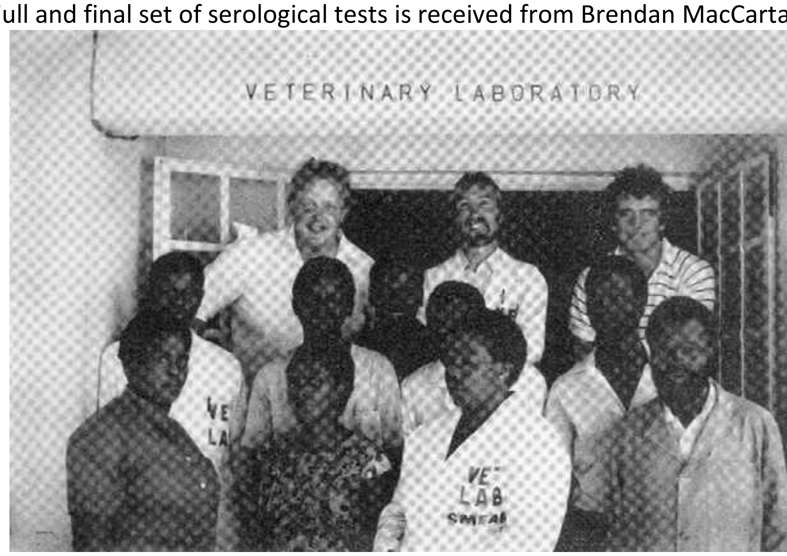
Expedition Itinerary

10/10/85	Expedition team departs from Edinburgh. Flight via Heathrow and Johannesburg to Manzini, Swaziland.
18/10/85	Pick-up vehicle is collected from Pietermaritzburg (on loan for 6 months from Pfizer's Ltd.).
23/10/85	Field work commences.
25/10/85	First cattle ticks are identified and despatched to Kwanyanga Veterinary Research Station for resistance testing by Coopers Animal Health (Pty) Ltd.
23/01/86	Brendan MacCartan commences Babesia and heartwater serological testing in the veterinary laboratory in Manzini, Swaziland.
08/04/86	Field work is completed. Final cattle ticks are despatched to Kwanyanga.
24/04/86	Team members view tick resistance testing during visit to Kwanyanga Veterinary Research Station.
01/05/86	Team members return to U.K.
04/06/86	Brendan MacCartan completes Babesia and heartwater serology in Manzini, Swaziland.
09/07/86	Frozen sera are despatched to Edinburgh.
11/08/86	Anaplasma serological testing commences at CTVM.
30/09/86	Anaplasma serological testing is completed at CTVM.
03/11/86	Full and final set of results of tick resistance tests is received from Kwanyanga Veterinary Research Station.
16/01/87	Full and final set of serological tests is received from Brendan MacCartan.



Tim Jagger, Brendan MacCartan, Pete Wedderburn and the staff of the Veterinary Laboratory in Manzini, Swaziland

Swaziland

Background to the Expedition

In September 1984, Archie Hunter of the Centre for Tropical Veterinary Medicine accompanied the Edinburgh University Veterinary expedition to Botswana where he stayed with the team members for a few weeks. On his return, he paid a short visit of a few days to the Swaziland veterinary authorities. Dr. Nick Gumede, the Director of Veterinary Services and a former post-graduate student of the CTVM, and his colleagues were very interested in the Botswana expedition. They were enthusiastic to host a similar expedition to Swaziland and it was agreed to organise a small team of two veterinarians to go out in 1985.

Peter Wedderburn and Tim Jagger, who at that point were just entering their final year of studies at the Royal (Dick) School of Veterinary Studies, had already approached Archie Hunter about the feasibility of organising an expedition following completion of their studies in the summer of 1985. Although time was short, on Archie Hunter's return to Edinburgh the wheels were set in motion to organise a 1985 expedition to Swaziland.

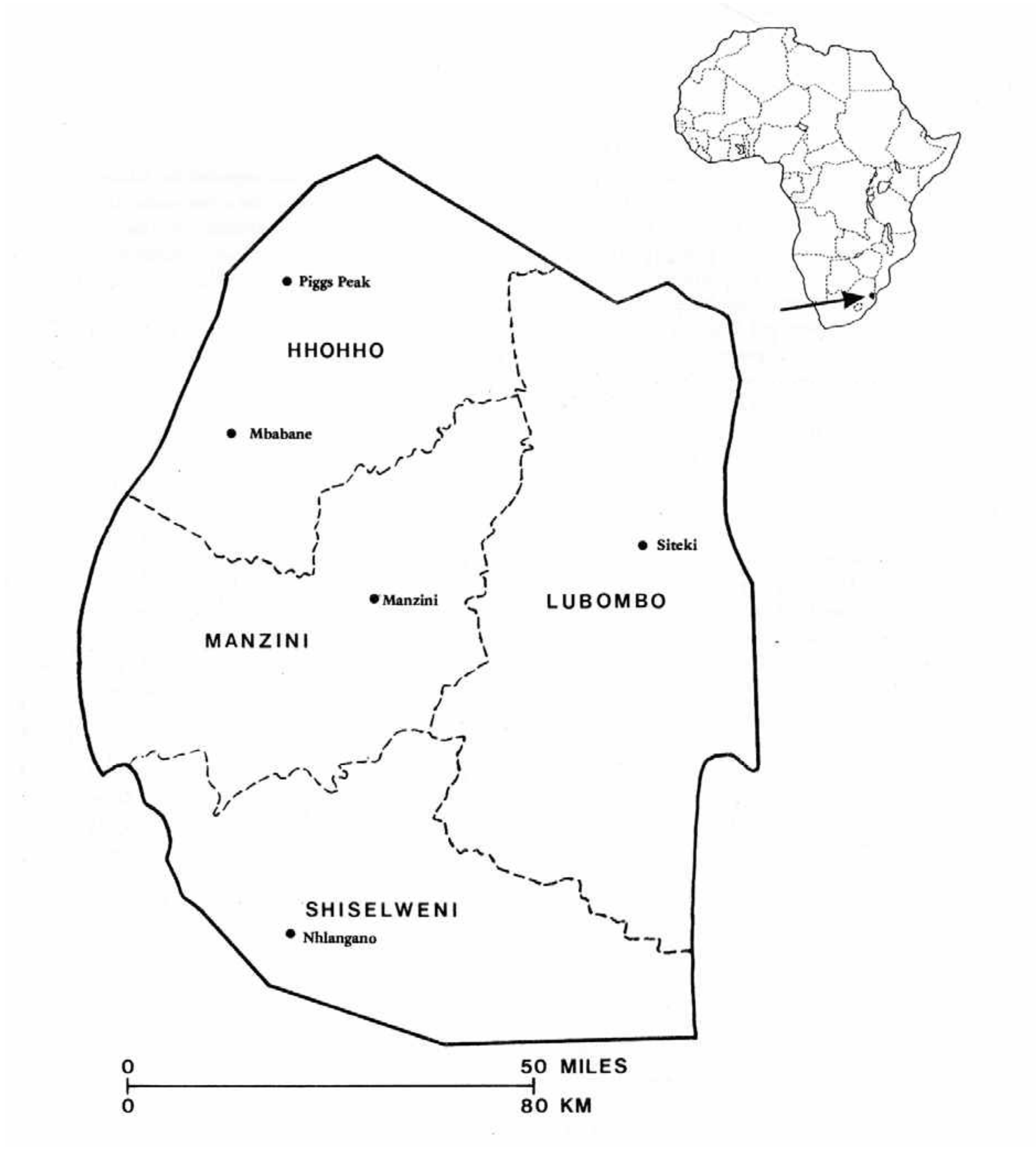
Brendan McCartan who was in charge of the veterinary laboratory in Manzini, agreed to take an active part in the expedition and it was agreed that he along with Peter Wedderburn and Tim Jagger would carry out three related research projects on ticks and tick-borne diseases as the country 's programme of tick-borne disease control was causing some concern to the Swaziland veterinary authorities. Archie Hunter agreed to act as adviser to the expedition which had the support of Professor D.W. Brocklesby, Director of the CTVM, and of the late Professor J.T. Baxter, who was then Professor of Veterinary Medicine and Dean of the Faculty of Veterinary Medicine at the University of Edinburgh.

By December 1984, a prospectus with estimated budget had been drawn up for circulation to potential sponsors and the task of funding the expedition started. The Swaziland Veterinary Department had agreed to provide most of the equipment required and also hostel type accommodation for Messrs. Wedderburn and Jagger, but it was decided necessary to purchase a pick-up truck in Swaziland for the field work. The gross budget was estimated to be £7,900. At one point it was feared that the funds raised would fall significantly short of this sum, but thanks to the generosity of Pfizer Ltd., and in particular the assistance of Dr. Roger Purnell, Pfizer Ltd. agreed to loan one of their pick-ups from their offices in South Africa to the expedition and so the budget was modified accordingly. As a result, the expedition was able to proceed and following a two week period of training and final preparation at the CTVM, Messrs. Wedderburn and Jagger departed from Edinburgh for Swaziland on October 10th, 1985.

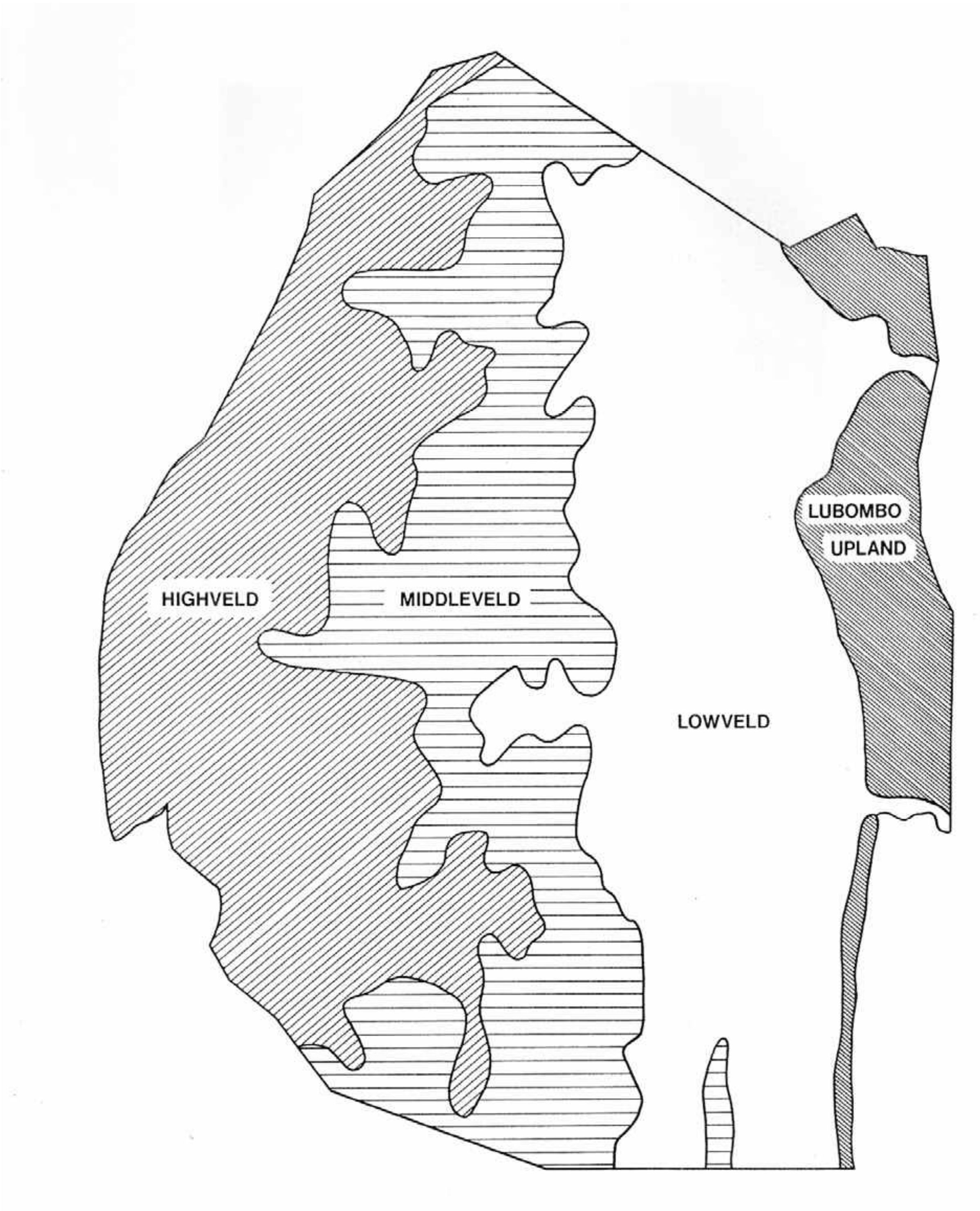
General Introduction

On the 11th of October 1985, Peter and Tim had their first views of the mountains and plains of Swaziland, as the Royal Swazi Airways aeroplane carried them over the western part of the country to the international airport near Manzini. This approach by air allows a considerable proportion of Swaziland to be seen, because the country is the second smallest on the African continent. Swaziland is approximately the same size as Wales, covering an area of 17,364 km^2. The maximum distance from North to South is 193 km and from East to West is 145 km. From their base at the Veterinary Laboratory in Manzini, it was possible to drive to virtually any part of the country in less than four hours.

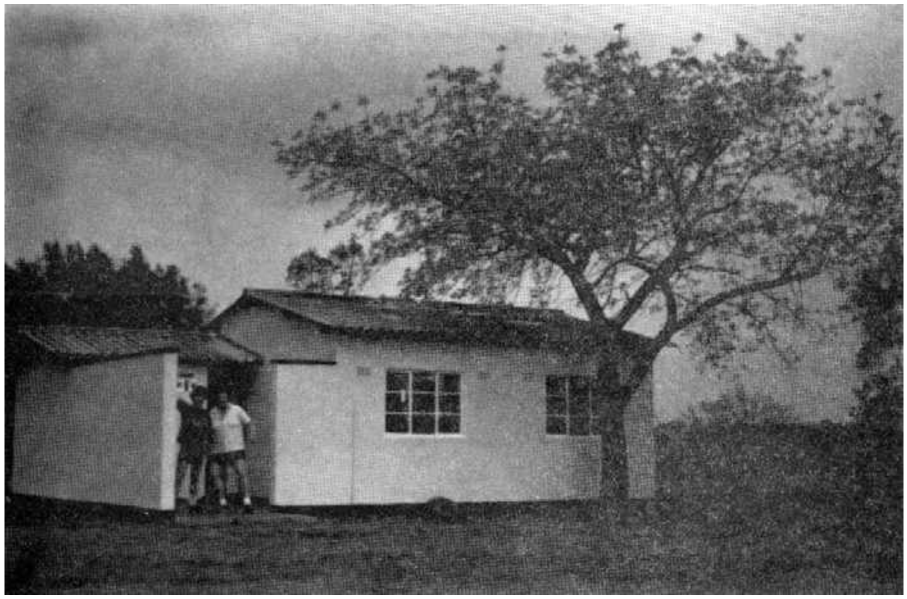
Situated in south-eastern Africa, Swaziland is landlocked, being bordered on the north, west and south by South Africa, and by Mozambique to the East. Swaziland is divided into four administrative districts, as shown on Map 1. The country is also divided into four distinct geographical regions, as shown in Map 2 and Table 1. The Highveld is mountainous, with the highest point at approximately 1,800 m. The Middleveld and the Lubombo Plateau are hilly, and the Lowveld consists of gently undulating savannah. The climate varies considerably between these regions, with the higher altitudes being cooler and more humid than the hot, dry lower lying areas. Generally, however, in winter, temperatures are cooler, and rainfall is scarce, whereas summers are very warm (with temperatures exceeding 40°C at times) and wet. Rain usually occurs in very heavy tropical downpours, which turn trickling steams into raging torrents of rivers and transform dirt roads into slippery mud baths. Tim and Peter's visit coincided with the summer months, and on several occasions, they found themselves trapped by such downpours. They spent one full night huddled in their vehicle, unable to move on what was usually a passable dirt road.



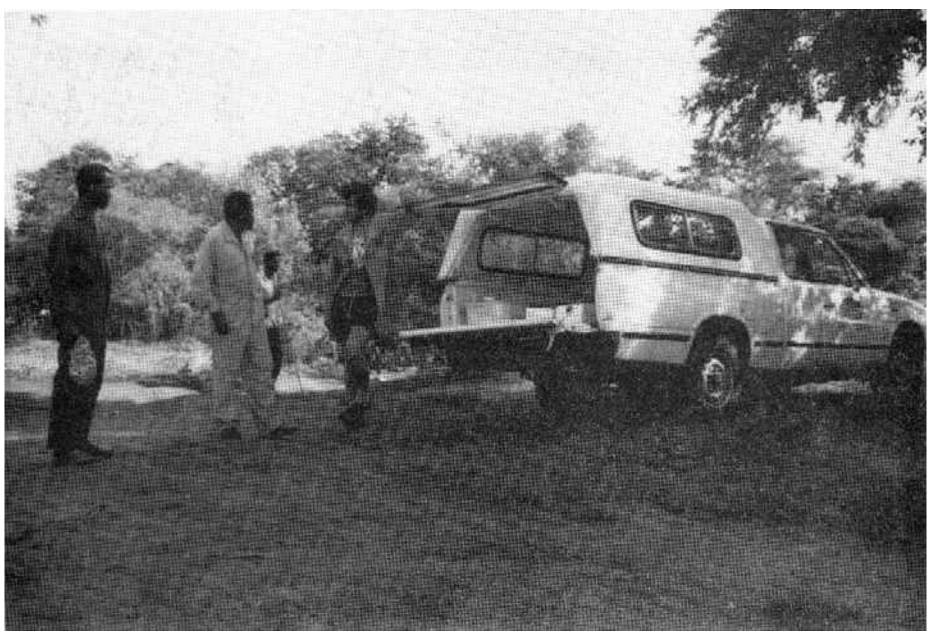
Map 1: Swaziland, showing location in Africa and administrative districts



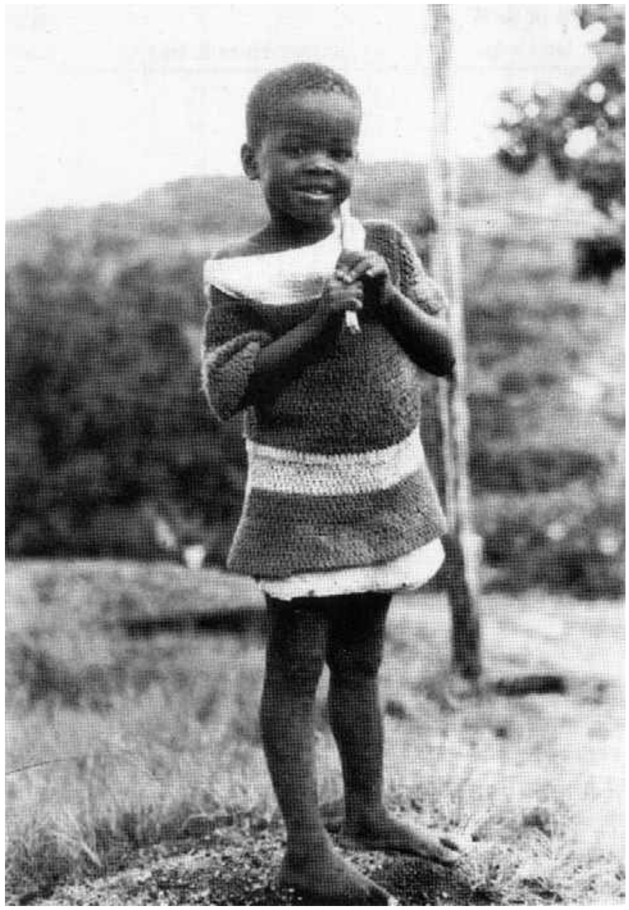
Map 2: Major natural regions of Swaziland



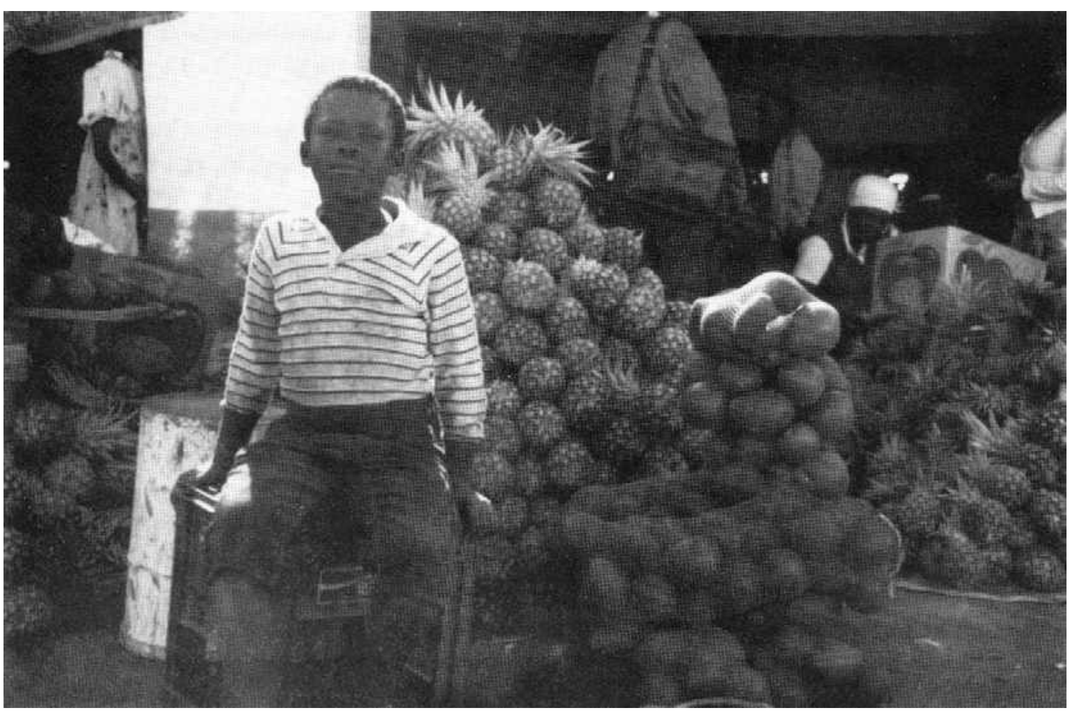
Expedition accommodation at the Mpisi Agricultural Training Centre near Manzini



Pete and friends with the pick-up truck on loan from Pfizer Ltd.



Swazi Child



Swazi boy at market

Table 1: Geographical Regions of Swaziland

Region	%of Total Land Area	Average Altitude (m)	Average Annual Rainfall (mm)
Highveld	29	1300	1250
Middleveld	26	700	900
Lowveld	37	200	700
Lubombo	8	600	800

The shallow ford in front of them had been transformed into a 20 metre wide river, and the gentle hill behind them had become a well lubricated mudslide! Swaziland has been inhabited since early Stone Age times, and over the centuries various different groups of people have lived in the country. The ancestors of modern Swazis were members of a number of different clans living in the region, who in the mid-19th century joined together to form a single nation, under the leadership of King Mswati. "Swazi", in fact, means "the people of Mswati". The present population of Swaziland is approximately 650,000, the vast majority of whom are members of the Swazi tribe. The Swazis are a peaceful and fun- loving people. In carrying out field work, Tim and Peter travelled extensively throughout Swaziland, and they were delighted to meet the same friendly waves and cheerful smiles from people at the roadside in every corner of the country. The two official languages are English and SiSwati. Although English is very widely spoken, SiSwati remains the national language of the Swazi people. Peter and Tim did not progress much further than "Sawubona" ("Hello"), "Yebo" ("Yes") and "Ngiyabonga" ("Thank you") and other simple sentences from the phrase book. However they did find it a challenge to, at least, initially attempt conversations in SiSwati. Their efforts usually ended with the Swazis, after much laughter, continuing the conversation in their fluent English!

Education is highly prized in Swaziland. There is an efficient system of primary and secondary schools throughout the country, and the opportunities for further education include technical colleges, the University of Swaziland, and numerous correspondence classes, all of which are well subscribed. The fact that better education generally leads to a better quality of life is widely recognised. The value of extra qualifications is especially apparent in an age when, as in the rest of the world, unemployment is beginning to make its mark. Swaziland is a member of the British Commonwealth, and has been independent since 1968. The traditional style of government is a monarchy. The late King Sobhuza II reigned from 1921 until his death in 1982, and his successor, King Mswati III was crowned on 25th April 1986. King Mswati III is one of the late King's many sons, and he was only 18 years old at the time of his ascent to the throne. The King is known as "Ngwenyama" ("The Lion"), and whilst he has the ultimate veto, he is assisted in governing the country by his mother the Queen, ("Indlovukati" the Great She Elephant), and by a complex system of modern parliament and traditional councils.

This mixture of modern and traditional ways of life is evident in many aspects of Swaziland today. For example, a net of health clinics ensures that almost everyone is within an 8 km walk of modern medical aid. The traditional healer ("Inyanga") however is still very popular (a typical fee for consultation being a live chicken for a minor ailment or a goat for a more serious condition). The road system, too, shows a marked contrast between the modern, well maintained tarred roads of the major communication routes and the twisted, ungraded, well-trodden tracks of remote areas, more suited to passage on foot than any form of mechanical transportation. The roads in Swaziland are indeed well used, by varied means of transport, from people on foot, to draught cattle or donkeys pulling carts, to bicycles, to modern (and not so modern) cars, buses and trucks. There are numerous private bus companies serving most main routes. These bus companies often have interesting titles, which are usually emblazoned in huge letters along the side of the bus. The 'Tit for Tat' bus company is well known, as is the 'Hope Does Not- Kill' bus company. There was even a 'Saliva' bus company, and Peter and Tim were reliably informed that this is not a SiSwati word! Hitchhiking is very widely practiced. The standard hitchhiking gesture, instead of the European “thumb", is a frantic waving up and down of the arm, as used to flag a car down in the UK. This caused Peter and Tim some confusion initially, but they were seen, when necessary, using the same gesture themselves, to hitch a lift!

There is also a railway system in Swaziland, but only goods are transported; there is no passenger service. Steam engines are still the standard locomotives, and the sight of these magnificent machines charging across the savannah trailing a long white plume of steam is one which certainly will not be forgotten.

Agriculture in Swaziland

Agriculture is very important to Swaziland, providing 70 per cent of her exports and employing over 50 per cent of her work force. There is a marked contrast between modern and traditional methods of production, which is closely linked to the two types of land tenure indicated in Table 2.

Table 2: Types of Land Tenure in Swaziland

Type of land tenure	% of total land area
Title deed land	44
Swazi Nation land	56

Tide Deed Land (TDL) is owned by private individuals and companies. These farms and estates tend to utilise modern principles of livestock husbandry and crop cultivation. The main products are beef cattle, sugar, citrus fruit, pineapples and cotton. Forestry is also a major industry.

Swazi Nation Land (SNL) is owned by the King, who holds it in trust for the nation. This is the traditional form of land tenure in Swaziland; in Swazi culture, individual land ownership is not recognised. The King, via a network of chiefs for each area, allocates a plot of land to every family living in rural districts. This plot consists of a site for the family homestead buildings and a surrounding small area of arable land for cultivation. The total size of each plot varies from 1 to 5 hectares. These family farms are generally managed on a subsistence basis, with maize for home consumption being the main crop. Sorghum, ground nuts, tobacco and cotton are also grown to some extent. Methods of cultivation are traditional, with draught oxen being used for ploughing, and weeding performed by hand. Levels of production are therefore low in comparison to modern agriculture. All SNL unsuitable for crop planting is not allocated to individual families, but is used instead as communal grazing for cattle and goats. Approximately ninety per cent of SNL is under grazing.

The livestock population of Swaziland is shown in Table 3.

Table 3: Livestock Population of Swaziland (1984 figures)

Livestock type	SNL	TDL	National total
Cattle	484,609	128,920	613,529
Goats	266,329	31,700	298,029
Sheep	19,843	8,618	28,461
Pigs	11,963	2,026	13,989
Poultry	586,895	117,423	704,318

Cattle are, by far, the most important domesticated animal in Swaziland. The traditional 'Nguni' breed is the foundation from which most of the current cattle population has been derived, but imported cattle of various breeds have considerably altered the appearance of the traditional animal through large scale crossbreeding. The Swazi people attach great importance to the possession of cattle, and large herds are indicative of wealth and status. However, as well as having this inherent value, there are numerous practical reasons why ownership of cattle is prized.

1) Meat is the most sought after type of food in Swaziland, although in fact Swazis are often very reluctant to slaughter cattle, and this will only be done if the cattle are injured or are ill, at important celebrations, or in times of scarcity of other foods

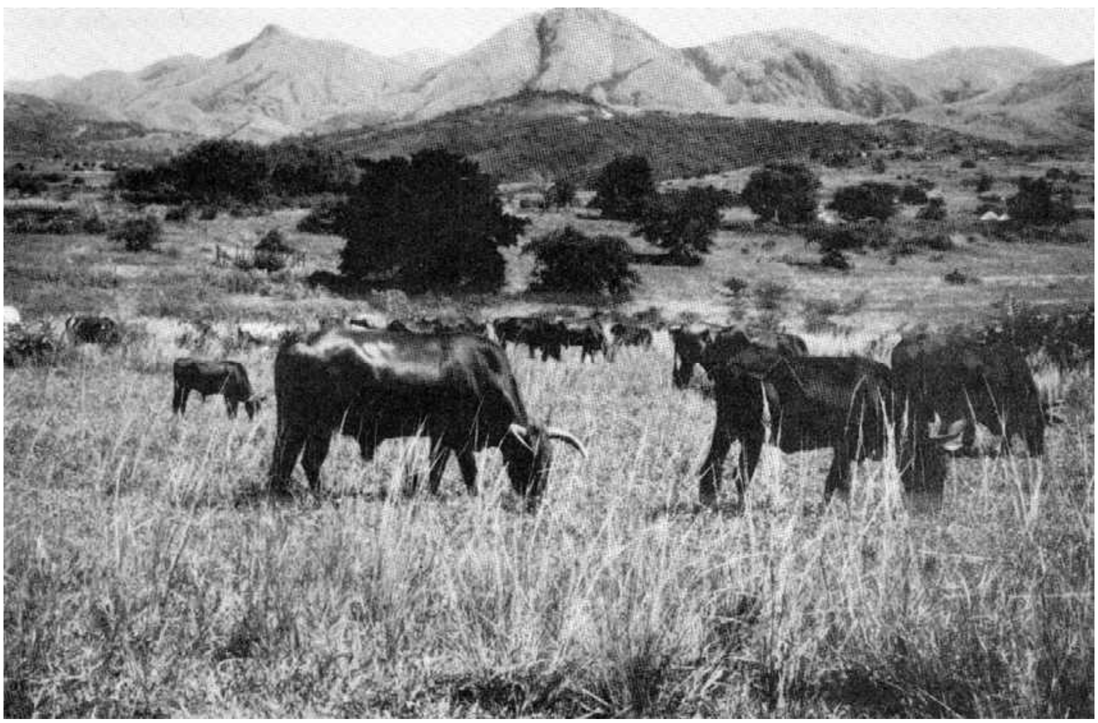
2) Cows provide a supply of milk (although generally only in small quantities, this is very useful for home consumption).

3) Oxen are widely used as draught animals for cultivation and transport.

4) Cattle manure is often used as fertiliser on arable land.

5) Cattle play an essential role in Swazi social customs. For example when a man marries, he must give a certain number of cattle to the family of his bride as payment or "lobola".

6) Cattle are a sensible financial investment. Even if levels of production are low, the cost of maintenance on communal grazing is minimal, and the return on money invested has been estimated as being at least 15 per cent, which is considerably higher than the 7 or 8 per cent currently offered by savings banks.



Cattle grazing near Piggs Peak in the north of Swaziland

For all of these reasons, there is an extremely high number of cattle on SNL. Swaziland has the densest cattle population in Africa, with 1.9 Ha of grazing land per stock unit. As a result, much of the communal grazing is overstocked and overgrazed, and soil erosion is a major problem (some erosion gullies would be literally deep and wide enough to drive a bus through). In addition, there is insufficient grazing for the cattle during the dry winters. No forage conservation (such as hay or silage production) is practiced, and as a result, malnutrition and starvation are the most important cause of mortality. Tim and Peter's arrival in October coincided with the end of the dry season, before the first rains of summer had fallen, and at this time the grazing land was brown and closely cropped. All of the cattle seen were lean to the point of emaciation, and a few seen lying beside the road were too weak to rise, with piles of dung accumulating behind them.

The Swaziland government is attempting to lessen the severity of this problem by erecting "fattening ranches". Stock owners pay a grazing fee in return for their cattle being fattened under good ranch management conditions prior to slaughter. Swaziland has an export abattoir which meets the standards required by the EEC, and considerable quantities of beef are now exported to Europe. The fact that Swaziland has been free of foot and mouth disease since 1969 is essential to this export market, and rigorous control measures are in force to prevent the reintroduction of the disease from Mozambique. These measures include two veterinary control fences 20 km apart, which create a 20km wide buffer zone all along the Mozambique border. All cattle, sheep and goats between these fences are vaccinated against foot and mouth disease, and there are strict quarantine regulations regarding movement of animals from this zone into the rest of Swaziland.

1. Ticks

1.1 Tick Species

There are four important genera of cattle ticks in Swaziland, *Amblyomma*, *Boophilus*, *Rhipicephalu*s and *Hyalomma*. From collections of engorged female ticks made from 305 dip tank areas in the course of the tick resistance survey, six species were identified and their identifications kindly confirmed by Dr. Jane Walker of Onderstepoort Veterinary Research Institute (Table 4). All are Ixodid ticks with a hard scutum or body shield, and all are potential vectors of tick-borne diseases or tick toxicoses. All are haematophagous, a blood meal being required between each developmental stage and in order for the eggs to develop. Ticks are classified according to the number of hosts they occupy during one life cycle i.e. as one, two or three host ticks. Not all of these hosts need be cattle.

Table 4: Tick Species Collected for the Tick Resistance Survey

Tick species	Common name	Number of locations from which recovered
Amblyomma hebraeum	Bont tick	196
Rhipicephalus evertsi evertsi	Red legged tick	173
**Rhipicephalus appendiculatus*	Brown ear tick	137
Boophilus decoloratus	African blue tick	58
Hyalomma species	Bont legged tick	42
Boophilus microplus	Pan-tropical blue tick	8

*A small number of *Rhipicephalus simus* and *Rhipicephalus capensis* species ticks may be included in this figure.

1.2 Economic losses due to ticks

Apart from their role as vectors of tick-borne diseases, ticks have a direct effect on cattle production in Swaziland.

Haematophagia - heavy infestations of ticks can cause pronounced anaemia and subsequent loss of production through their blood sucking activities.

Physical damage - the Bont tick, *Amblyomma hebraeum*, causes deep seated abscesses which are often attacked by screwfly larvae. Teats can become non-functional leading to reduced milk production and problems suckling calves.

The Brown ear tick, *Rhipicephalus appendiculatus*, can cause crumpling and even loss of the ear pinnae.

Tick worry - unsettled cattle will graze less and produce less.

Tick toxicoses - toxins in the saliva of the Bont-legged tick, Hyalomma truncatum; cause sweating sickness in susceptible calves less than one year old. A generalised moist eczema develops. Between 30 per cent and 70 per cent of affected calves die, there is no specific treatment.

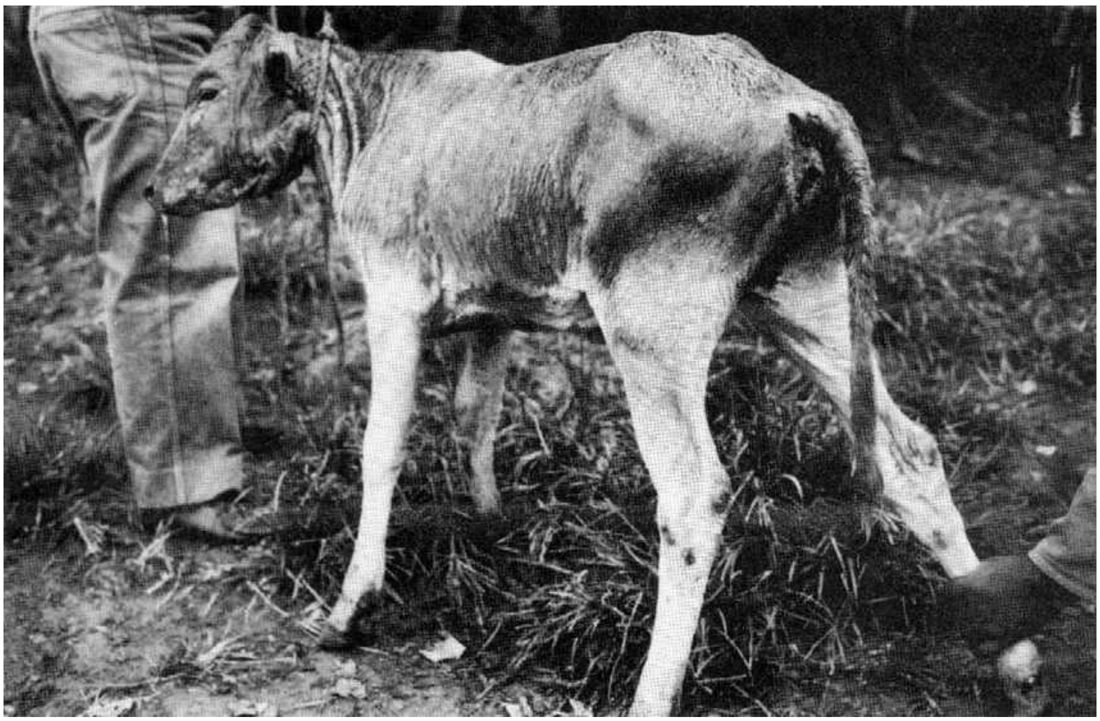
Heavy infestations of the Brown ear tick, *R. appendiculatus*, can cause a toxic syndrome with loss of pro-duction and increased susceptibility to disease.
Such losses can be minimised by effective tick control, reducing the numbers of ticks on individual cattle.

2. Tick-borne Diseases of Cattle

2.1 Babesiosis or redwater

Babesiosis is a tick borne disease of mammals, caused by protozoan parasites of the genus Babesia

2.1.1 Clinical signs. Babesia parasites cause extensive breakdown of red blood cells, which results in the release of large amounts of haemoglobin, staining the urine red or even black in colour (hence the common descriptive term of "redwater"). There is a marked pyrexia, jaundice is usually seen, and affected animals usually die within two or three days unless treated. In some cases, the brain is involved, causing nervous symptoms such as hyper-excitability and incoordination to develop. This form of the disease is always fatal.



A calf with sweating sickness

2.1.2 Variable severity of clinical signs. The severity of clinical babesiosis varies considerably, and depends principally on two factors:

Susceptibility of cattle. This relates to the age, immune status and breed of the cattle involved.

Species of *Babesia* parasite. In Swaziland, two species of Babesia are present, *Babesia bigemina* and Babesia bovis. There are important differences between these species.

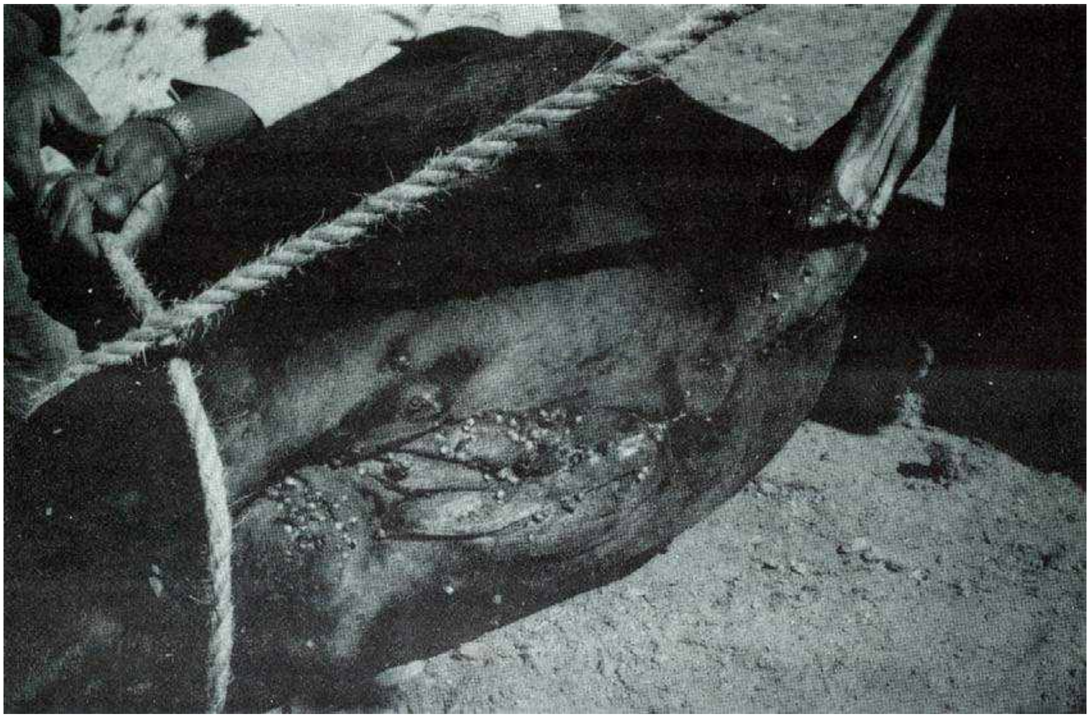
2.1.3 Babesia bigemina. *B. bigemina* causes "African Redwater", and has been identified as the causal agent in outbreaks of babesiosis in Swaziland for many years. Outbreaks in recent years have been less severe suggesting that many cattle in Swaziland possessed some degree of immunity to African redwater.

2.1.4 Babesia bovis. *B. bovis* causes "Asiatic Redwater", and was first isolated from cattle in Swaziland in the past decade. It was suspected to be the cause of the many severe outbreaks of babesiosis in recent years; it was assumed that because most cattle had had no previous exposure to the parasite, they possessed no immunity, and so were highly susceptible to the disease. The nervous form of babesiosis is particularly common with *B. bovis* infection, and many such cases have been confirmed at the veterinary laboratory in Swaziland in the past few years.

2.1.5 Treatment. A number of drugs can be used to successfully treat bovine babesiosis. In Swaziland, the drug most commonly used is imidocarb ("Imizol" or "Forray 65").

2.1.6 Immunity. If cattle recover from babesiosis, strong immunity develops, which lasts for months or years. This immunity is usually of a type known as 'premunity', when it is associated with persistent low concentrations of the Babesia parasite in the bloodstream. The animal shows no sign of the disease, but is, a "carrier". This fact is important when considering the maintenance of infection within an area. Premune, carrier animals may develop the clinical disease if stressed.

Heavy infestation of Rhipicephalus appendiculatus on the ears of a cow



Infestation of Amblyomma hebraeum and ***Rhipicephalus evertsi evertsi***
on the perineum and scrotum of a young bull

2.1.7 Transmission of Babesiosis. Two ticks are involved with the transmission of babesiosis in Swaziland.

a) *Boophilus decoloratus*, the African blue tick, which has been widespread in Swaziland for many years.
b) Boophilus microplus, the Pantropical blue tick, which had never before been positively identified in Swaziland.

B. bigemina can be transmitted by both of these ticks, whereas B. bovis can only be transmitted by Boophilus microplus. Therefore, African redwater may occur when either tick is present, whereas Asiatic redwater can only occur in areas where B. microplus is found.

2.1.8 Babesiosis in Swaziland. Redwater is a well-recognised, serious problem in Swaziland, but clinically, African and Asiatic redwater are not often easily distinguished.

2.2 Cowdriosis *or* heartwater

Cowdriosis, more commonly referred to as heartwater, is a rickettsial infection of domestic and wild ruminants. The causal agent is *Cowdria ruminantium,* and it is transmitted only by ticks of the *Amblyomma* genus.

2.2.1 Clinical signs. *C. ruminantium* forms colonies in vasculo-endothelial cells, and produces clinical reactions which vary from inapparent to peracute. In the acute form, pyrexia and variable central nervous signs (such as walking in circles or with a high stepping gait) are seen. These usually progress to convulsions and then to death. Less acute cases may show a transient pyrexia and diarrhoea. The severity of clinical signs depends largely on the age and immune status of the cattle involved.

2.2.2 Treatment. Tetracylines are the treatment of choice, but they must be given in the earliest stages of the disease to be effective.

2.2.3 Immunity. Cattle recovering from heartwater develop immunity which lasts for months or years. There is a post-infection carrier state, but it only lasts for a few weeks after recovery, and immunity to the disease persists for long after this.

2.2.4 Transmission of heartwater. The only vectors of C. ruminantium are Amblyomma ticks. A. hebraeum is the only tick of this genus to be found in Swaziland, and therefore the only vector of the disease. Trans-stadial transmission of infection occurs, but there is no trans-ovarian transmission. Therefore, for an infection of C. ruminantium to be maintained, each new generation of tick must be re-infected.

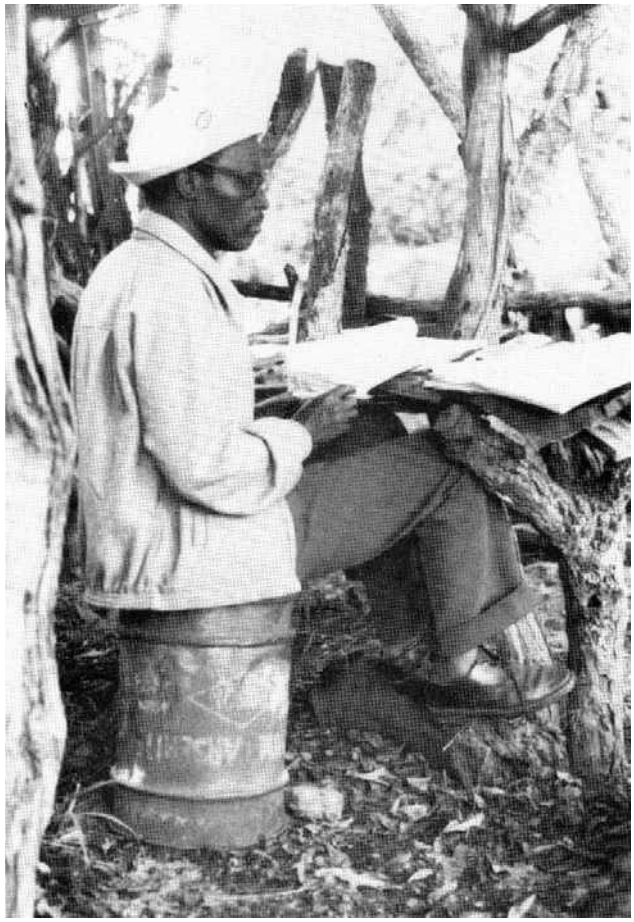
2.2.5 Heartwater in Swaziland. It has been known for many years that heartwater is prevalent in many parts of Swaziland and that enzootic stability exists in many areas. Problems with outbreaks of heartwater are generally seen following movement of stock either into or out of infected areas. There has never been any clear definition of infected and non-infected areas, and outbreaks of heartwater recur frequently, especially at the start of the wet season.

2.3. Anaplasmosis or gallsickness

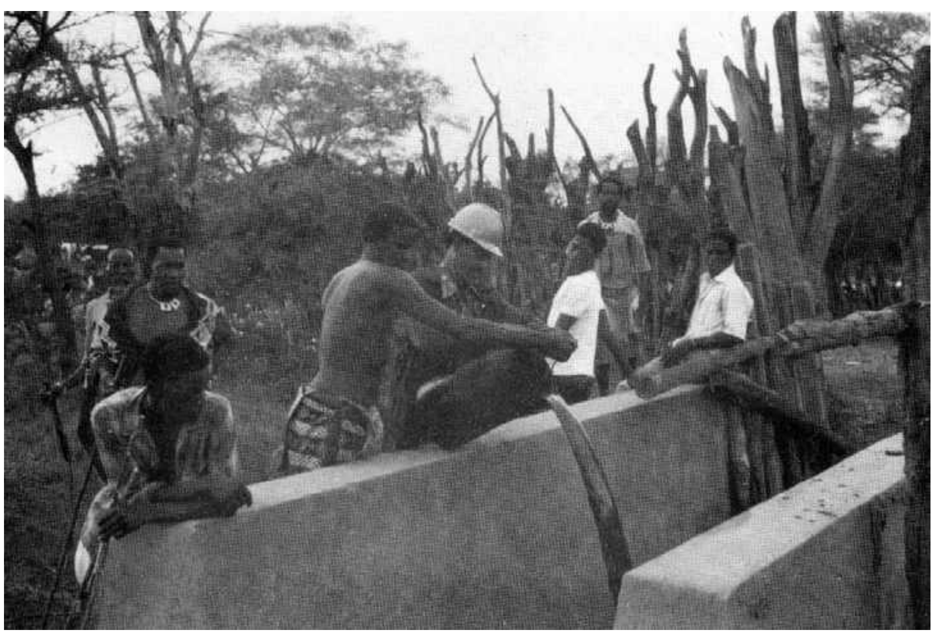
Anaplasmosis is a rickettsial infection of cattle, caused by *Anaplasma marginale*.

2.3.1 Clinical signs. *A. marginale* parasitises red blood cells, causing widespread red blood cell destruction, and thus a progressive anaemia. The clinical reaction varies from peracute to inapparent. In a typical, acute case, there is marked pyrexia, the lymph nodes enlarge, and breathing becomes laboured. Anaemia or jaundice may be seen. Urine is of normal colour, and affected animals become slightly incoordinated. Death may occur at any time from one to four days after the initial signs.

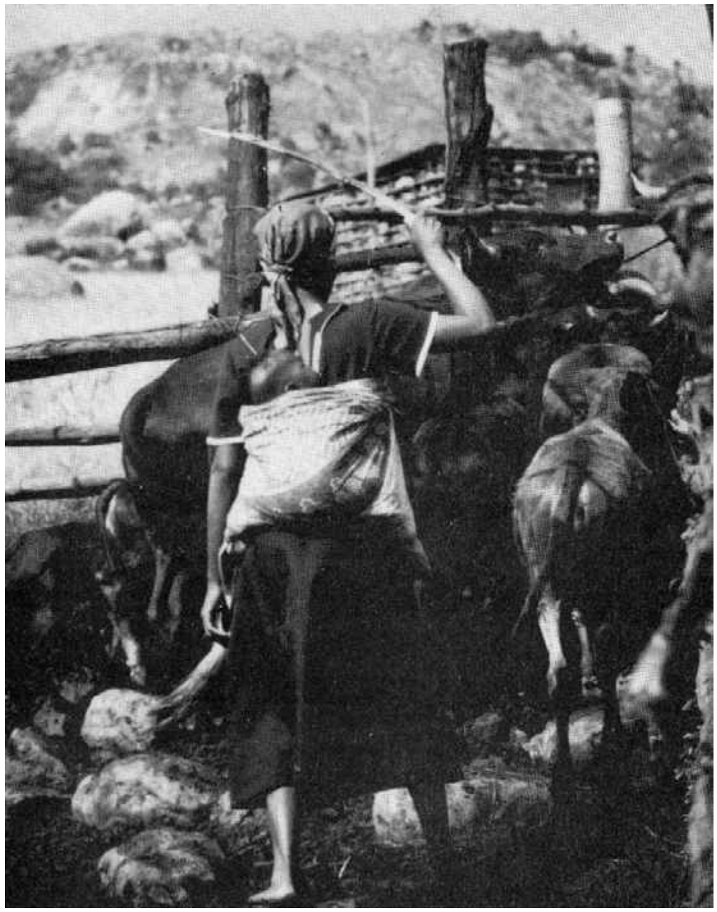
2.3.2 Treatment. The tetracyclines are effective in controlling anaplasmosis if given early enough before the parasitism of red blood cells has become too advanced. Symptomatic palliative treatment and good management are very important in aiding recovery. Anaplasmosis may be complicated by concurrent infection with other tick borne diseases, especially babesiosis.



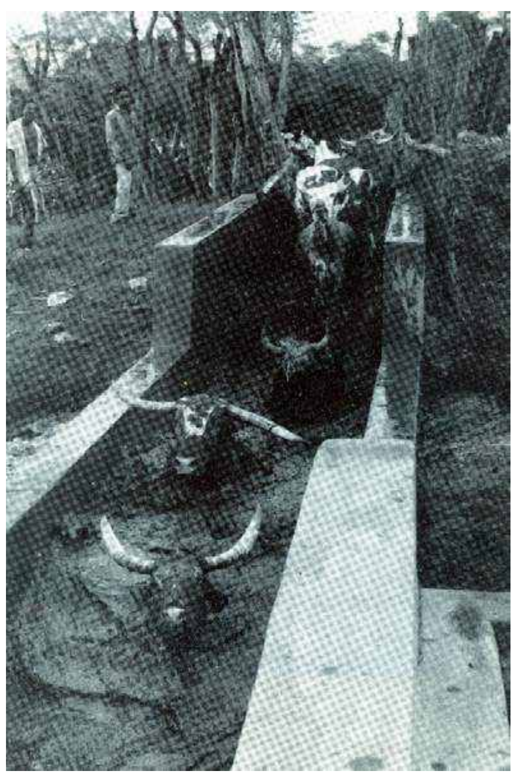
An animal health inspector counting cattle into the collecting kraal before dipping



Replenishing a dip-tank with fresh acaricide



Cattle being herded into the dip tank from the collecting kraal



Cattle being dipped

2.3.3 Immunity. Cattle recovering from anaplasmosis acquire a solid immunity which may last for years. As in babesiosis, this immunity is "premunity" i.e. it is associated with a persistent low infection with A. marginale. Recovered animals will therefore usually be carriers of the infection.

2.3.4 Transmission. Anaplasmosis can be transmitted in several ways:-

(I) Ticks. Ticks are the natural hosts of A. marginale, but while many genera have been shown to be capable of transmitting the infection , Boophilus species are thought to be the most important vector. However Rhipicephalus and Hyalomma genera of ticks may also be important in Swaziland.

(II) Biting flies. Transmission of A. marginale is possible via mechanical transference of blood by biting flies.

(III) Surgical instruments etc. A. marginale may also be transmitted by the mechanical transference of blood which may occur with the repeated use of hypodermic syringes, tattooing tools, or other surgical instruments.

2.3.5 Anaplasmosis in Swaziland. Anaplasmosis is not generally considered to be a serious problem in Swaziland. However, sporadic deaths do occur throughout the wet season, particularly towards the end of summer and in early autumn. Occasionally outbreaks with a high mortality rate do occur on individual farms.

2.4 Benign theileriosis

Benign theileriosis is caused by the protozoan parasite *Theileria mutans*, and is spread by the Bont tick, A. hebraeum, the Brown ear tick, *R. appendiculatus* and the red legged tick, *R. evertsi evertsi*. The disease is characterised by mild fever, anaemia and swelling of the lymph nodes. Other tick-borne diseases and salmonellosis may be superimposed on this condition.

2.5 Economic Losses Due To Tick-borne Diseases

There are no readily available figures on the incidence of tick-borne diseases in Swaziland; however diagnoses recorded in the Central Veterinary Laboratory, Manzini, indicate their importance (Table 5).

Table 5: Diagnoses Recorded In the Central Veterinary Laboratory, Manzini 1982-1985

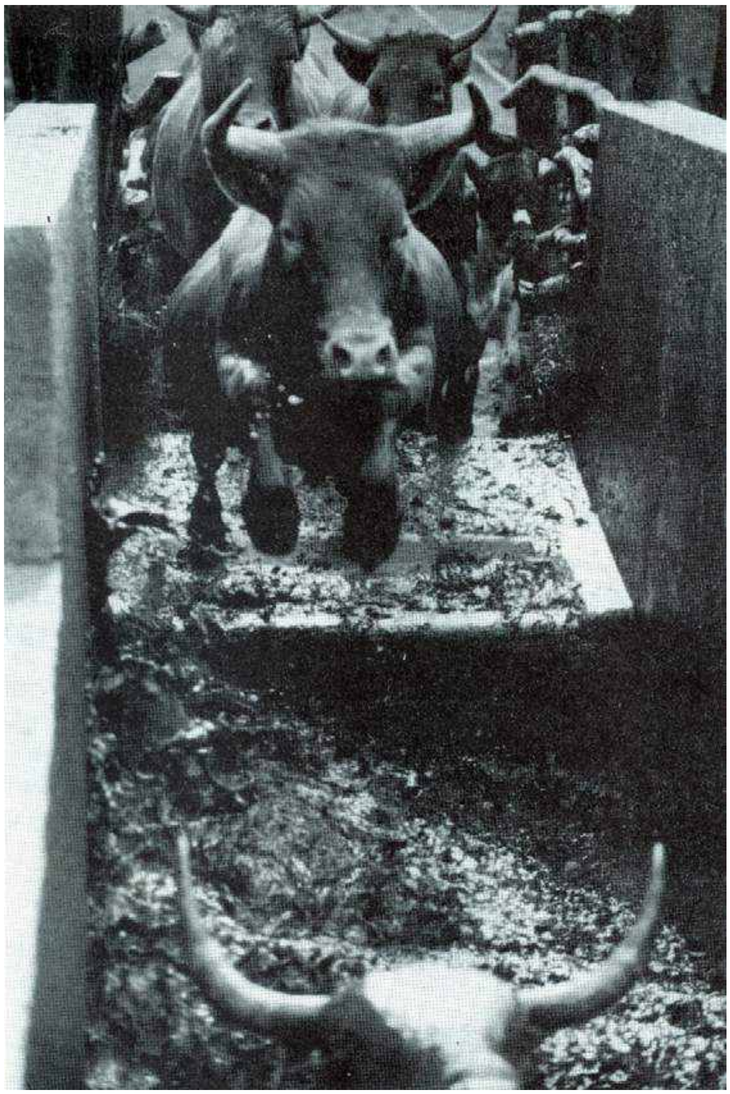
Year	Total bovine disease diagnoses	Total bovine tick-borne disease diagnoses	% tick-borne disease diagnoses
1982	854	219	25.6
1983	887	245	27.6
1984	719	194	27
1985	493	168	34.1

These figures indicate the relative importance of tick-borne diseases as a cause of cattle morbidity and mortality. They are biased i.e. most samples were submitted from the Manzini district with a high proportion from private farms.

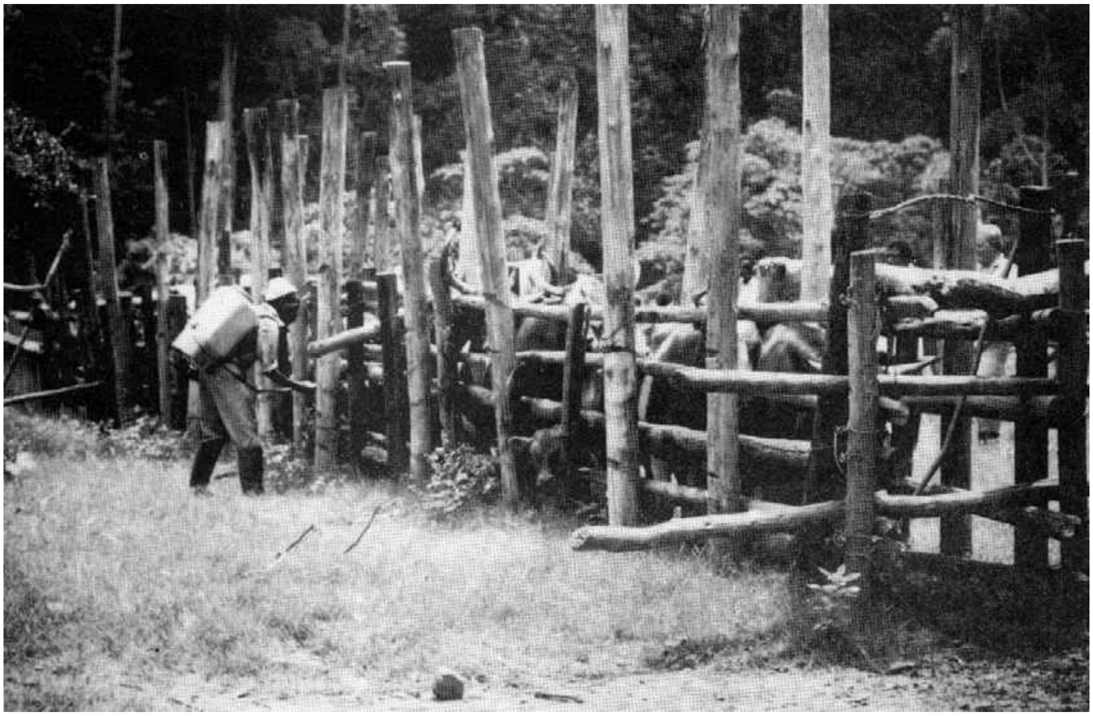
Blood smears from all dead or slaughtered bovines are examined in the Smears Laboratory in Manzini for evidence of parasitism (Table 6).

Table 6: Smears Laboratory Analysis 1982-1984

Year	Total Smears	Slaughtered	Died	% Died	Redwater	Anaplasmosis	Benign theileriosis
1982	127,582	71,984	55,593	43.6	640	10	5
1983	99,106	67,061	32,045	32.3	747	4	1
1984	99,673	59,253	31,420	34.7	664	3	1



Cattle entering the dip-tank


Hand spraying of cattle with acaricide

The large numbers of slides submitted to the Smears Laboratory and the limited number of staff make accurate screening impossible. As such, the figures on disease incidence are unreliable. Of interest are the high proportion of cattle which die as against being slaughtered. Even if the incidence of tick-borne diseases was quite low they would still represent a major economic loss to the Swaziland cattle industry. Informed estimates of the mortality due to tick-borne diseases range between minimal and 40 to 50 per cent of all mortality in cattle. Overall, no clear assessment can be made of economic loss due to ticks and tick-borne diseases of cattle in Swaziland.

3. Control

Historically, the control of ticks and tick-borne diseases of cattle in Swaziland has centred around the application of chemicals to the cattle to kill the ticks. Vaccines are available against heartwater, redwater and anaplasmosis but little use is made of them except on some private farms. This policy has its roots in the history of disease control in Swaziland.

3.1 A Brief History of Tick Control In Swaziland

Cattle dipping on a large scale in Swaziland was initiated in response to the challenge posed by East Coast fever (ECF). Attempts to eradicate this disease centred around the control of its vector, the Brown ear tick, *Rhipicephalus appendiculatus*, by dipping cattle in a suspension of sodium arsenite. ECF kills 80 to 100 per cent of susceptible cattle.

1933 Swaziland had 169 dip tanks and a cattle population of 414,971 cattle.

1934 148 cattle died from ECF. Strict quarantine and short interval dipping were applied to infected areas. In contact areas were also quarantined.

1941 248 cattle died from ECF on European owned farms in Southern Swaziland. Poor dipping management was blamed.

1946 The first trials were run on a -γBHC cattle dip. The Principal Veterinary Officer reported; "I feel confident that many ranches will take advantage of this new discovery to replace the crude, only partially effective and most dangerous drug, Arsenite of Soda," It was to be 40 years before arsenite was withdrawn from use as a cattle dip in Swaziland.

1947 Resistance to arsenic in the Blue tick, B. decoloratus, was recognised in Swaziland. Ninety six cattle died due to ECF.

1949 *B. decoloratus* was now recognised as being -γBHC resistant in some areas.

1951 Fencing of enzootic ECF areas commenced.

1957 117 cattle deaths were attributed to ECF.

1960 The last case of ECF was recorded in Swaziland.

1965 A foot and mouth disease epidemic was contained largely due to the effectiveness of the cattle movement permit system introduced during ECF control.

1967 Quarantines were lifted on the last two remaining ECF infected areas.

1973 70 cattle in one herd died due to the misuse of arsenite.

1982 The use of improved acaricides for government dip tanks was approved provided communities met the cost themselves.

1985 676 dip tanks or spray races were in service in Swaziland.

1986 Senior veterinary staff agreed to withdraw supplies of sodium arsenite, ending its use as an acaricide in Swaziland.

The present-day system of tick control differs little from that employed to control ECF either in methods or organisation. Compulsory supervised dipping, the cattle movement permit system and the work of the smears laboratory are all directly descended from this period of disease control.

3.2 Methods of Acaricide Application

There are now four methods of acaricide application in use in Swaziland:

1. Dip tanks
2. Spray races
3. Hand spraying
4. Hand dressing.

The first two are by far the most important.

3.2.1 Dip tanks. Dip tanks remain the most popular and effective form of acaricide treatment in Swaziland, especially in government tank areas. Dip tanks ensure thorough wetting of the cattle. Cattle are counted and held in a collecting kraal before being forced to jump into, and swim along the length of, the concrete tank. They are then held in a "draining race" whilst excess fluid drains back into the tank. Dip tanks are expensive to build and are immobile but they are cheap to maintain. The tank must be calibrated accurately i.e. its capacity in litres permanently marked on the side of the tank at a safe level for dipping. This aids the veterinary assistant in accurately diluting the acaricide when filling the tank. A similarly calibrated "side tank" of @ 2,500 1 capacity aids in replenishing the tank with acaricide at the correct dilution.

Dip tanks in Swaziland range in capacity from 10,000 to 30,000 1, some being up to seventy years old. Large tanks, whilst ideal for arsenite use, are expensive to use with modern acaricides, and some older tanks have been reduced to a more economical capacity of 15,000 to 17,500 I.

Dip tanks are charged (filled) and replenished at different dilutions of acaricide to compensate for "stripping" (the removal of panicles of acaricide on the animal's coat). There are a variety of acaricides used in Swaziland with different methods of dilution and use:

> e.g. Triatrix T.R.R - this biogradable acaricide is added to the dip tank in equal quantities at each dipping, according to the tank capacity; a "total replacement system".

Disnis® - this acaricide must be added at a higher concentration when replenishing than when filling the dip tank to compensate for stripping. Regular monthly testing of dip concentration is necessary.

Too high a concentration of acaricide increases costs, residues and toxicity. Too low a concentration reduces efficacy and is thought to promote acaricidal resistance in ticks. Tanks must be cleaned regularly (every 35,000 to 50,000 cattle dipped) as the build-up of organic material reduces acaricidal action and increases stripping. Accurate records of acaricide replenishment are necessary.

Table 7: Dip-tanks And Spray Races In Government and Private Tank Areas - June 1985 Survey

	Number of Dip-tanks	**%of total**	**Number of Spray Races**	**%of total**	**Total**
Government tank areas	376	96.7	13	3.3	389
Private tank areas	180	62.7	107	37.3	287

Total tanks/spray races in use 676
Not in use 113
Unknown 3

3.2.2 Spray races. A spray race consists of a permanently fixed, open ended shute, with entry and exit races. Water is pumped through large orifice nozzles at low pressures and high volumes. Fluid returns to a sump to be filtered and recirculated. Spray races reduce costs as only sufficient acaricide is prepared for each day's operation. The process is quicker and less stressful, acaricides which are unstable in dip tanks can be used and acaricides can be readily changed. However, wetting is less efficient, more water is required and stripping is rapid, necessitating the addition of acaricide during the operation. The big drawbacks are the cost of maintenance, the cost of operation and the possibility of mechanical failure. Whilst spray races are used on over one-third of private farms, their use in government tank areas remains minimal.

3.2.3 Hand spraying. This is a simple method of acaricide application suitable for small numbers of animals (less than ten). Pressures are low and thorough wetting requires 10 to 15 I of fluid per animal with special attention to tick predilection sites such as the ear, axilla, groin and perineum.

In Mkhoqueni in Hhohho, 208 head of cattle were being routinely hand sprayed. Wetting was not thorough and control would breakdown in the face of moderate to high tick challenges.

3.2.4 Hand dressing Standard solutions of acaricide, oil based fluids, liquids or dusting powders are all used. Estimates of the amount of hand dressing vary between tank areas. One possible factor is its increased usage when conventional dipping breaks down.

3.3 Control of Dipping

Swaziland is divided into "tank areas" which are supervised by Veterinary Assistants (VAs). Each tank area has either a dip tank or a spray race for the treatment of cattle, sheep and goats in that area. Tank areas are classified as "private" or "government" depending upon whether they serve private farms or Swazi tribal trust land. Veterinary Officers or District Veterinary Officers are based in five main centres; Piggs Peak, Mbabane, Manzini, Siteki and Nhlangano. The Senior Veterinary Officer and Director of Veterinary Services are based in Mbabane, the capital.

In addition to stock dipping, the Animal Health Department is responsible for movement control, population records, quarantine, meat inspection, the Veterinary Investigation Laboratory and disease control. Communication is good. Veterinary Assistants meet with their local Animal Health Inspectors in sub-district offices each Friday morning. Senior Animal Health Inspectors report to the District Veterinary Officers in each area. Transport at a local level is a problem. No VAs are issued with transport, and although some may receive a bicycle allowance, others may have to walk up to six miles to supervise a single dipping. Only two sub-offices use government transport whilst even district offices are short of vehicles and petrol.

3.4 Dipping Strategy

Dipping is compulsory and fines can be charged for non-attendance in government tank areas. The frequency of dipping is determined by the geographical location of the dip tank i.e. Highveld - fortnightly dipping in the summer and monthly dipping in the winter; Lowveld - weekly dipping in the summer and fortnightly dipping in the winter. The increased intensity of dipping is timed to correspond to the greatest adult tick challenge. Tick burdens in the highveld are generally lower than in the middleveld or lowveld. Dipping takes place after dawn on Monday to Thursday mornings in government tank areas and also on other days on private farms. Dipping policy in Swaziland aims to control tick populations and so reduce the incidences of tick-borne diseases to an acceptable level. Only a few private farmers have attempted to eradicate ticks on their land by high intensity, short interval dipping.

Interruptions to the dipping program do occur in individual tank areas. Some tank areas will not dip when it is raining; historically rain increased scalding and toxicity due to sodium arsenite. Whilst the government used to supply sodium arsenite free of charge to dip tank communities, it no longer does so due to widespread tick resistance. Communities must now purchase their own improved acaricides but there is no legislation to cover such purchases. There are often periods therefore when the money runs out and no acaricide is purchased. In an area where regular dipping has created a susceptible population, the potential for an epidemic of tick-borne diseases exists.

There is an urgent need in Swaziland for legislation to cover dipping costs either indirectly through a "cattle tax" or directly through a "dipping fee ".

Aims of the Expedition

Consultations with veterinary field staff in Swaziland established three important aspects of tick and tick-borne disease control requiring further investigation. These became the aims of the expedition.

1. To assess the extent of the resistance of cattle ticks to acaricides in use.

2. To assess the distribution of Boophilus ticks, the vectors of Redwater in Swaziland.

3. To provide epidemiological data on the prevalence of tick-borne diseases of cattle by performing a serological survey.

With these aims in mind, the following three projects were embarked upon.

Project 1: Tick Resistance Survey

1. Introduction

The results of tick resistance studies in Swaziland from 1972-1982 indicated significant levels of resistance to arsenic, organochlorine and organophosphate acaricides in the tick population. The main aim of this survey was to attempt to quantify how far resistance to these acaricides had developed since that time.

2. Materials and Methods

2.1 Tick collections

It was realised in planning this project that use could be made of existing veterinary field staff to collect tick samples. Meetings were arranged with Veterinary Assistants (VAs) responsible for supervising dip tanks in the sub-district selected for the next week's sampling. These meetings took place conveniently on the Friday mornings when VAs routinely gathered in their sub-district offices. Dip-tanks were selected for blood sampling for the serological survey and all the VAs were asked to collect tick samples. These samples were picked up at the next week's meeting and transported to the Veterinary Laboratory in Manzini for identification and postage.
Only engorged adult female ticks taken from untreated cattle were required for testing. These were collected from unrestrained cattle in the dip-tank collecting kraal prior to dipping and were detached manually by gentle pulling. Engorged female ticks were easily differentiated from male and immature ticks by their comparatively large body size.

Certain tick species, e.g. *Amblyomma hebraeum* and *Rhipicephalus evertsi evertsi*, proved easy to collect from the unrestrained animal and were well represented in the samples received (Fig. 1). Others, e.g. *Boophilus* species, were less easy to collect and required the animal to be cast. In order to obtain a uniform geographical distribution of samples from the 676 dip-tanks, ticks were collected from a minimum 20 per cent of dip-tanks in each of the 28 sub-district areas.
Once collected, ticks were placed in ventilated plastic cylinders along with tissue paper and transported as soon as possible to the Veterinary Laboratory in Manzini. They were then identified to genera or species level. Live ticks which had not started to lay eggs were parcelled, still in their containers, and mailed by parcel post to Coopers Animal Health (Pty) Ltd., Kwanyanga Research Station in East London, for resistance testing. Some specimens were lost or delayed in the post but a check was kept to ensure that sufficient samples reached the laboratory.

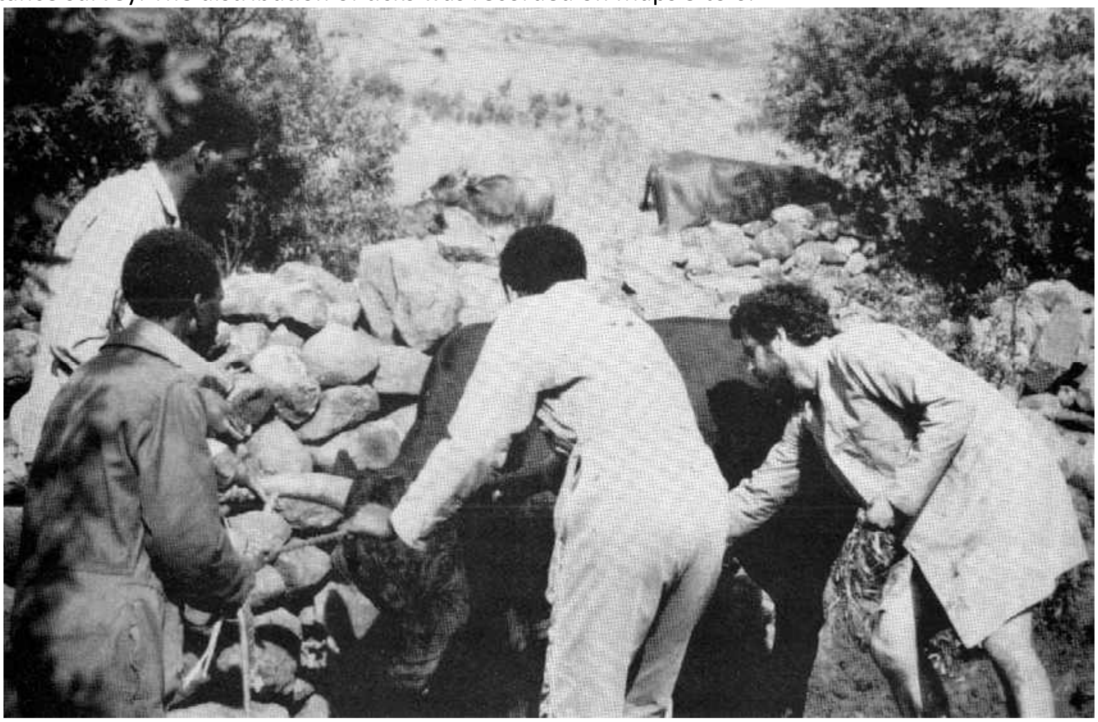
2.2 Resistance Testing

On receipt at Kwanyanga, engorged female ticks were identified and placed in an incubator at 24°C and 80 per cent R.H. and allowed to lay eggs. The subsequent larvae were tested at 14 to 21 days post hatching. The technique used was described by Shaw (1966) and later modified to include a longer holding period for larval ticks after treatment. Larval ticks were immersed for ten minutes between two filter papers in a serial range of dilutions of the test acaricide. The larvae were then removed, dried, and a number placed in a folded filter paper packet which was sealed to prevent escapes. After 72 hours in an incubator at 24°C and 80 per cent RH, the percentage mortality was assessed. Water controls were run concurrently with each test and corrections made for control mortality using Abbot's formula. From a plot of corrected percentage mortality against acaricide concentration on logarithmic-probability graph paper, the Lc_{50} and Lc_{99} values for each field sample were calculated. (The $Lc_{50/99}$ represents that concentration which will kill respectively 50 and 99 per cent of ticks). Although it had been intended, it was not possible to submit this data for probit analysis.

3. Results

3.1 Tick Species

Six commonly occurring species or genera of cattle ticks were identified from collections made for the tick resistance survey. The distribution of ticks was recorded on Maps 3 to 6.



Collecting ticks from cattle before dipping

A morning's collection of engorged adult female ticks

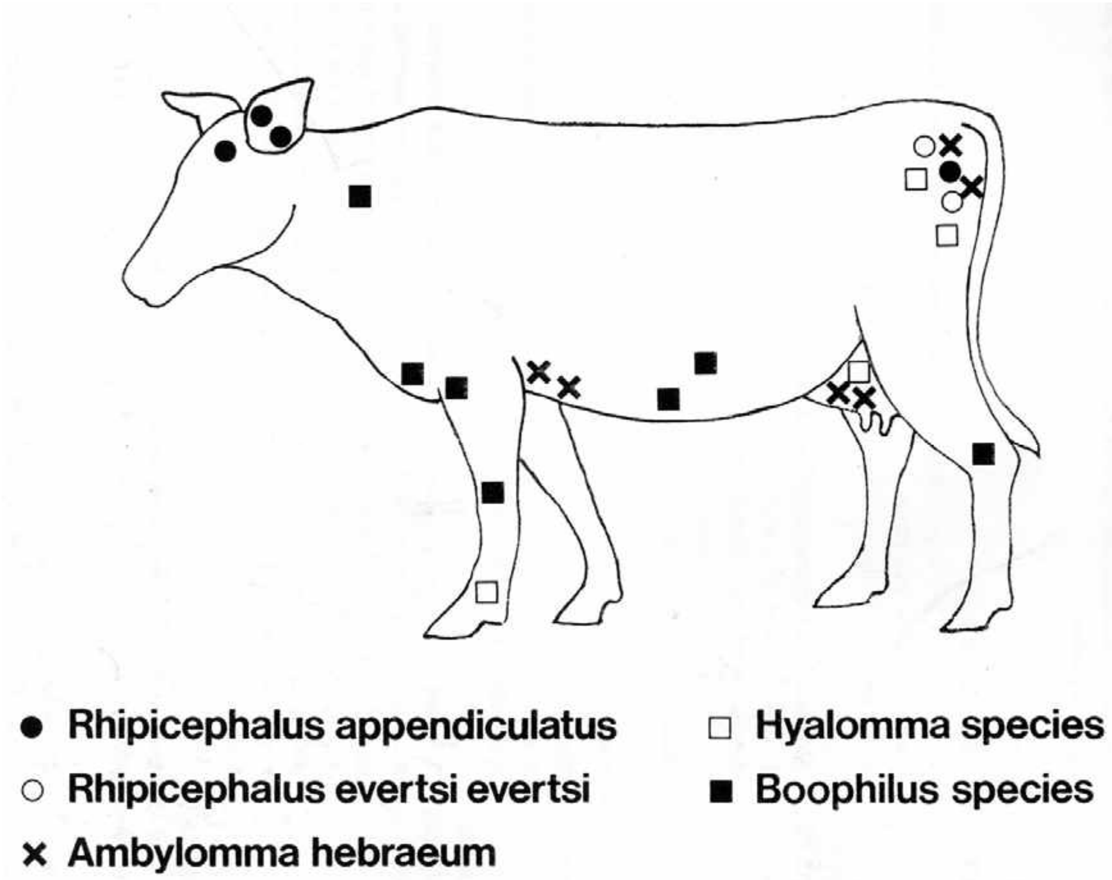


Fig. 1: Predilection Sites for Adult Ticks of the Commonly Occurring Cattle Tick Species in Swaziland

Amblyomma hebraeum (Map 3)
Common name: The South African Bont-tick

Hosts: Adults are found on cattle, large antelope and wild bovids. Immatures (larvae and nymphs) are also found on small mammals and ground feeding birds.

Life cycle: A three host tick. Adults are most active in the summer.

Cattle diseases Transmitted: Heartwater, benign bovine theileriosis.

Distribution: *A. hebraeum* ticks were found at 64 per cent (194) of the 301 dip-tanks surveyed. From the map it can be seen to be uniformly distributed in the lowveld and middle- veld with sporadic pockets in the highveld. These pockets probably coincide with favourable microclimates as this tick requires tree and bush cover to survive at higher altitudes

Rhipicephalus evertsi evertsi (Map 4)
Common Name: The Red-legged tick.

Hosts: Adults feed on the larger domestic animals and wild herbivores. Immatures may in addition infest wild hares.

Life cycle: A two host tick. Adult numbers are highest from January to May.

Cattle diseases transmitted: Benign bovine theileriosis, spirochaetosis,

Distribution: *R. evertsi evertsi* ticks were found at 57 per cent (171) of dip-tanks sampled. This species is uniformly distributed through the lowveld, middleveld and highveld. This tick is not found in areas where average annual rainfall is less than 250 to 280 mm. Mean annual rainfall rarely falls below 500 mm even in the drier areas of Swaziland.

Rhipicephalus appendiculatus (Map 5)
Common name: The Brown ear tick.
Hosts: A wide range of the larger domestic and wild animals with a predilection for cattle.

Life cycle: A three host tick. Adults are most active in the summer.

Cattle diseases transmitted: Corridor disease, benign bovine theileriosis, East coast fever, tick toxicosis.

Distribution: *R. appendiculatus* was found at 45 percent (136) of dip-tanks sampled although this figure may include a small number of R. capensis species ticks. *R. appendiculatus* is confined mainly to highveld and middleveld areas although it can exist in any area of greater than 400 mm annual rainfall provided vegetation is adequate. It is rarely found above 1,500 m altitude (the average highveld altitude in Swaziland is 1,300 m).

Hyalomma species (Map 6)
Dr. Jane Walker of Onderstepoort Veterinary Research Institute, Pretoria, kindly identified *H. truncatum* and it was thought that *H. marginatum rufipes* was also present although it was not possible to differentiate between these two species.

Common name: The Bont-legged tick.

Hosts: Larger domestic and wild animals. Immatures are found on birds, hares and rodents.

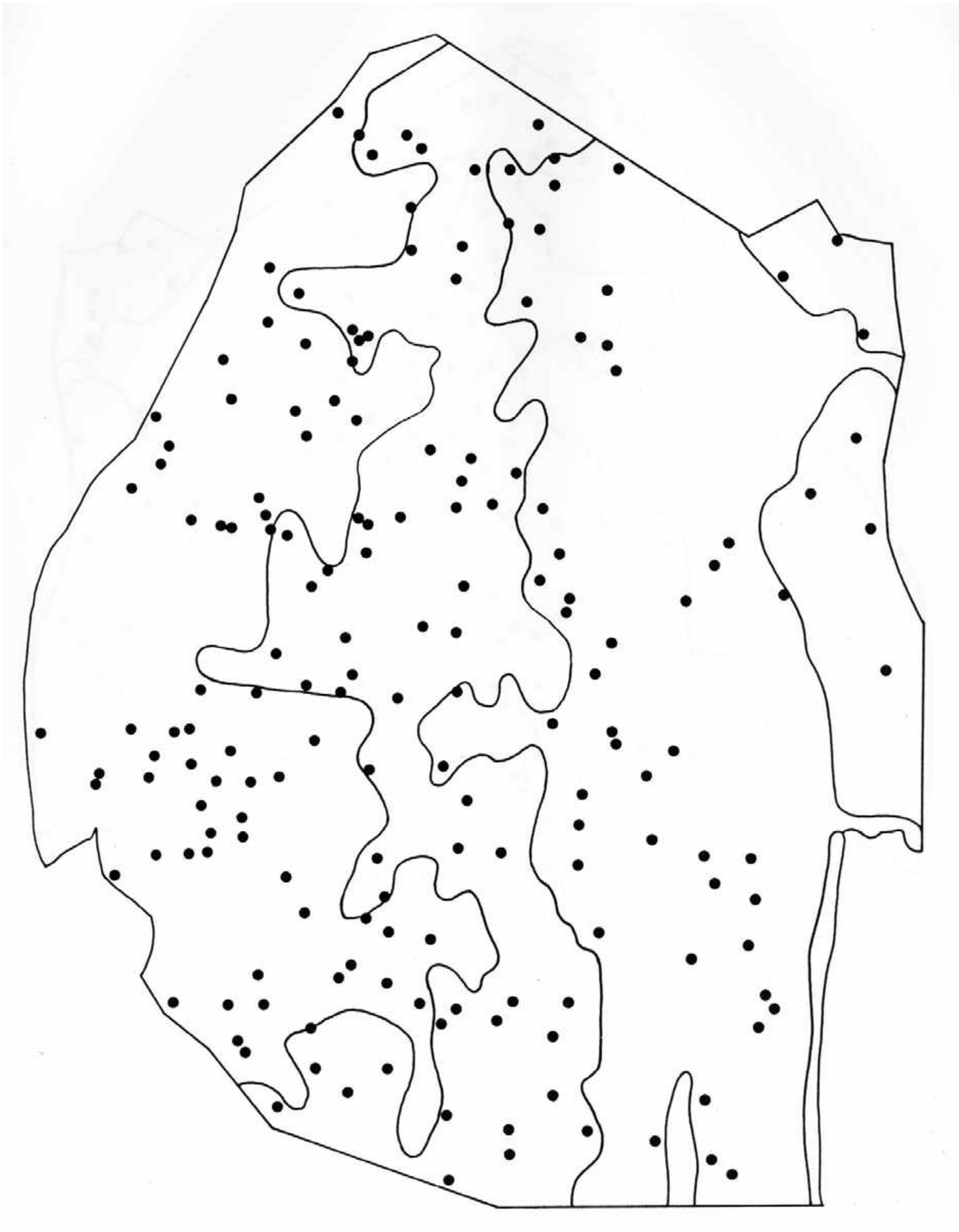
Life cycle: Two host ticks. Most active in the summer.

Cattle diseases
Transmitted: *H. truncatum* causes sweating sickness in calves.

Distribution: *Hyalomma* species ticks were found at 14 per cent (42) of dip-tanks surveyed. *H. marginatum rufipes* is found in areas of up to 650-750 mm rainfall per year and *H. truncatum* in areas of up to 640 mm per year. This tick can be seen to be distributed the lowveld, middleveld and highveld regions. Tick collections in the south of the country probably coincided with the period of greatest adult activity.

Boophilus decoloratus
This species was found at 19 per cent (56) of the dip-tanks surveyed. Its distribution is discussed in Project Two.

Map 3: Distribution of *Amblyomma hebraeum* in Swaziland



Map 4: Distribution of *Rhipicephalus evertsi evertsi* in Swaziland

Map 5: Distribution of *Rhipicephalus appendiculatus* in Swaziland

Map 6: Distribution of *Hyalomma* species in Swaziland

Boophilus microplus
This species was found at 3 per cent (8) of dip-tanks sampled. Its distribution is discussed in project Two.

3.2 Tick Resistance

For each field strain of tick tested against a particular acaricide, a "provisional" factor of resistance (FOR) was calculated comparing the LC_{50} of the test strain with the LC_{50} of a susceptible reference strain of the same species, e.g.

Boophilus species ticks from Shiselweni 650 dip-tank "Mfenyane"
LC_{50} of test strain against arsenic = 2.6
LC_{50} of Kwanyanga reference strain against arsenic = 0.9

"Provisional" FOR $= \frac{2.6}{0.9} = 2.9$

Based on the laboratory's experience the following criteria were applied.

Arsenic	FOR less than 1.5	ticks susceptible
	FOR greater than 1.5	ticks resistant
Toxaphene (Organochlorine)		
	FOR less than 5	ticks susceptible
	FOR greater than 5	ticks resistant
Dioxathion (Organophosphate)		
	FOR less than 5	ticks susceptible
	FOR greater than 5	ticks resistant

Maps 7 to 11 illustrate the distribution of ticks which are susceptible or resistant to the three test acaricides. Table 8 compares the results of the current survey with the results of previous tick resistance testing in Swaziland between 1972 and 1982. The results are not strictly comparable as previous survey results are based on a comparison of LC_{50} and/or LC_{99} values unlike the current survey which utilised only the LC_{50} values.

4. Discussion

In Swaziland, treatment of cattle with acaricides remains the most important method of tick control. The efficacy of this treatment depends on two factors.

(I) Management. The acaricide must reach the tick at the correct concentration and must be applied often enough to control or eliminate tick infestations.
(II) The susceptibility of the ticks. The acaricide must be effective against all stages of the commonly occurring tick species. The development of resistance by the tick obviously reduces the efficacy of the treatment.

Failure of tick control, recognised as an increased tick burden on treated cattle, can be due to problems associated with either or both of these factors. The development of resistance often follows poor management.

4.1 Management of Tick Control in Swaziland

The majority of cattle are treated either in spray races or dip-tanks on a regular basis. The frequency of treatment is controlled by legislation. Probably one of the most common causes of failure of tick control in Swazi- land is the application of acaricide at an incorrect concentration, e.g.

Sodium arsenite -- the unavailability of dip-side test kits in recent years has meant that many tanks charged with this acaricide were probably not operating at the correct concentration.

Disnis® (chlorfenvinphos and toxaphene) - the concentration of the toxaphene component of this dip is tested in samples taken to the Veterinary Laboratory in Manzini (Table 9). With approximately 250 dip-tanks using Disnis® this represents an average of less than two submissions per tank per year. It is generally accepted that tanks should be tested at least twelve times annually in order to ensure an effective dipping concentration.

More modern acaricides are easier to apply at the correct concentration e.g. Triatix TR® (amitraz). This acaricide is biodegradable and so the same amount of chemical is added each week to the tank - a "total replacement" system. The amount added depends only upon the capacity of the vat. Factors relating to dip-tank management, which may have a bearing on the development of tick resistance, were evaluated by means of a questionnaire form completed at 164 of the dip-tanks visited. Pertinent points are:-

(I) Forty five of the dip-tanks visited (27.4%) were not calibrated i.e. their capacity was unknown, making accurate acaricide dilution difficult.

(II) The change from arsenic to modern acaricides had occurred relatively recently. At 105 dip-tanks (64.0%), this change had occurred sometime after 1980. This may help explain the relatively slow emergence of organophosphate resistance.

(III) Only 56 dip-tanks (34.1%) considered that tick resistance may be a problem in their area.

(IV) At 23 dip-tanks (14.0%) dipping had been discontinued, usually due to a lack of money to buy acaricide. The potential exists for serious outbreaks of tick-borne disease in such areas.

Even when an effective acaricide is used at the correct concentration and at recommended intervals, tick control can still breakdown. In such circumstances the development of acaricidal resistance in the tick population should be suspected.

Table 8: A Table Comparing % Resistant Strains and the Number of Strains of Ticks Tested In The 1972-1982 and 198s-1986 Tick Resistance Surveys in Swaziland

Tick Species	**Arsenic**		**Organochloride**		**Organophosphate**	
	1972 - 1982	**1985 -1986**	**1972 - 1982**	**1985 -1986**	**1972 - 1982**	**1985 -1986**
A. hebraeum	83% (29)	29% (7)	86% (7)	46% (92)	47% (17)	32% (126)
R. evertsi	86% (22)	0% (4)	100% (9)	6% (36)	0% (9)	0% (72)
R. appendiculatus	87% (15)	100% (3)	100% (5)	28% (18)	0% (8)	0% (45)
Boophilus species	97% (73)	60% (5)	68% (19)	0% (2)	3% (31)	0% (8)
Hyalomma species		100% (1)		0% (2)		0% (11)
Total strains tested	-139	-20	-40	-150	(65)	-262

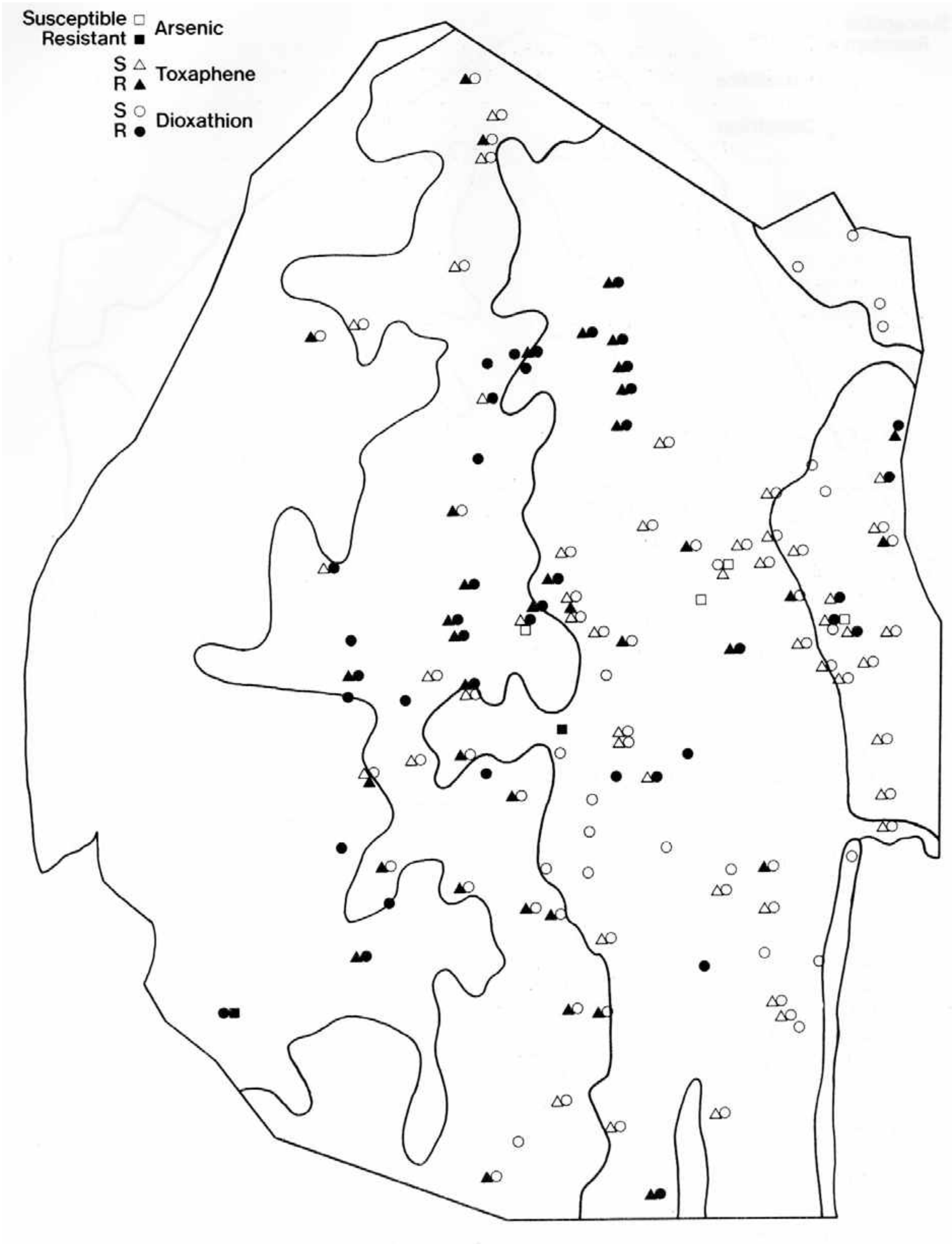
Table 9**:** Results of Disnis® Dip Samples Tested in the Period 1/4/8S TO 31/3/86

	Number of samples	**%of samples**
Understrength	290	6S.8
Over-strength	44	10
Correct strength	107	24.2
Total	**441**	**100**

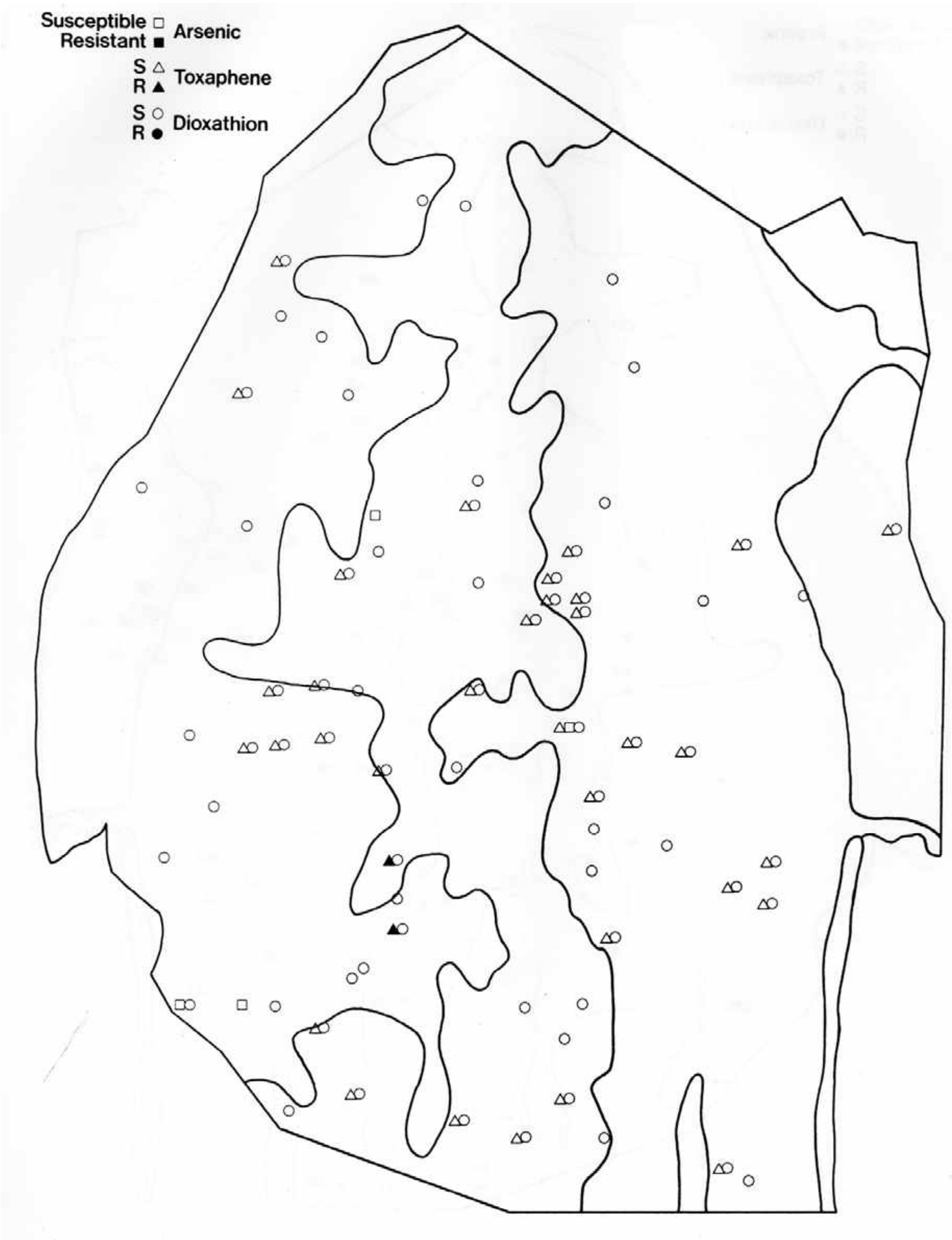
Table 10: Acaricides in use in Swaziland- June 1980's

Chemical group	**Trade name**	**Number of tanks**	**%of tanks**
Amidine	Triatix	272	40.2
Organophosphate	Disnis+	258	38.2
Organophosphate	Bacdip	50	7.4
Organophosphate	Supamix	5	0.7
Organophosphate	Supona	3	0.4
Organophosphate	Bovitik	22	0.3
Organophosphate	Delnav	2	0.3
Arsenical	Sodium	44	6.5
Pyrethroid	Sumitik	16	2.4
Pyrethroid	Ektoban ‡	14	2.1
Pyrethroid	Bayticol	5	0.7
Pyrethroid	Libriekto	3	0.4
Pyrethroid	Decatix	2	0.3
Total		**676**	**99.9**

+Disnis also contains an organochlorine component
‡ Ektoban also contains an amidine component

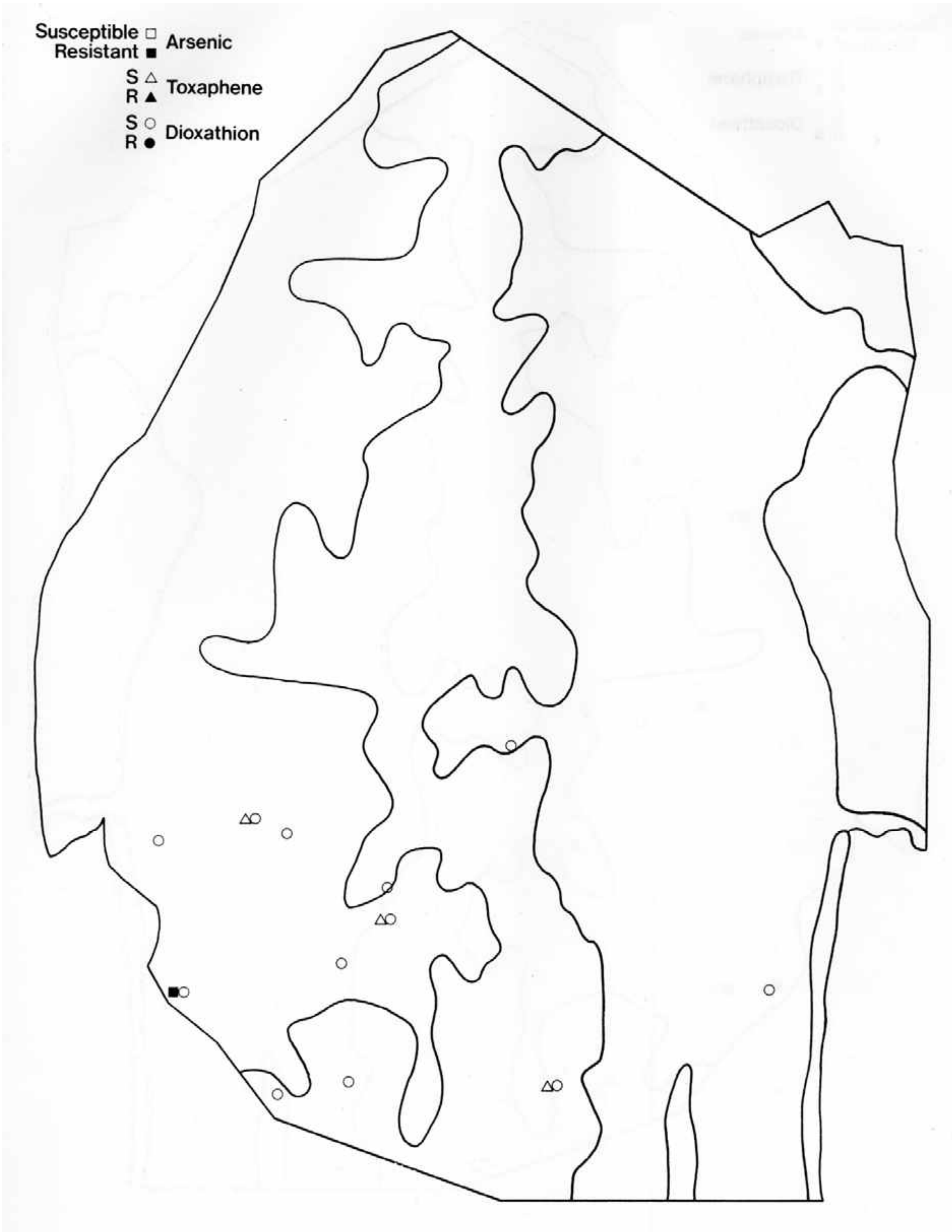


Map 7: Susceptibility to Acaricides of *Amblyomma hebraeum* Ticks in Swaziland

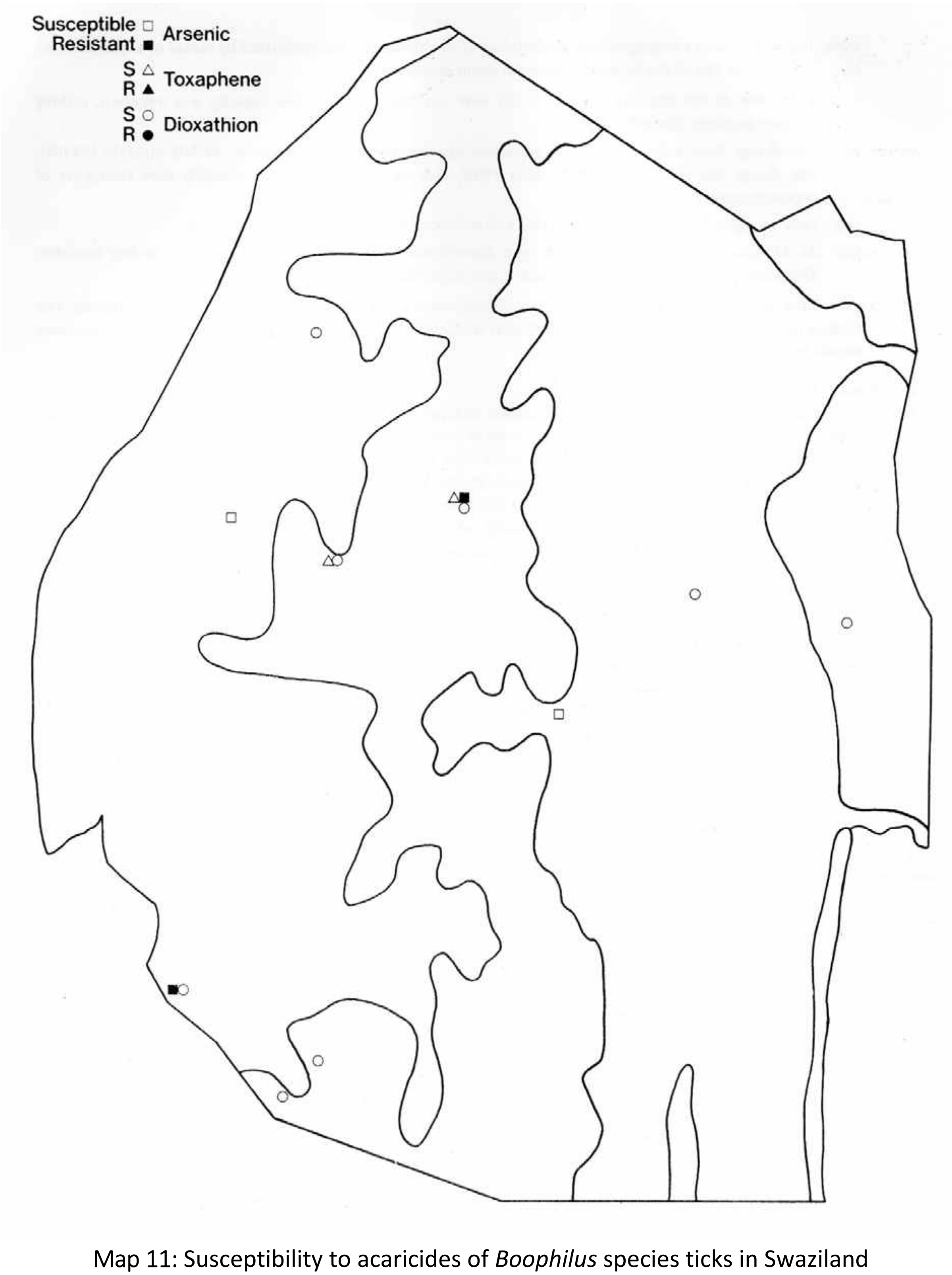


Map 8: Susceptibility to acaricides of *Rhipicephalus evertsi evertsi* ticks in Swaziland

Map 9: Susceptibility to acaricides of *Rhipicephalus appendiculatus* ticks in Swaziland



Map 10: Susceptibility to acaricides of *Hyalomma* species ticks in Swaziland



Map 11: Susceptibility to acaricides of *Boophilus* species ticks in Swaziland

4.2 Tick Susceptibility to Acaricides

Individual acaricides can be broadly classified into larger groups. Of these arsenic, organochlorines, organophosphates, amidines and pyrethroids were all in use in Swaziland at the time of the survey (Table 10). Experience has shown that, given sufficiently high selection pressures, strains of ticks will emerge which are resistant to the acaricides used to control them. In Swaziland short dipping intervals are enforced by legislation but mismanagement, as mentioned previously, of dip concentrations may encourage resistance development. Where many different acaricides are used, as in Swaziland, selection for resistance in the tick population could be continuing for several different types of acaricide simultaneously.

Resistance, once established, persists and accumulates. This has been demonstrated in Southern Africa for arsenic, organochlorines, DDT and the organophosphates. Once an acaricide is discarded due to failure of control it cannot be returned to. Further, cross resistance occurs within groups e.g. organophosphates and organochlorines. It also occurs between groups; Whitehead (1959) demonstrated cross resistance between DDT and naturally occurring pyrethrum. This has extended to the newly developed synthetic pyrethroid compounds. Resistance in a tick population is pre-existing at a very low level and increases in response to selection pressure. Once established in a population it is spread mainly through cattle movement and communal grazing. This demonstrates the importance of quarantining areas where dipping has stopped or where tick control has broken down.

In Swaziland, and in Southern Africa in general, resistance has been slower to arise than in Australia. This is due to the presence of two and three host ticks which develop resistance less quickly than one host ticks such as *B. decoloratus* and *B. microplus*. In addition, short interval dipping, necessary to control multihost ticks, has delayed the emergence of resistant strains in the tick population.

4.3 Discussion of Results

The significance of the results. Laboratory testing of tick samples forms only part of an investigation into the failure of tick control. Normally such an investigation would include checking equipment, taking and testing a dip sample for strength, examining cattle before and after dipping and conducting small scale field trials where necessary. Laboratory tests are however invaluable in performing a survey of tick resistance due to the low cost and rapid results, when compared to in vivo methods such as tests on infested cattle. The Coopers Research Station at Kwanyanga have been performing larval immersion tests for many years both for product development and as a service, for resistance detection, to farmers and veterinarians. Reference data for susceptible tick populations is readily available, operator efficiency is ensured, and experience in interpreting results is available. The use of larval ticks produces a uniform sample for rapid testing where the response, death or inability to walk, is easily measured.

In the interpretation of the results the LC_{50} values have been used as they are normally more precise than the LC_{99} values although the latter give more clear indications of the heterogenicity of the response of the population to the chemical. It is felt that the survey results do demonstrate whether or not tick resistance to acaricides of the arsenical, organochlorine and organophosphate groups is a problem in Swaziland.

4.3.1 Arsenic.

Resistance to arsenic by *B. decoloratus* was first observed in Swaziland in 1947. In 1975 Matthewson published work showing resistance to arsenic in the multihost ticks *R. evertsi evertsi*, *A. hebraeum* and *R. appendiculatus* in Swaziland. The actual mechanism of resistance is unclear but is specific to arsenic. Previous survey results in Swaziland identified arsenic resistance in A. hebraeum, *R. evertsi evertsi*, *R. appendiculatus* and *Boophilus* sp. The present survey confirmed resistance in *A. hebraeum*, *R. appendiculatus* and *Boophilus* sp. and also demonstrated arsenic resistance in one strain of *Hyalomma* sp. tick. The use of arsenic when modern, more effective acaricides are available is not satisfactory. A government ban on its purchase and distribution in March 1986 should lead to its total withdrawal.

4.3.2 Organochlorines.

Resistance by *B. decoloratus* to yB.H.C. was recognised in Swaziland in 1949 - only 3 years after its introduction. Cross resistance occurred with the other organochlorines i.e. dieldrin and toxaphene (introduced in 1952). Organochlorine resistance was demonstrated in South Africa to *B. decoloratus* (1952), *R. evertsi evertsi* (1961) and *R. appendiculatus* (1965). In 1977 Baker published work showing resistance to toxaphene by A. hebraeum in Swaziland. Again the mechanism of resistance is not known. Previous survey results in Swaziland indicated resistance to toxaphene by *A. hebraeum*, *R. evertsi evertsi*, *R. appendiculatus* and *Boophilus* sp. The present survey, performed on a larger number of samples, confirmed resistance in *A. hebraeum*, *R. evertsi evertsi*, and *R. appendiculatus*. Toxaphene is present with an organophosphate, chlorfenvinphos, in the dip Disnis® which was in common usage at the time of the survey. The efficacy of the organochlorine component must be in some doubt on those properties where there is resistance. This dip chemical has since been removed from the market.

4.3.3 Organophosphates.

In 1967, *B. decoloratus* ticks were shown to have developed organophosphate resistance in Berlin near East London. In 1978 Baker published work including an account of organophosphate resistance in *A. hebraeum* ticks on the Bar R Ranch in Swaziland. Resistance to organophosphate acaricides arises through a decrease in the sensitivity of tick acetylcholin- esterase enzyme to these inhibitors. An increase in detoxification can also occur. Development of resistance to one organophosphate does not mean that all organophosphates will also become ineffective and resistance can often be overcome by a change within the group. The previous survey results in Swaziland demonstrated organophosphate resistance in *A. hebraeum* and *Boophilus* sp. ticks only. The present survey confirmed resistance in strains of *A. hebraeum* whilst failing to demonstrate resistance in other tick species. The present survey tested for resistance to Dioxathion but it must be remembered that *A. hebraeum* strains resistant to dioxathion may still be susceptible to other organophosphate compounds. The survey does however indicate that a potential problem exists and where organophosphate acaricides fail to control tick populations, especially *A. hebraeum*, a change to an acaricide which is chemically unrelated would be advised. There is at present not enough evidence to recommend the withdrawal of organophosphate acaricides in Swaziland.

4.4 Future Tick Control in Swaziland

In the immediate future chemical control will remain the most important method of tick control

(I) Amidines especially amitraz (Triatix®) have advantages over organophosphate compounds. They can be easier to maintain at the correct concentration, offer greater residual activity and are, in Africa, free of resistance problems. (In February 1980 field resistance was confirmed in *B. microplus* ticks in Queensland, Australia). When resistance does arise in B. decoloratus it may be possible to use amidines in combination with other new acaricides.

(II) Synthetic pyrethroids unfortunately do show cross resistance with DDT resistant strains of ticks. This can be overcome by increasing the concentration two or threefold or by using an organophosphate as a synergist (the organophosphate acts by inhibiting the enzyme responsible for pyrethroid detoxification).

In the future more use may be made of chemicals to modify tick behaviour (e.g. repellents or pheromones), pyrethroid impregnated ear tags, slow release implants (e.g. ivermectin), predators, more resistant cattle strains and vaccines to increase host resistance. In the meantime acaricides should be looked upon as an expensive, essential non-renewable resource and their efficacy should be maintained by continued short interval, high intensity dipping with careful management. Acaricides should not be changed until it is essential to do so in order to maintain tick control.

5. Acknowledgements

Our thanks go to Dr. D.A. Davis and the staff of Kwanyanga Research Station, Coopers (South Africa) (Pty) Limited, Greenfields, East London, R.S.A., for the time and effort they devoted to testing tick samples from Swaziland .

Thanks also to Dr. Jane Walker of Onderstepoort Veterinary Research Institute, Pretoria for her help in identifying tick species and to Dr. M.D. Matthewson of Coopers Animal Health Ltd., Berkhamsted, England, for his help in interpreting the data and advice on the manuscript.

We would also like to acknowledge with thanks the assistance provided by staff of the Swaziland veterinary services and the support of the Chief Veterinary Officer, Swaziland, Dr. N. Gumede.

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Project 2: The Distribution of *Boophilus* Species Ticks in Swaziland

1. Introduction

Boophilus decoloratus, the African blue tick, is indigenous to Africa and probably parasitized wild ungulates before developing a taste for domestic cattle. *B. microplus*, the pantropical blue tick, is not and was probably introduced to south and east Africa on cattle imported from Asia via Madagascar. A 1940 survey of ticks in Swaziland reported the presence of the former but not the latter species, despite its existence in neighbouring Portuguese East Africa, now Mozambique. As recently as 1978 B. microplus had not been found in tick collections ma.de for the ongoing tick resistance survey in Swaziland. Both species act as vectors for the agents of gallsickness and redwater in cattle. However, whilst *B. decoloratus* transmits *Babesia bigemina*, the protozoon parasite responsible for African redwater, *B. microplus* also transmits *Babesia bovis*, the organism responsible for Asiatic redwater. Recent outbreaks of Asiatic redwater in Swaziland had provided indirect evidence of the presence of *B. microplus* and it was decided to map the distribution of the two species using samples collected for the tick resistance survey.

2. Materials and Methods

2.1 Collection of Ticks

Engorged female *Boophilus* ticks were included in field collections made for the tick resistance survey.
Initially only low numbers were received compared to other species and this was attributed to:

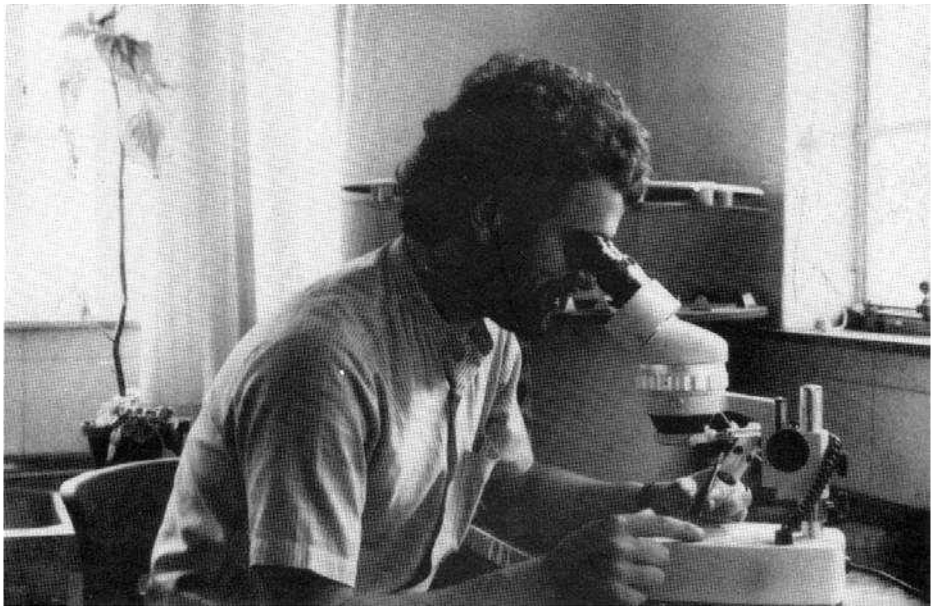
(I) The use of improved acaricides and short summer dipping intervals had considerably reduced the population of Boophilus ticks. Boophilus ticks are one host ticks spending about three weeks on the host animal. This makes them much easier to control than e.g. *Amblyomma* ticks, three host ticks, the adults of which may be on the host animal for less than a week.

(II) The attachment sites of Boophilus ticks on the neck, dewlap and underline made them difficult to collect from unrestrained animals compared to e.g. *Rhipicephalus appendiculatus* which attaches around the ears.

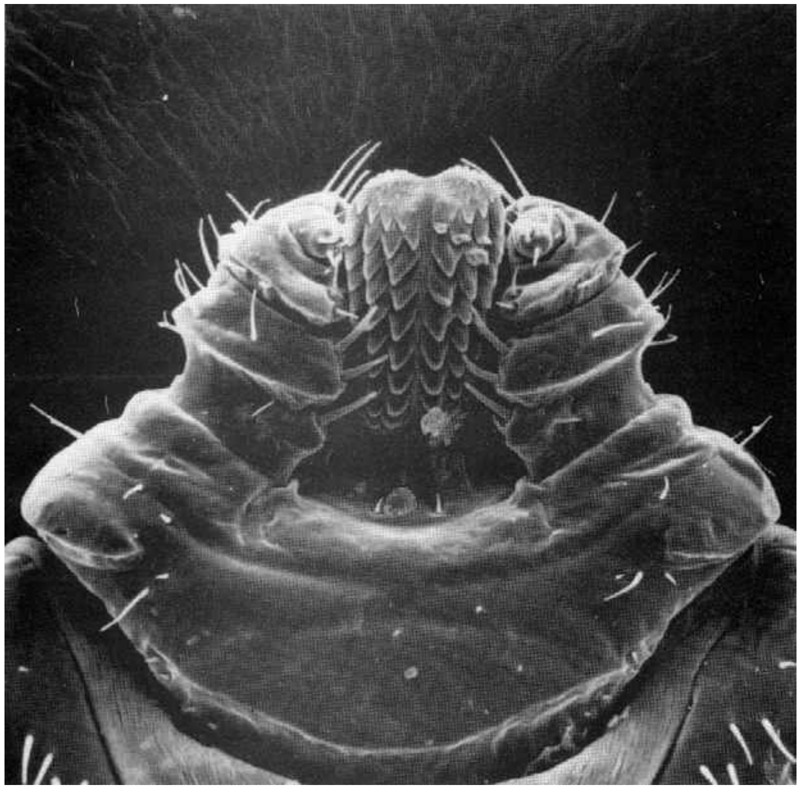
A fact sheet was produced for Veterinary Assistants who were encouraged to cast cattle in order to collect *Boophilus* ticks. Special collections were made from dip-tanks where *Boophilus* ticks were most prevalent i.e. where sodium arsenite was still used or where dipping had been suspended.

2.2 Identification

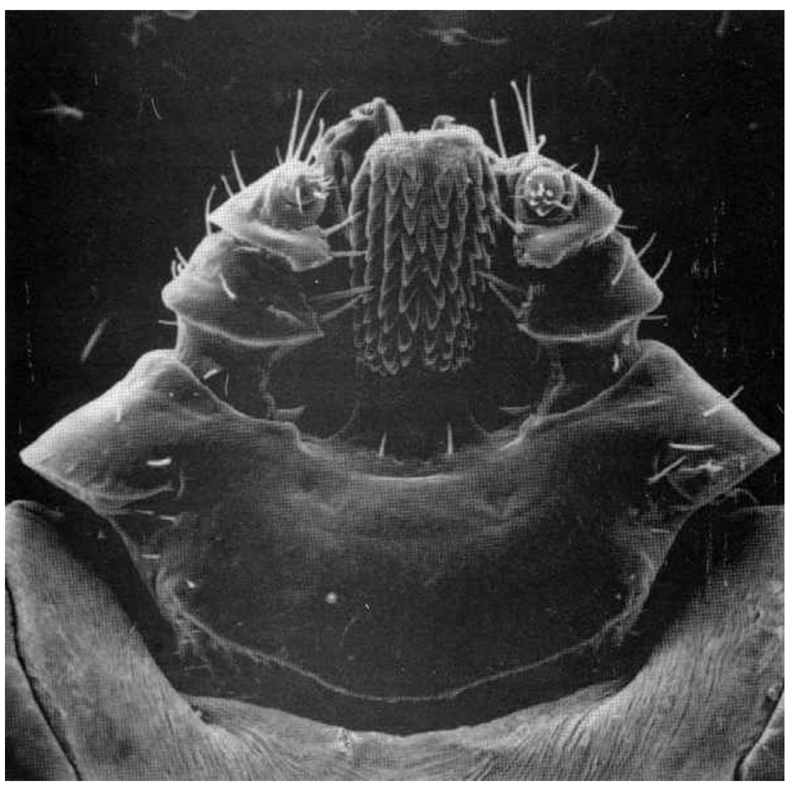
Ticks of the *Boophilus* genus were identified on gross examination and then further examined under a x45 stereobinocular microscope in order to distinguish between the two species. The differentiating features are illustrated in the following scanning electron micrographs.



Differentiation of *Boophilus* species of ticks using a stereobinocular microscope



Scanning electron micrograph of the mouthparts of *Boophilus decoloratus*. Note three vertical rows of teeth on each side of the hypostome and the convex protruberances with setae on the medial aspects of the first palpal segments



Scanning electron micrograph of the mouthparts of *Boophilus microplus*. Note four vertical rows of teeth on each side of the hypostome and the concavity of the medial aspects of the first palpal segments

A number of *Boophilus* ticks could not be differentiated into species due to tissue obscuring the mouthparts, damage to the dentition or detachment of the mouthparts during collection.

3. Results

Species	Number of dip-tank areas from which recovered
B. decoloratus	58
B. microplus	8
Unidentified Boophilus ticks	9
Total	75

(Mean sample size 32 ticks, range 1 to 207 ticks)

The distribution of *Boophilus* ticks in Swaziland is shown in Map 12.

4. Discussion

The results show a widespread distribution, of *B. decoloratus* with a patchy distribution of *B. microplus*. Workers in South Africa have suggested that where these two species occur together there will be interspecific competition. Further it appears that B. decoloratus is being replaced by *B. microplus* in some areas (Spickett and Malan, 1978). *B. microplus* should be considered as the invading species in Swaziland accounting for mixed infestations, whilst *B. decoloratus* is the long established species still occurring alone in many areas (Spickett, personal communication.) Factors which could affect this interspecific competition include climate, reproductive potential and resistance to acaricides.

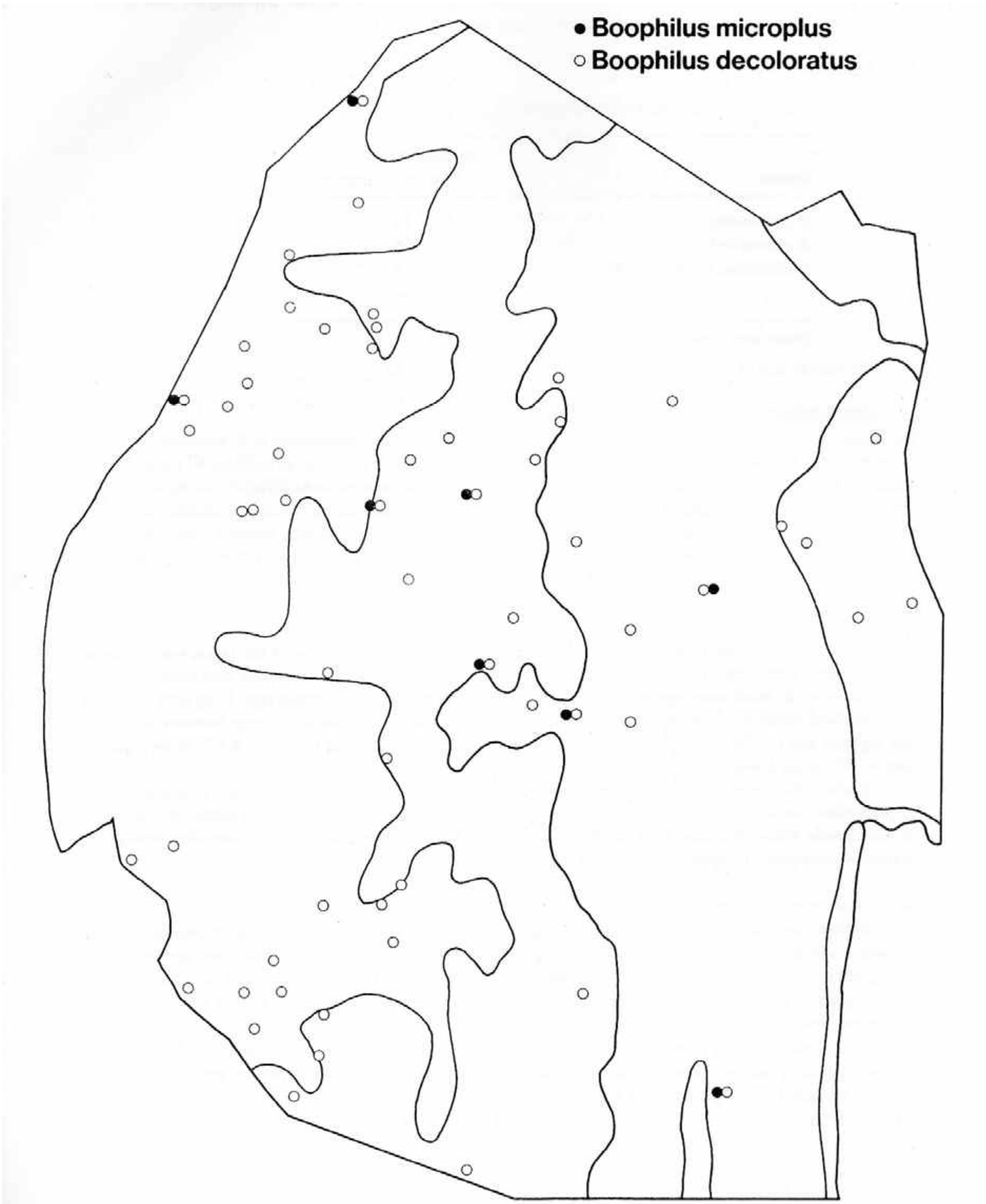
4.1 Climate

Gothe (1967) found a significant difference in cold tolerance between larvae of the two species i.e. some *B. decoloratus* larvae could survive at -10°C for 24 hours whilst *B. microplus* larvae could only tolerate o0c for up to 72 hours. B. decoloratus eggs were slightly more cold resistant than *B. microplus* eggs. Long term data from the Swaziland Ministry of Natural Resources shows mean minimum temperatures to range between 10.8°C in the highveld and 14.3°C in the lowveld. Absolute minimum temperatures range between -8.4°C in the highveld and -o.s0c in the lowveld.

Gothe (1967) considered that winter conditions in South Africa would influence the spread and survival of *B. microplus,* the larvae of which are exceptionally susceptible to cold whilst it would not restrict the spread of *B. decoloratus* although it may limit numbers and activity. He considered that decreasing humidity would play a more important role in limiting the spread of *B. decoloratus*.

4.2 Reproductive Potential

Spickett and Malan (1978) reported cross-mating's between the two species to be sterile. *B. microplus* males showed a slightly greater, though statistically insignificant, mating capacity. Females of the two species showed no significant difference in oviposition potential. They concluded that the replacement of B. decoloratus by *B. microplus* in some areas must be due to factors other than reproductive capacity such as adaptation to environment, development of resistance to ixodicides and favourable weather conditions. Unpublished work by Norval and Sutherst shows only 10 per cent hybridisation under natural mating conditions, indicating mating preference for their own species or assortative mating (Spickett, personal communication). Sutherst further demonstrates that in the presence of assortative mating, *B. microplus* with its higher reproductive potential is able to displace *B. decoloratus* over a long period of time. This assumption obviously contradicts the work of Spickett and Malan.



Map 12: Distribution of *Boophilus* ticks in Swaziland

4.3 Resistance to Acaricides

Baker et *al* (1978) studied the ixodicidal resistance of *B. decoloratus* and *B. microplus* ticks in collections from the eastern coastal regions of South Africa and the Transkei. They concluded that, apart from arsenic, *B. microplus* was the most susceptible of the two species to ixodicides. They noted that this had not stopped the spread of *B. microplus* into new areas and its consolidation in others. Evidence was found in Swaziland of contiguous spread between dip-tank areas. Many cattle died in an outbreak of redwater at the Zombodze dip-tank in the Manzini district despite the regular use of Triatix TRR (amitraz) The infection was thought to have spread from the neighbouring quarantined dip-tank Mampondweni, a site from which both *B. decoloratus* and *B. microplus* were recovered on two separate occasions. Presumably, ticks were picked up from communal grazing areas by the Zombodze cattle. Given that B. microplus was recovered mainly from tank areas where arsenite was used or where dipping had broken down it would seem that effective dipping and strict quarantine of areas where dipping has stopped could help limit the spread of the tick and therefore Asiatic redwater. Where grazing is shared between neighbouring communities, the danger of contiguous spread between dip-tank areas should be considered.

It remains to be seen if *B. microplus* will establish itself in Swaziland at the cost of *B. decoloratus* or whether natural conditions and effective, intensive dipping can control its spread.

5. Acknowledgements

We wish to thank all those responsible for collecting material for the tick resistance survey. Our special thanks go to Dr. Jane Walker of Onderstepoort Veterinary Research Institute, Pretoria and Dr. A. Walker of the CTVM, Edinburgh, for their help in differentiating the two *Boophilus* species. We would also like to thank Heloise Heyne of the Department of Entomology, Onderstepoort Veterinary Research Institute, for the permission to use her excellent scanning electron micrographs of *Boophilus* tick mouth parts. Dr. A.M. Spickettt, also of Onderstepoort Veterinary Research Institute, provided invaluable insight into the interpretation of our results.

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Project 3: A Serological Survey of Tick-borne Diseases of Cattle in Swaziland

1. Introduction

One of the main aims of the expedition was to carry out a serological survey of tick borne diseases (TBDs) in Swaziland. It had been estimated that TBDs may have been causing up to 50 per cent of cattle mortality during the summer months in Swaziland. However, the exact situation was not clear, partly because only a very small proportion of cattle deaths were submitted to the veterinary laboratory for a full post mortem, and partly because of problems in collecting accurate and detailed data about cattle diseases and deaths from inaccessible rural areas. A serological survey had never before been undertaken in Swaziland, and was considered to be essential for obtaining a clearer picture of the TBD situation .

1.1 Diseases Studied

The serological survey studied the most important TBDs in Swaziland, which are listed below.

African redwater, caused by *Babesia bigemina*
Asiatic redwater, caused by *Babesia bovis*
Heartwater, caused by *Cowdria ruminantium*
Gallsickness, or anaplasmosis, caused by *Anaplasma marginale*.

The purpose of the survey was to determine the presence or absence of antibodies to each of the above disease agents in sera collected from young cattle all over Swaziland.

1.2 Antibodies as indicators of the Prevalence of Disease

If antibodies to a disease agent are found in serum collected from an animal, this indicates that the animal has been previously exposed to that disease agent. Thus, by measuring the proportion of animals which possess antibodies to a particular disease, a close approximation can be obtained of the prevalence of that disease. To obtain the most current assessment of the disease situation, it is important to analyse only sera collected from young animals. Thus, in this survey, only cattle aged between one and three years were sampled. The presence of antibodies in these sera gave a reliable indication that the disease agent had been in the area within the past three years. In sera from older animals, any antibodies present could be the result of exposure of the animal to the disease agent at any time during the animal's life, i.e. possibly many years previously.

1.3 Antibodies as Indicators of the Immune Status of Animals.

Antibodies are not merely useful indicators as to whether or not an animal has been exposed to a disease. Their function in the animal is to provide protection against the disease concerned by forming an important part of the body's defences. Thus, as well as indicating the prevalence of a disease agent, the proportion of animals in an area which possess antibodies gives a reliable guide to the proportion of animals which are immune to that disease. This can be invaluable information when planning control of TBDs.

1.4 Enzootic Stability

If a high proportion of cattle in an area have antibodies to a tick borne disease, this indicates that most cattle have been infected and are immune to that disease. Few clinical cases of the disease are seen, and there is a low mortality rate. This situation is described as "enzootic stability". Enzootic stability arises in areas where cattle ticks are not controlled, resulting in constant spread of the causative agents of TBDs from animal to animal. In an enzootically stable area, calves are infected with the disease agent at an early age. Fortunately, young cattle are not seriously affected by TBDs, for two reasons:-

(I) Antibodies passed to the calf from its mother protect the calf against many TBDs for approximately the first two months of life.

(II) Calves possess an "innate resistance" to TBDs, the mechanism of which is not fully understood. However, this resistance is not related to antibodies, and it lasts up to around nine months of age (although there is considerable variation between different animals and for the different tick borne diseases).

In an area of enzootic stability, young cattle are first exposed to TBDs while they are still resistant to the disease. They therefore show no obvious signs of disease, but antibodies are still produced. These antibodies protect the animals as they grow older and lose their innate resistance. Subsequently, the tick population in the area ensures that cattle are frequently re-exposed to the disease agent, periodically boosting antibody levels. Thus, immunity to the disease is maintained throughout the animal's life.

1.5 Significance of Immune Status to Cattle Movement

Areas of enzootic stability (with an immune cattle population) may exist within a short distance of areas of instability (where the cattle population is highly susceptible to disease). Movement of cattle from one area to another can therefore cause considerable disease problems.

1.5.1 Susceptible cattle moving into areas where enzootic stability exists. Problems are encountered when cattle are brought in from areas where ticks are well controlled to enzootically stable areas where there is a high tick population. These cattle have no previous exposure to TBDs, and so have no protective antibodies. They are therefore extremely susceptible to TBDs, and a very high mortality rate is seen.

1.5.2 Cattle moving from enzootically stable areas into populations of susceptible cattle. An animal in an area of enzootic stability is likely to carry a substantial tick burden. When such an animal moves into another area, a proportion of the ticks detach from the original host and may re-attach to cattle in the new area thus putting them at risk to TBDs.

1.6 Aims of the Serological Survey

Using the results of the serological survey, it was hoped to achieve two main objectives

(I) To obtain a national picture of the prevalence of TBDs in Swaziland

(II) To identify areas of enzootic stability to each TBD.

2. Materials and Methods

2.1 Sera Collections

It was intended to collect blood samples from cattle in a number of different locations spaced evenly apart, and to achieve as broad as possible coverage of the whole country. Swaziland is divided into a patchwork of dip-tank areas. All cattle are dipped regularly at their local dip- tank. It seemed logical to collect blood samples from cattle as they were brought together to this local centre to be dipped.

Veterinary Assistants (VAs) supervise dipping at each dip-tank. The VAs from each sub-district assemble every Friday at the local veterinary office for a weekly meeting with their colleagues and immediate superiors. This meeting was attended by team members on the Friday before it was intended to visit the dip-tanks of an area. Lengthy discussions were held with the local VAs, explaining the aims of the serological survey and then arranging dip-tanks to be visited during the following week. Directions for finding dip-tanks often had to be given in some detail, because they were often located far from any main road or any major landmarks. Particular disease problems were discussed with the VAs, and attempts were made to visit, when possible, individual dip-tanks where serious problems existed.

Cattle in Swaziland are dipped at sunrise, to avoid stressing the animals in the oppressive heat of the day. Cattle are usually herded to the dip-tank in darkness, and dipping commences as soon as there is sufficient day-light. When collecting blood samples, it was necessary to arrive at the dip-tank at the same time as the cattle. This allowed a few minutes before dipping started for discussion with the local farmers, to explain to them the reasons for blood sampling their cattle.

The dip-tanks were often a three or four hour drive away from the team's home base, and so to reach them before dawn, it was frequently necessary to set off from home literally in the middle of the night. The usual departure time was 4.00 a.m. but on one particularly memorable occasion the alarm clocks rang at 1.00 a.m. Midday siestas became essential to the team's continuing health and sanity! When visiting the more remote dip-tanks, whenever possible, overnight accommodation was found in the immediate vicinity of the tanks, to minimise early morning travelling time. When visiting several dip-tanks on different days in a remote area, the team stayed in some isolated locations for up to a week at a stretch, to minimise travelling time and to cut fuel costs.

Cattle are only dipped on four days of the week, from Monday to Thursday. Initially samples were only collected from one dip per day (i.e. four per week). However the team was soon joined by two Veterinary Assistants, Sipho Hlatshawyo and David Ngwenya. With their help, up to 14 dip-tanks per week were visited. A smaller number of additional sera were made with the help of other veterinary staff as follows:-

(I) Veterinary Field Staff. In some areas, the existing veterinary field staff collected blood samples from their local dip-tanks.

(II) Export abattoir. The veterinary surgeon at the EEC export abattoir collected several batches of sera from cattle which had been brought in for slaughter.

2.1.2 Number of cattle sampled. The aim was to collect blood samples from 30 cattle aged between one and three years at each tank using the criteria of Norval *et al*., (1983, 1984). One hundred and eighty six such "complete" collections were made. In addition, smaller collections were made from a further 30 dip-tanks. In total, 5,895 sera samples were collected from 216 dip-tanks.

2.1.3 Processing of Blood Samples for Storage. Blood samples were returned to the laboratory in Manzini as soon as possible after collection. They were then left standing for several hours to allow efficient clot formation. Blood clots were then extracted, and the sera centrifuged to remove any further cellular deposits. Finally, the sera were decanted into 2 ml polystop tubes, and stored in a deep freeze at -20°C.

2.1.4 Obtaining a Local History of Disease Problems. When visiting dip-tanks, an attempt was made to determine the recent history of disease outbreaks in each area, with the aid of questionnaires. Although useful information was obtained from some areas, in general it was extremely difficult to obtain an accurate assessment of specific disease problems. This was partly because in most rural areas, extensive veterinary investigation of disease outbreaks was not performed. Treatment was generally carried out by the local veterinary assistant on the strength of clinical signs only. In addition, in most areas, no formal written records of disease problems were kept. If there had been a change of local veterinary staff in the recent past, it was therefore very difficult to obtain any sort of accurate disease history.

2.2 Babesia Serology

The Indirect Fluorescent Antibody (IFA) test (Ross and Lohr, 1968) was used to screen sera for antibodies to *Babesia bigemina* and *B. bovis*. The test was performed in the veterinary laboratory in Manzini, Swaziland.

2.2.1 Preparation of Specific Antigen.

The specific antigen for the IFA test was produced with the help of the Onderstepoort Veterinary Research Institute. Splenectomised calves were infected with either *B. bigemina* or *B. bovis.* The blood concentration of *Babesia* parasites was monitored by examining blood smears four times daily. When the parasitaemia reached a concentration of 3-5 per cent, blood was collected for specific antigen preparation. Red blood cells were separated from the whole blood, washed, and re-suspended in a saline solution.

Multitest teflon coated microscope slides, each containing 15 wells, were used as antigen slides. A drop (±6J.Ll) of washed red blood cells were placed in each well. Since a proportion (3-5 per cent) of those blood cells contain Babesia parasites, each well was coated with a thin layer of Babesia antigen. These slides were air dried, wrapped in tissue paper, sealed in plastic bags and then stored at -20°C.

2.2.2 Test Procedure.

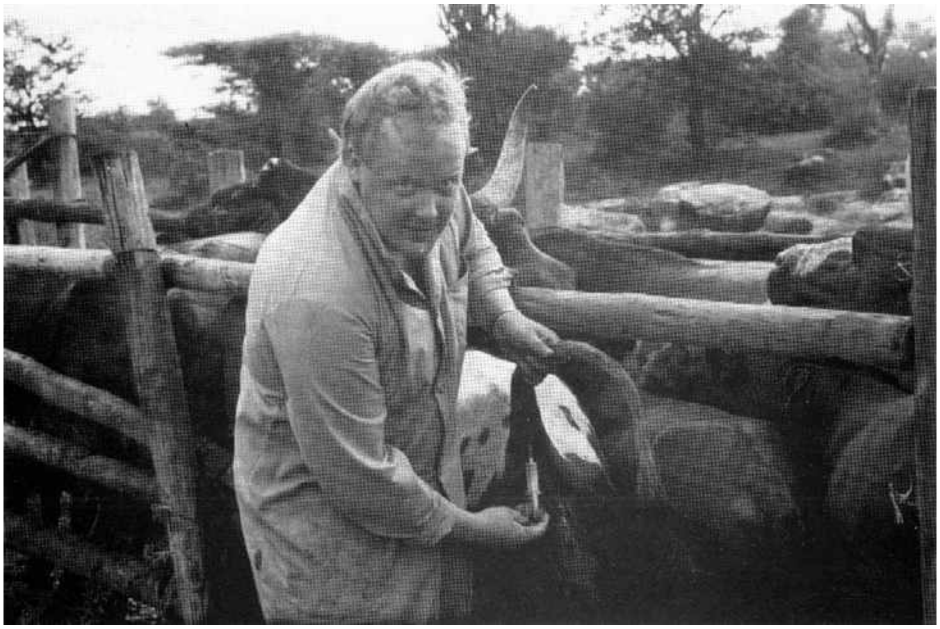
Antigen slides, immediately before use, were incubated at 37°C for 10 minutes and then fixed in cold acetone. The test sera, together with positive and negative control sera, were removed from the deep freeze and thawed out completely at room temperature. They were then diluted 1:80 in phosphate-buffered saline (PBS) and a drop of the resulting dilution was added to each well. On each 15 well slide, 13 test sera were examined, together with one positive and one negative control. The slides were incubated at 37°C for one hour (to allow antibody-antigen reactions to occur) and then the serum was washed off. If the test serum contained antibodies to the Babesia concerned, these would now be attached to the Babesia antigens which coated the wells. To visualise these antibody-antigen complexes, the slides were stained with a fluorescent conjugate (anti-bovine antiserum, conjugated with a fluorochrome). This fluorescent conjugate adhered to any bovine antibodies present. In the test, the only bovine antibodies present in each well would be those reacting with the *Babesia* antigen coating the well i.e. specific anti-Babesia antibodies . These were, therefore, “labelled" with the fluorescent conjugate. When each well was examined under a microscope with an ultraviolet light source, these antibodies (now linked to the fluorescent conjugate) were seen as bright points of fluorescence. In other words, if fluorescence was seen in a well, antibodies to that Babesia must be present in that test sera.

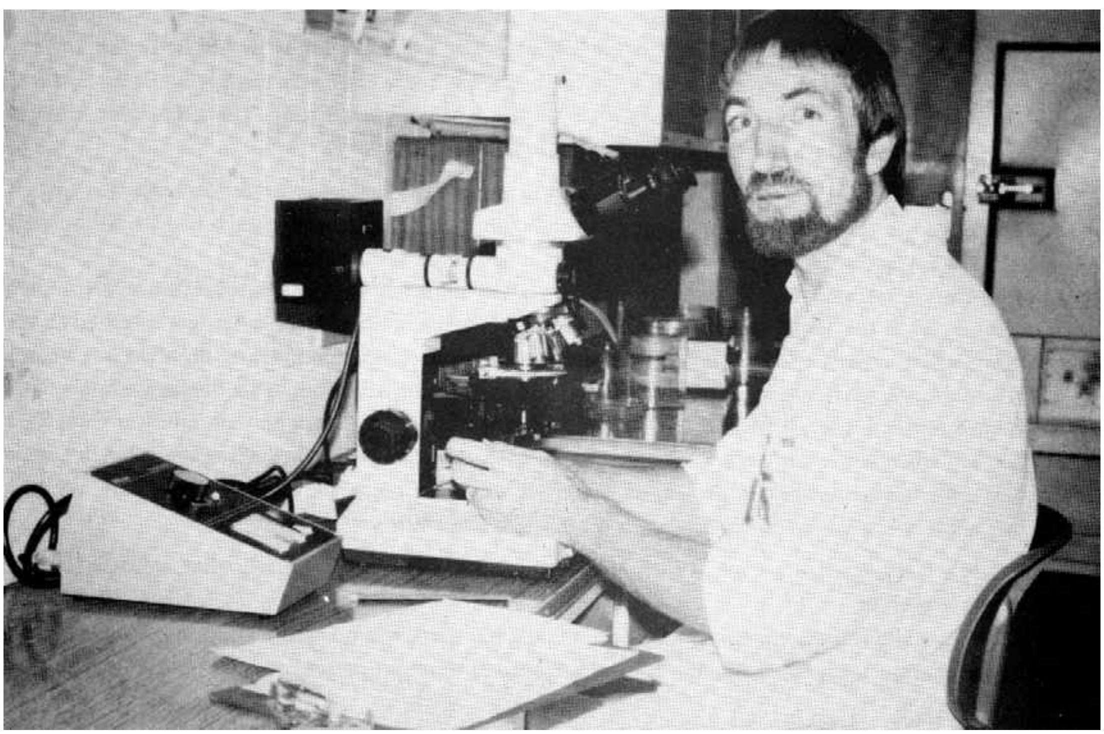
Sera could, in this way, be classified as positive or negative for antibodies to each *Babesia* parasite.

a) **Positive** - Bright fluorescence was seen in the well, indicating that specific antibodies were present (i.e. the animal had been exposed to the specific Babesia parasite in question).

b) **Negative** - Only dim, non-specific fluorescence was seen, indicating that no specific antibodies were present.

Using this technique, it was possible to screen many batches of sera to determine the relative numbers of positive and negative sera in each dip-tank area.


Tim collecting blood from the tail vein for the serological survey


Reading the IFA test using a fluorescent microscope

2.3 Heartwater serology

The Indirect Fluorescent Antibody (IFA) test was used to screen blood samples for antibodies to heartwater (Du Plessis, 1986). The principle of the IFA test is exactly the same as the IFA test used to screen antibodies to babesiosis. The test was performed in the veterinary laboratory in Manzini, Swaziland. *Cowdria ruminantium* itself cannot be isolated for use as an antigen in the same way as the *Babesia* parasites, because unlike the latter, *C. ruminantium* is only present transiently in the bloodstream of infected animals. The *babesia* parasitise red blood cells directly, whereas *C. ruminantium* colonises the endothelial cells of blood capillaries throughout the body. Whereas it is easy to harvest infected red blood cells as a supply of Babesia antigen, it is very difficult to collect infected capillary endothelial cells to use as a source of *C. ruminantium* antigen. Brain smears from artificially infected animals have been used as a source of antigen, but the results have not been satisfactory.

For the serological survey in Swaziland, the antigen for the IFA test was obtained by infecting mice with the Kuhm strain of heartwater, which was originally isolated from a goat. This unique strain of heartwater when artificially inoculated into mice, causes clinical signs resembling heartwater, and eventual death of the mice. (Most strains of heartwater cannot infect mice). The Kuhm strain of heartwater is morphologically indistinguishable from *C. ruminantium* and is immunologically very closely related. The Kuhm strain can be isolated from infected mice, in infected macrophage cells from the peritoneal cavity. It therefore serves as a convenient source of antigen for an IFA test for heartwater.

2.3.1 Preparation of specific antigen. To prepare the antigen for the IFA test, a batch of 6 week old mice were inoculated intraperitoneally with 0. 3ml of the Kuhm strain of heartwater. The mice were killed when the first clinical signs were seen (around 10 days after inoculation). Infected macrophage cells were then collected by flushing out the peritoneal cavity with a buffered saline solution. The harvested saline was centrifuged, and the deposit was washed several times, to obtain a suspension of infected cells. These cells were re-suspended in a buffered solution, and a drop was placed on each well of a 15 well multitest teflon coated slide. The slides were allowed to dry, wrapped in tissue paper and tin foil, and stored in liquid nitrogen at -200°C.

2.3 .2 Test procedure. The test itself was performed in exactly the same way as the Babesia IFA test. A drop of test serum diluted to 1 in 80 with phosphate buffered saline (PBS) was placed in each of 13 wells on each slide. Known positive and negative sera were added to the remaining 2 wells as controls. The test slides were incubated at 37°C for one hour (to allow antibody-antigen reactions to occur) and then the serum was washed off. If the serum contained antibodies to *C. ruminantium*, these were now attached to the Kuhm strain antigens which coated each well. To visualise these antibody-antigen complexes, the slide was stained with a fluorescent conjugate (anti-bovine antiserum conjugated with a fluorochrome). This conjugate adhered to any bovine antibodies present, and when each well was examined under a microscope with an ultraviolet light source, these "stained" antibodies were seen as bright points of fluorescence within the macrophages which coated the well. Since the only bovine antibodies present in each well would be those adhering to the specific antigen, sera could then be classified as positive or negative for antibodies to heartwater.

a) Positive - Bright fluorescence was seen within macrophages in the well, indicating that antibodies to *C. ruminantium* were present.

b) Negative - Nonspecific fluorescence was seen in some cells but there was no bright intra-cytoplasmic fluorescence within the macrophages i.e. antibodies to *C. ruminantium* were not present.

U.K. and the CA test was performed at the CTVM in Edinburgh.
Samples from 11 dip-tank areas were damaged in transit, and so these areas are omitted in the results.

2.4.1 Test procedure. Using the test kit capillary tubes and droppers, drops of test serum, stained Ana- plasma antigen and bovine serum factor (conglutinin) were mixed on a card. After rotation for four minutes, the test was read. Serum containing antibodies to A. marginale caused agglutination which was seen as visible clumping on the card. Negative sera did not produce such clumping.

3. Results

3.1 Babesiosis

The results are shown in the accompanying maps and histograms. The maps also show dip-tank areas where the different species of *Boophilus* ticks were identified (from Project 2).

3.1.1 B. *bigemina* (Map 13, Fig. 2). *B. bigemina* was found to be very widely spread throughout most of Swaziland. At over half of the localities sampled, more than 60 per cent of the cattle were positive serological reactors, at only 3 (1.6 per cent) of the dip-tank areas, there were no positive serological reactors identified. This correlated closely with the finding in Project 2 of widespread occurrence of *Boophilus decoloratus*, the tick principally involved with transmission of *B. bigemina*.

3.1.2 *B. bovis* (Map 14, Fig. 3). *B. bovis* was much less prevalent than *B. bigemina*, with only seven dip-tank areas (3.8 per cent) having more than 60 per cent positive reactors. Although *Boophilus microplus* (the vector tick of B. bovis) was not collected from all of these tanks, it was, in most cases, isolated at one of the surrounding dip-tanks (see Project 2). Thirty seven dip-tank areas (19.9 per cent) had no positive reactors in the sample group and 94 dip-tank areas (50.5 per cent) had a low number (1-20 per cent) of serological positives.

3.2 Heartwater

The results are shown in Map 15 and Fig. 4.

The map shows clear regional variation. Nearly all dip-tank in the lower lying Eastern three-quarters of the country had a large proportion of serologically positive animals (>60 per cent positive).
The higher lying areas of the Western one-quarter of Swaziland had a very low proportion of serological positives.
As expected, there was a very close correlation with the distribution of the vector tick, *A. hebraeum*.

3.3 Anaplasmosis

The results are shown on Map 16 and Fig. 5.
Only nine dip-tank areas (5.1 per cent) had no positive reactors, but 135 tank areas (73.2 per cent) had 20 per cent or less serologically positive animals. Eleven dip-tank areas (6.2 per cent) had between 41 and 80 per cent positive reactors, and no tank areas had more than 80 per cent serologically positive reactors.

4. Discussion

4.1 Babesiosis

African redwater, caused by *B. bigemina*, seems to be endemic throughout most of Swaziland. However, in 50 dip-tank areas, (26.9 per cent) there were only 40 per cent or less serologically positive animals. This would suggest that in these areas 60 per cent or more of the young adult population have had no previous exposure to African Redwater, and therefore no immunity. Therefore, significant morbidity would be expected in the event of *B. bigemina* being introduced to the area. These dip-tank areas with a lower proportion of positive reactors are evenly spread throughout most of the country, suggesting that they are not merely associated with regional or climatic factors limiting the spread of the vector tick, *B. decoloratus*. They are more likely to be associated with more effective control of the tick population in these areas, through more efficient dipping of cattle. The presence of such a large proportion of susceptible cattle in over one-quarter of the country's dip-tank areas would suggest enzootic stability for African Redwater does not exist in Swaziland as a country (although the situation of enzootic stability does exist at many individual dip-tanks).

Asiatic redwater, caused by *B. bovis*, is much less prevalent than African redwater. This is very closely related to the limited spread of the vector tick *B. microplus*, which is discussed in Project2. The high proportion (50.5 percent) of dip-tank areas with low numbers of serologically positive animals are probably associated with the extensive movement of cattle which occurs from area to area within Swaziland. It should be realised that although such dip-tank areas may not currently have a problem with Asiatic redwater, there is the potential for a serious problem. Serologically positive cattle are probably carriers of the Babesia parasite, and so if the vector tick *B. microplus* was to move into the area at any time in the future, there could be transmission of B. bovis from the small proportion of serological positives to the susceptible cattle population. The situation in Swaziland should be seen, therefore, as highly unstable, with the vast majority of dip-tank areas having highly susceptible cattle populations. However, small pockets of enzootic stability do exist at individual dip-tanks.

4.2 Heartwater

The widespread distribution of the vector for heartwater, *A. hebraeum*, throughout the lower altitudes indicated that there is only limited control of this species in Swaziland. In these areas, a high proportion of cattle serologically positive for heartwater were identified indicating effective transmission of *Cowdria ruminantium* throughout the cattle population. Enzootic stability could be said to exist in these areas, whereas in the higher lying areas found largely unsuitable for *A. hebraeum*, there were only a low number of serologically positive animals. At first it seems surprising to find any serological positives in areas *where A. hebraeum* is not found. However, this can be attributed to incoming movement of serologically positive cattle from lower lying areas. Such cattle movement occurs on a relatively large scale in Swaziland. The situation in these areas can be described as unstable, with a high proportion of the cattle population being very susceptible to heartwater. Serious disease outbreaks would therefore be expected when these susceptible cattle were moved from the higher lying areas to lower lying areas where heartwater is endemic. It would be essential in such a situation to take preventative measures against such an outbreak of disease.

In addition if cattle carrying tick burdens of *A. hebraeum* are moved to higher lying areas, they should be effectively dipped before any contact with the local population of cattle, to prevent the transmission of heart- water to these susceptible cattle via transfer of even low numbers of *A. hebraeum* ticks. *A. hebraeum* ticks cause physical damage to cattle, and in areas where the tick is widespread the tick population must be controlled to minimise the physical damage and the resulting economic loss. However, it is important to allow the continuing survival of sufficient ticks to ensure efficient transmission of heartwater to young cattle in order to maintain the enzootically stable situation in areas where it exists. It is difficult however to place precise limits on the exact number of ticks required to do this.

4.3 Anaplasmosis

The results show that there were very low numbers of serologically positive animals to anaplasmosis throughout most of Swaziland. This would indicate that an unstable situation for anaplasmosis existed in most of the country. There were individual dip-tanks with higher populations of serologically positive animals. It might be sensible to advocate care when moving susceptible cattle into these dip-tank areas. However, because of the uncertainties regarding transmission of anaplasmosis and the lack of any reported serious problem associated with anaplasmosis in Swaziland, it is difficult to draw any absolute conclusions from the results.

5. Acknowledgements

We would like to thank, first of all, Brendan MacCartan for his help, from the initial planning of the survey, to carrying out the Babesia and Heartwater IFA tests.

We would also like to thank Sipho Hlatshawyo and David Ngweny a for their invaluable assistance with the field work.

Thanks are also due to the staff at the Onderstepoort Veterinary Research Institute, especially Dr. F.T. Potgeiter and Dr. J .L. du Plessis for their help in setting up the Babesia and Heartwater IFA tests.

We are also grateful to Mr. A. Hunter and the staff of the CTVM for carrying out the anaplasmosis card agglutination test in Edinburgh.

Finally, we would like to express our gratitude to all of the field staff of the Veterinary Department in Swaziland for their help, and especially to the staff of the Central Veterinary Laboratory in Manzini for their enthusiastic assistance.

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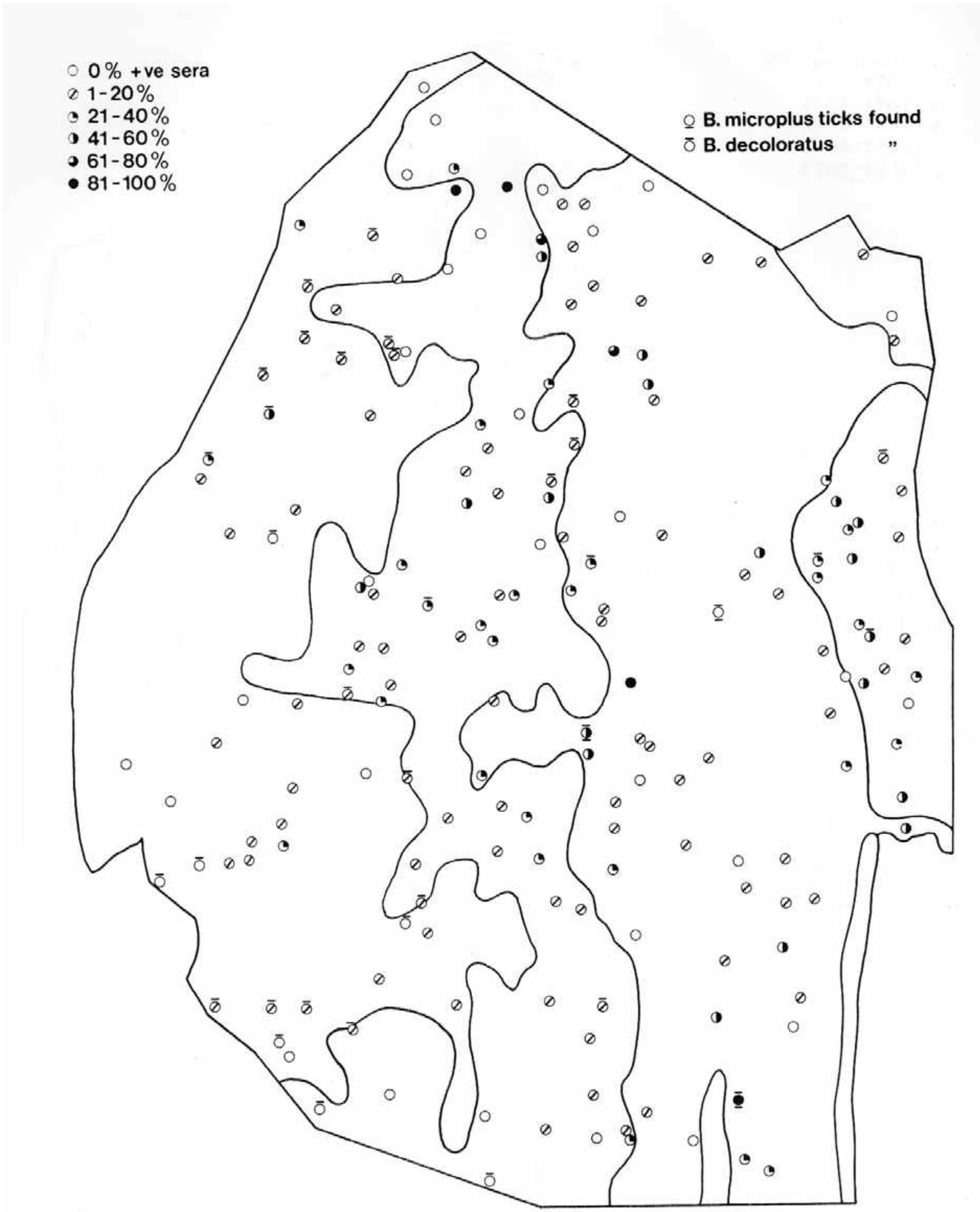
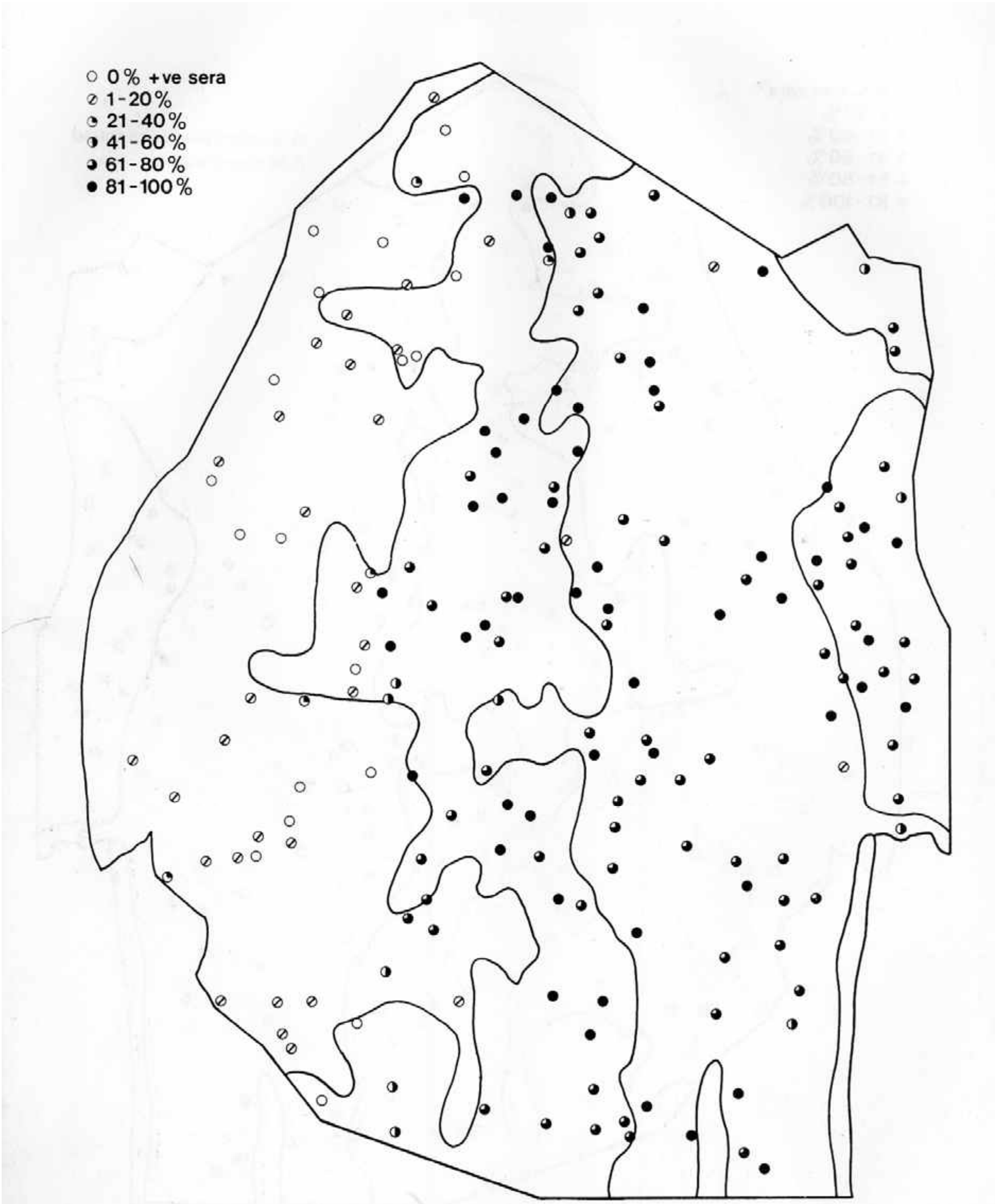
Map

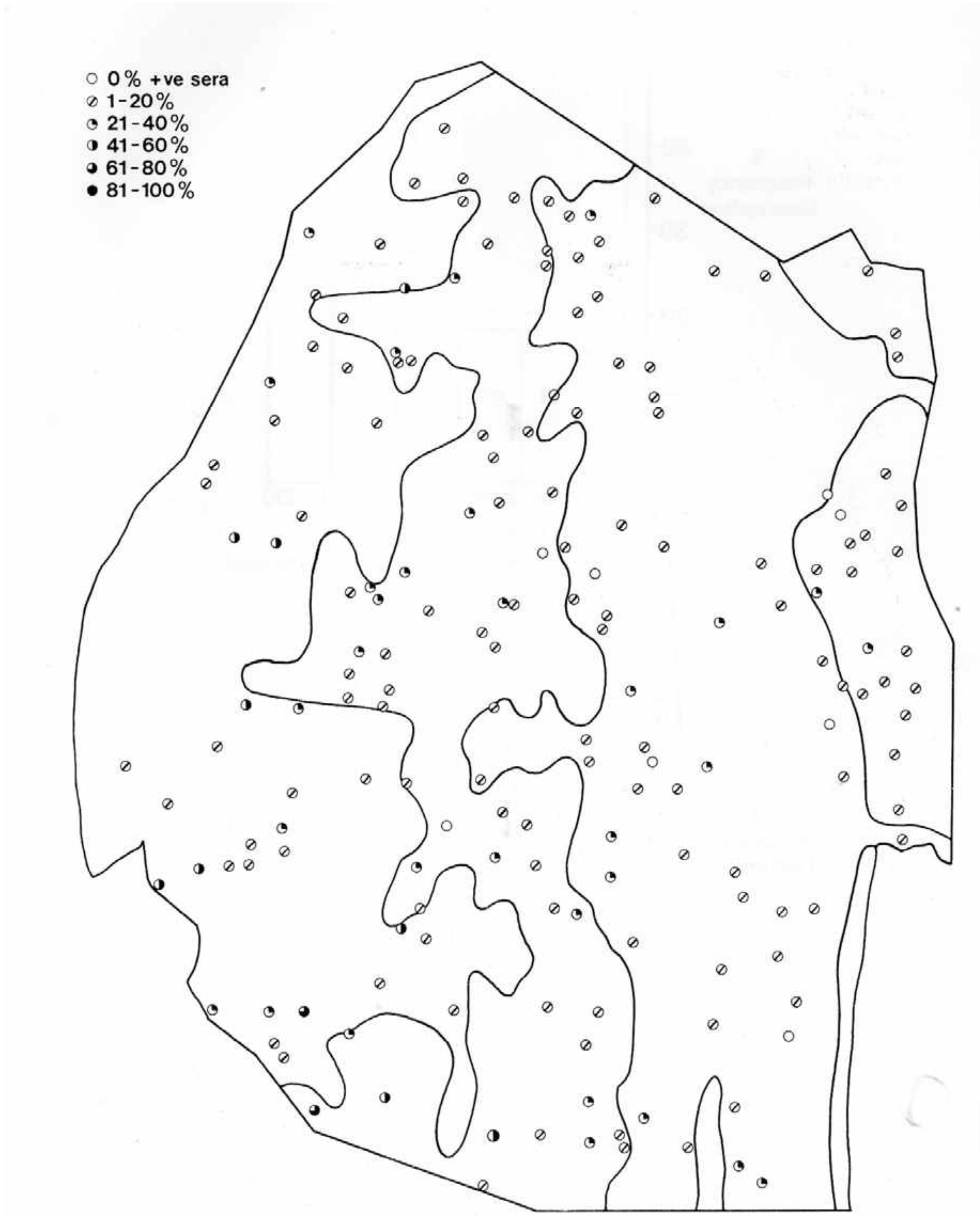
Map 13: Localities from which sera were tested showing epidemiological status of *B. bigemina* in Swaziland



Map 14: Localities from which sera were tested showing epidemiological status of *B. bovis* in Swaziland



Map 15: Localities from which sera were tested showing epidemiological status of *C. ruminantium* in Swaziland



Map 16: Localities from which sera were tested showing epidemiological status of *A. marginale* in Swaziland

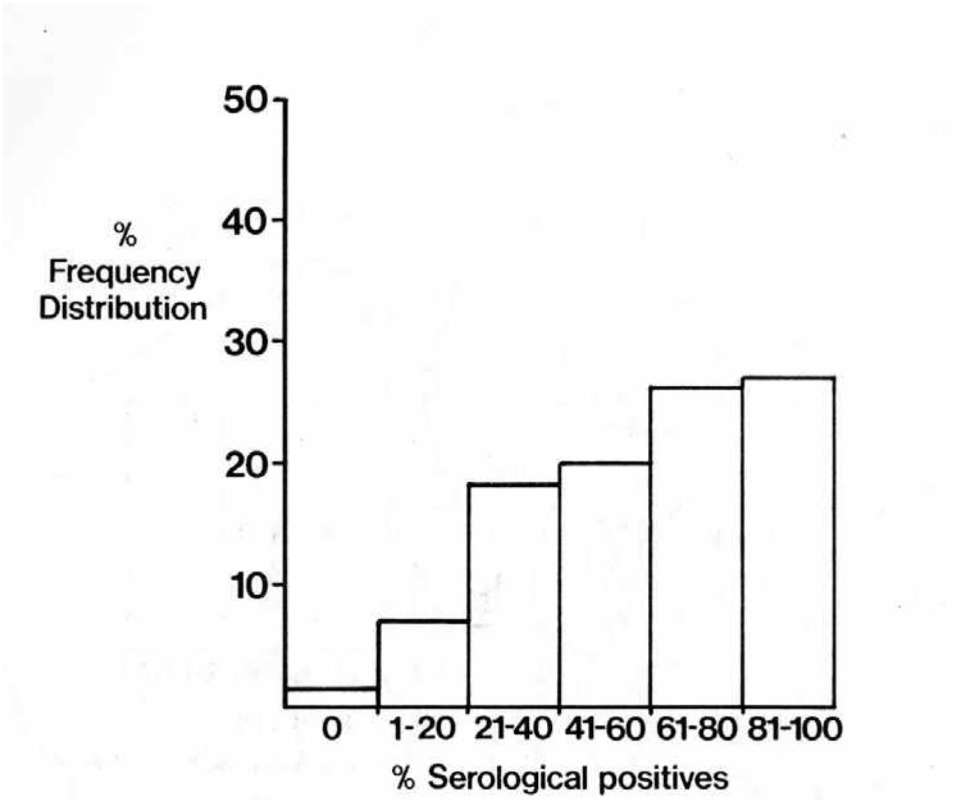


Figure 2: Occurrence of serological positives for *B. bigemina* in Swaziland

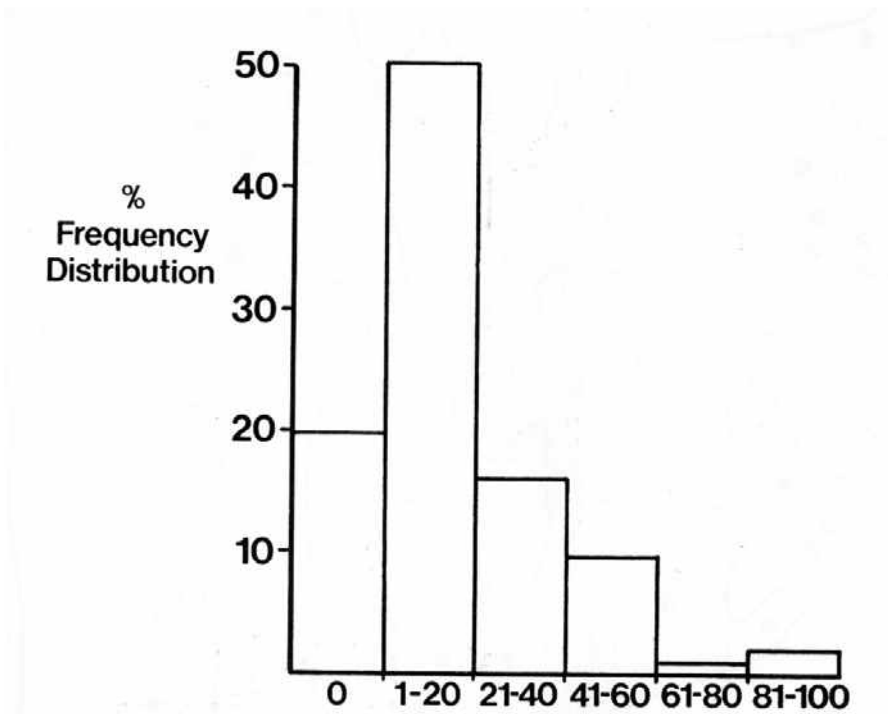


Figure 3: Occurrence of serological positives for *B. bovis* in Swaziland

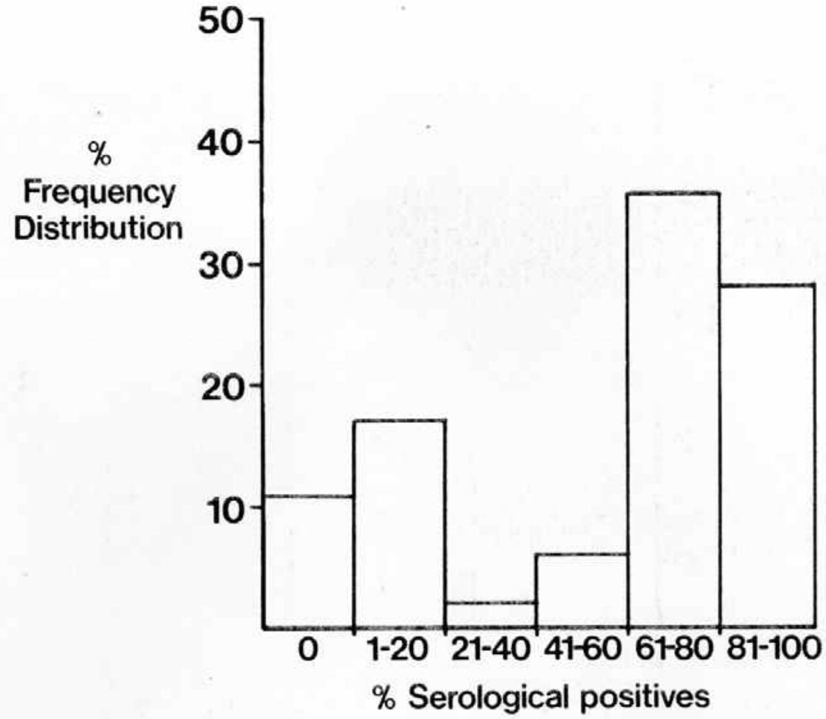


Figure 4: Occurrence of serological positives for *C. ruminantium* in Swaziland

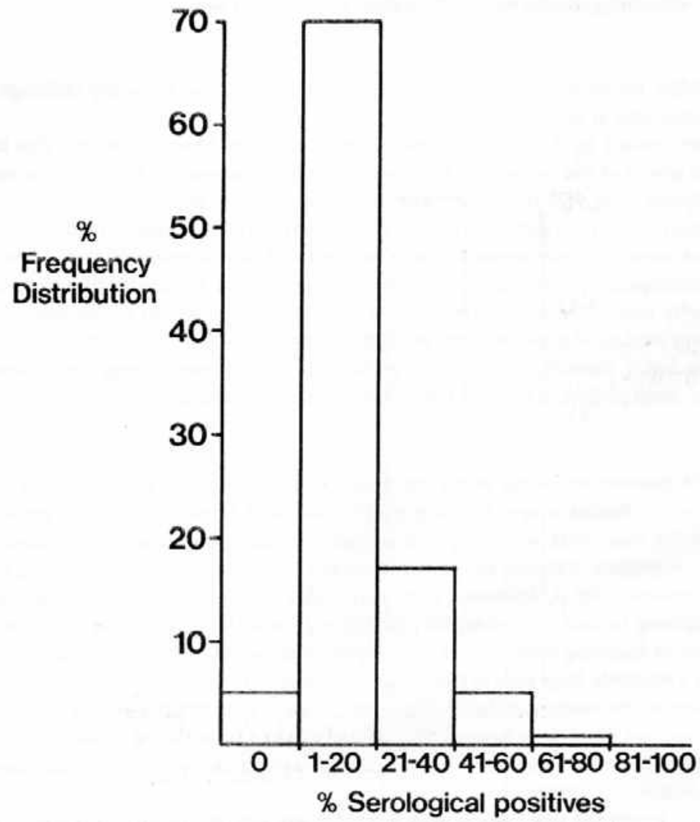
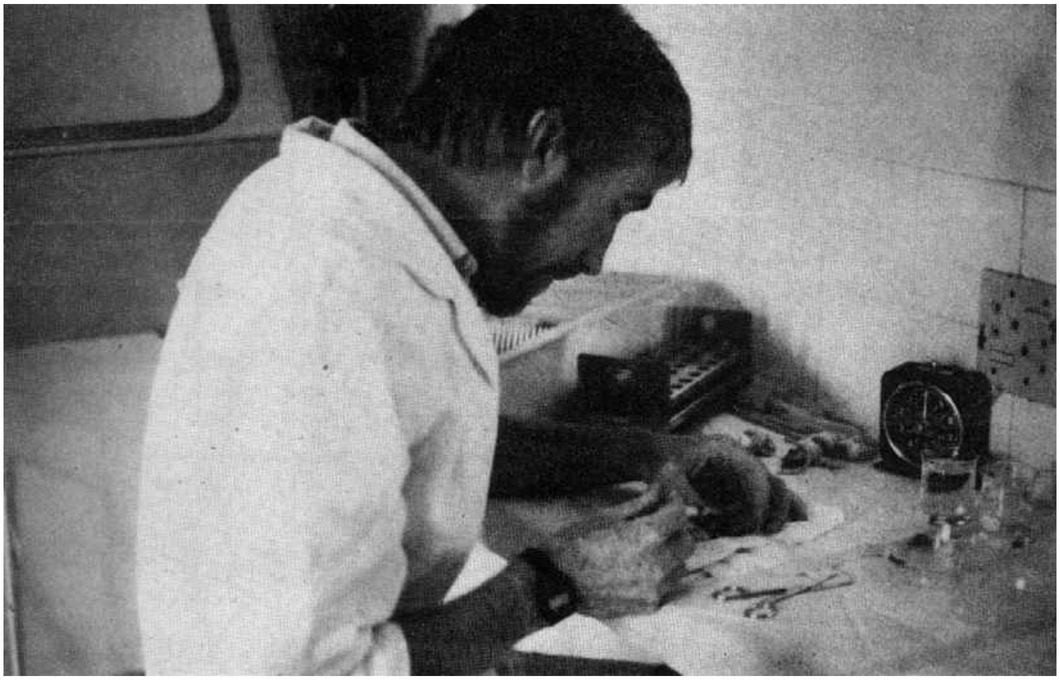


Figure 5: Occurrence of serological positives for *A. marginale* in Swaziland



Harvesting specific heartwater antigen from infected mice

Conclusions and Recommendations

The following recommendations are based upon the results of the three projects.

1. **Tick Resistance.** Careful management of dipping i.e. the use of acaricides at correct concentrations should effectively delay the spread of acaricide resistance in Swaziland. The dipping intervals currently enforced by legislation in Swaziland are effective and should be maintained.

2. **Tick Resistance.** Organophosphate acaricides need only be withdrawn from use when there is clear evidence of a resistance problem in a particular location. As it is not practical to test other candidate acaricides within the organophosphate group, it is recommended that a chemically unrelated acaricide should be used instead e.g. amidine or pyrethroid acaricides. Once withdrawn, organophosphate acaricides should not be used again at the same location.

3. ***Boophilus* Ticks.** Effective dipping coupled with strict quarantine of dip-tank areas where dipping has stopped are important to control the spread of B. microplus and therefore the spread of Asiatic redwater. Cattle from dip-tank areas adjacent to quarantined dip-tank areas should be carefully monitored for signs of redwater, especially where communal grazing is practiced, since there is evidence of contiguous spread in such circumstances. The continued existence of *B. decoloratus* in Swaziland despite decades of intensive dipping suggests that the prospects of eliminating B. microplus are poor.

4. **Heartwater.** Care should be exercised in moving cattle susceptible to heartwater from dip-tank areas in the highveld to dip-tank areas in the lowveld, where heartwater is endemic. Consideration should be given to vaccinating such cattle.

5. **Heartwater.** Cattle being moved from lowveld to highveld dip-tank areas should be dipped prior to contact with the local susceptible cattle population, to prevent transmission of heartwater.

Clinical Work

Team members were principally involved with successful completion of the expedition projects. However, since there were only fifteen other veterinary surgeons in the whole of Swaziland, it was inevitable that they became involved with treatment of a number of disease conditions in livestock.
Many pharmaceutical companies had made generous contributions to the expedition in the form of veterinary drugs. These were inva1uable in assisting the team to perform this clinical work.

1. Cattle

A wide variety of clinical cases were seen during visits to dip-tank. Severe tick inflicted wounds were common and these were often complicated by secondary bacterial and screwworm infestation. Several cases of sweating sickness were seen in calves. The parasite *Parafilaria bovicola* was seen on numerous occasions, causing bleeding skin lesions in the neck and shoulder area. A number of difficult calvings were attended, and on one occasion, first aid had to be given to a calf which had almost drowned during its first swim through a dip-tank.

Helminthiasis was suspected in many cases and routine dosing of young stock with anthelmintics often encouraged farmers' cooperation with blood sampling and tick collection. Other routine veterinary work undertaken included visits made to farms with Swaziland Government veterinary field staff. Some severe cases of preputial prolapse in Brahman bulls were surgically corrected, and a full fertility investigation was undertaken on one farm where there was a problem with a low conception rate. Many post mortem examinations were seen, since the team's base at the Veterinary Laboratory in Manzini was also Swaziland's only veterinary investigation centre with full post mortem facilities. Cases of redwater, heart- water and anaplasmosis were seen, as were deaths caused by blackquarter and various plant poisonings.

2. Goats

There is a large goat population in Swaziland, but relatively few veterinary problems were encountered. A herd of valuable Angora goats was vaccinated against heartwater, but in most goat herds this is not undertaken.

3. Dogs

Tick related problems in dogs were commonly seen. Massive tick burdens were seen on many animals and canine babesiosis (caused by *Babesia canis* and known as "biliary" in Swaziland) was very common. Unless given in the earliest stages of the disease, treatment was not always successful. Many owners encouraged their dogs to swim through cattle dip-tanks to minimise tick burdens. Rabies is a very serious problem in Swaziland, and during the team's visit, both human and numerous canine cases were reported. However, through an efficient dog vaccination campaign throughout the whole country, rapid examination of brains of suspected clinical cases at the veterinary laboratory in Manzini and strict control measures in infected areas, the problem of rabies is relatively well controlled. Both team members were also involved with the full spectrum of routine canine clinical work as encountered in small animal practice in the U.K., including performing numerous neutering operations on dogs and bitches.

4. Cats

Cats are not widely kept as companion animals in Swaziland, and relatively few were encountered in clinical work.

5. Poultry

The poultry industry makes an important contribution to Swaziland's economy. Many poultry carcases were submitted to the veterinary laboratory in Manzini for post mortem investigation, and conditions seen included Newcastle Disease, chronic respiratory disease, infectious bronchitis, infectious laryngotracheitis, severe internal parasitism and coccidiosis.

6. Horses and Mules

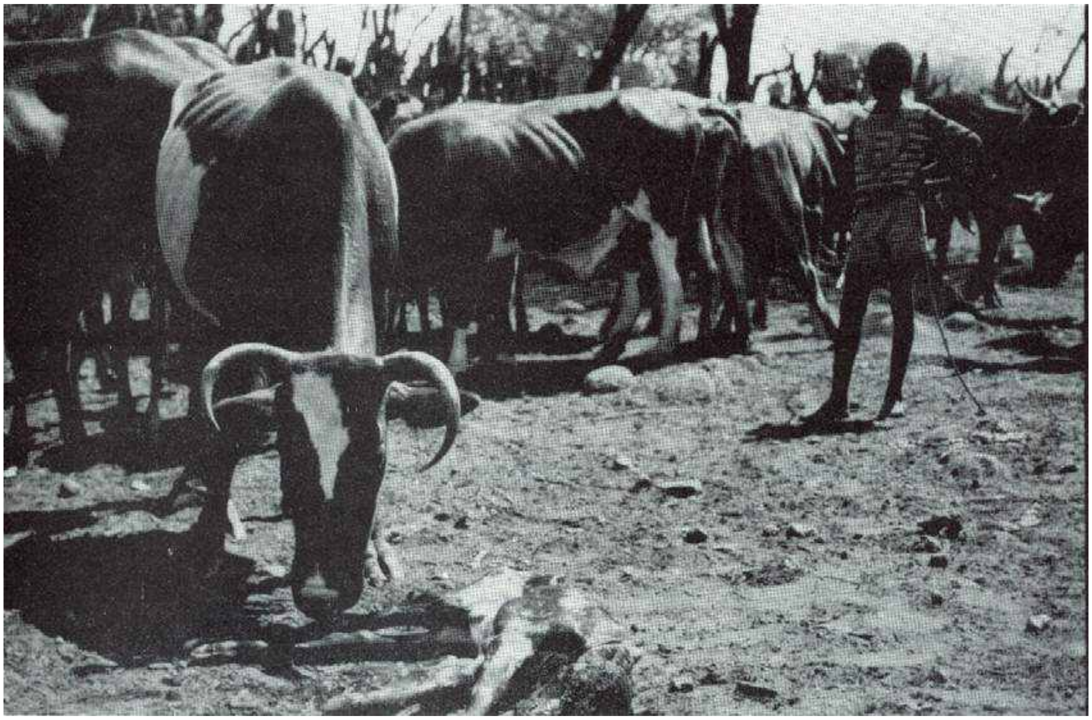
A small horse population exists in Swaziland but travel by horseback IS not widely practised. However, horse riding is a popular leisure pursuit, and a competitive endurance ride provided a busy Sunday checking pulse and respiration rates for one team member.

Mules are used as draught animals in the forestry industry in western Swaziland. One mule impaled itself on a wooden stake causing severe laceration to the chest.

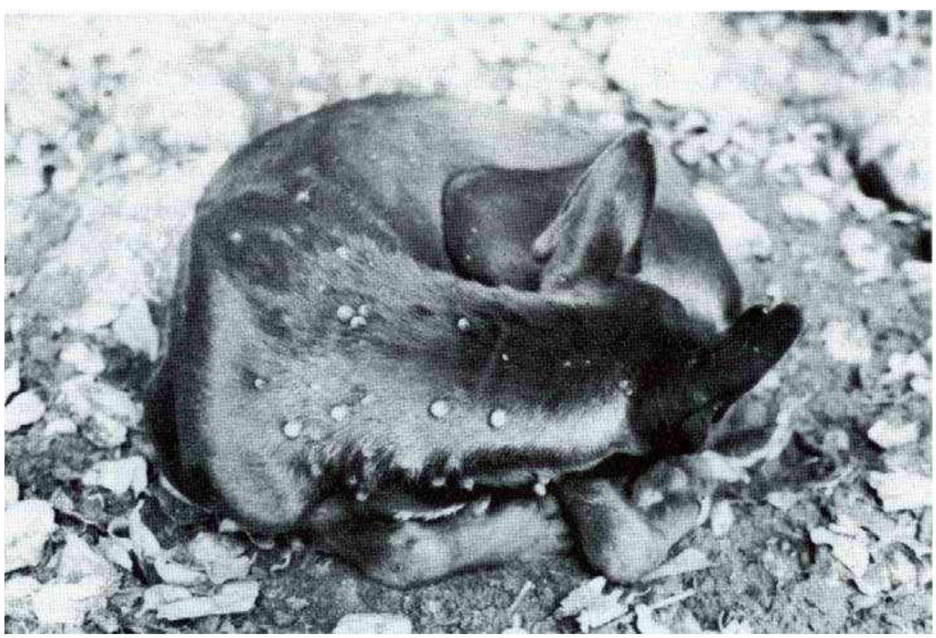
7. Baboon

A baboon, kept as a companion animal, was the victim of a road traffic accident resulting in a ruptured prolapse of the rectum which was surgically corrected.

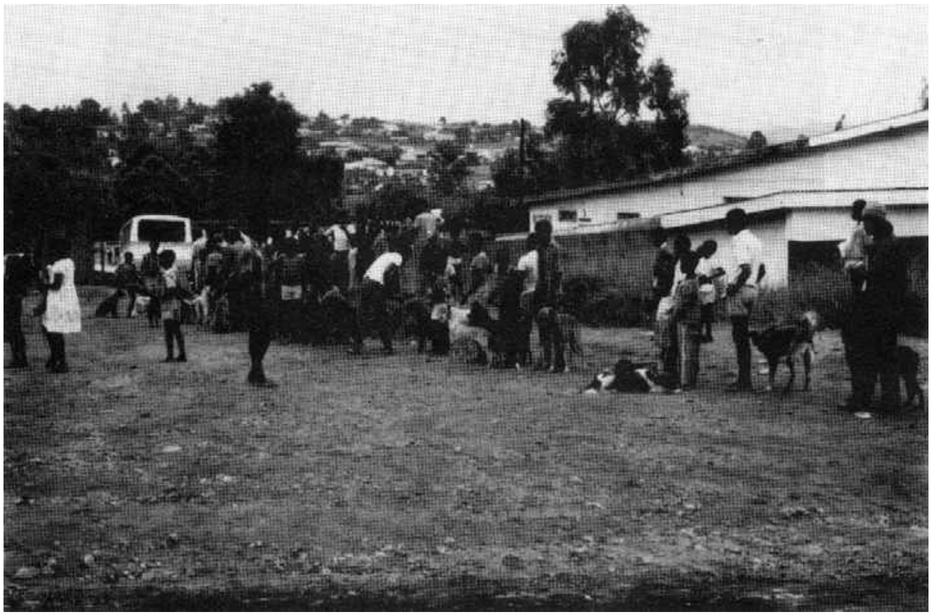
Treating a bull on visit to the dip-tank



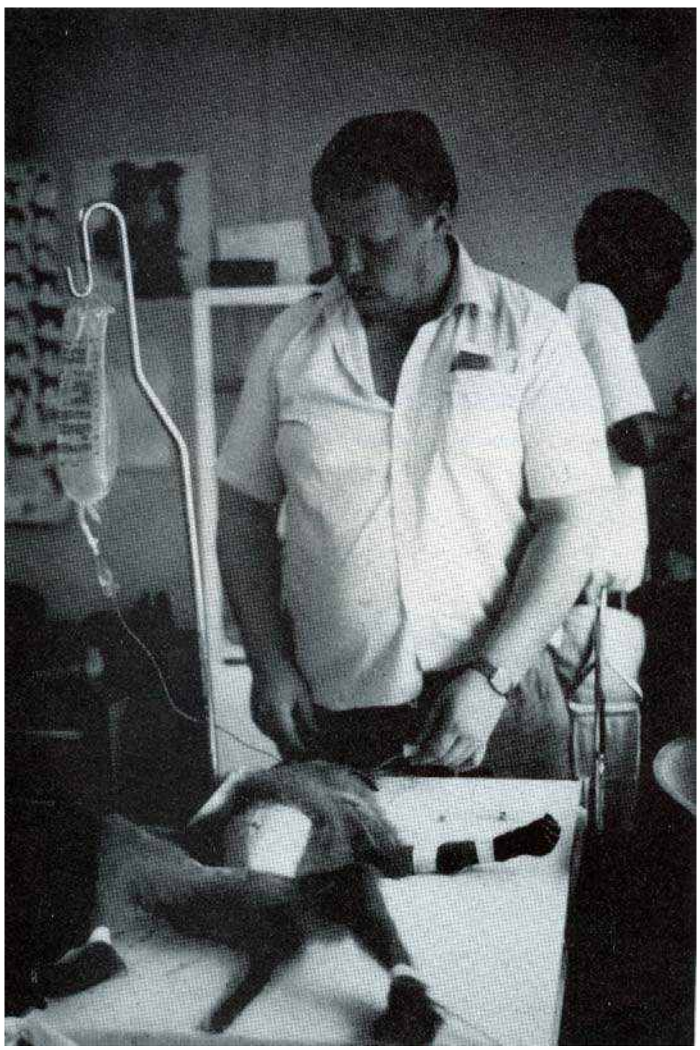
A cow with a new-born calf at a dip-tank



A dog with a heavy infestation of ticks



Owners in queue with dogs at a rabies vaccination clinic



Monitoring and intravenous drip as the baboon recovers from anaesthesia

Recreation

1. Sports

Life in Swaziland is lived outdoors, and many sports are popular, with excellent recreational facilities available. Many competitive hours were spent in the evenings on tennis courts, and as much time cooling off with refreshing swims. Pete trained arduously for a marathon, and eventually ran his first full 42 km race in February in 3 hours 26 minutes and 30 seconds. Tim settled for the more rational goal of a 6 km fun run in Manzini. Both team members also played golf, football and even rugby at different times during their stay.

2. Wildlife

The animals of the African bush proved to be a constant source of interest. There were first of all "routine" day to day spotting of large tortoises on footpaths, small crocodiles on riverbanks and brief glimpses of antelope by the roadside. There were also more stressful close encounters with scorpions and snakes. Then there was more organised wildlife spotting in official game sanctuaries. Swaziland has a remarkable number of game parks for the size of the country, and team members visited as many as possible as often as spare time allowed. A weekend was spent camping at Mbuluzi, genuine warthog stew was consumed at Mlilwane and wildebeest, waterbuck, zebra and impala were seen at Ehlane. Visits were also made to Kruger National Park only 30 miles across the border from Swaziland, which covers a huge area of conservation, larger than Swaziland itself. The full spectrum of African wildlife was seen here, from cheetah and lion to elephant and giraffe. On one visit, team members were guests of the Kruger Park Veterinary Department during rinderpest vaccination trials on buffalo.

3. Travel within Swaziland

While visiting a series of dip-tanks on successive days in isolated parts of Swaziland, attempts were made to find accommodation in the vicinity of the tanks being visited. Many kind people acted as very hospitable hosts. Local veterinary staff, British, Canadian and American volunteer workers, and even just friendly local people were extremely helpful in this way. The chance was taken, while staying in some of these inaccessible areas, to see parts of Swaziland which might otherwise have been overlooked. On one occasion, near Pigg's Peak, a local schoolteacher led the way on foot to a series of Bushman paintings. Bushmen hunted wildlife in Swaziland until the last century, and these remarkable paintings showed hunting scenes, etched in colour on the sheltered faces of huge boulders.

During another stay in the Pigg's Peak area, a visit was made to a Centre for Appropriate Technology, where workshops trained local people in such diverse skills as carpentry, welding, pottery, shoemaking, screen-printing and weaving. There was also a demonstration of practical, easily constructed, handmade and hand powered machines, which in various ways could ease the workload of daily rural life. In the far south of the country a rural health clinic was visited. A Scottish volunteer nurse, who was based at the clinic, made daily house calls by motorbike to patients in isolated villages. She also assisted the local traditional healer, or "inyanga", with some of his more difficult cases. During a visit to the inyanga's "hospital", Pete was given a free traditional "consultation". The inyanga cast his "bones" on the floor of his mud-hut at Pete's feet. Pete was relieved to hear that the pattern they settled in indicated that he was in a reasonable state of health!
Halley's Comet passed through the skies over Swaziland during the later stages of the expedition. Team members had many clear sightings of the comet from different parts of Swaziland, with the clear, unpolluted rural skies giving ideal viewing conditions.

4. Social Life

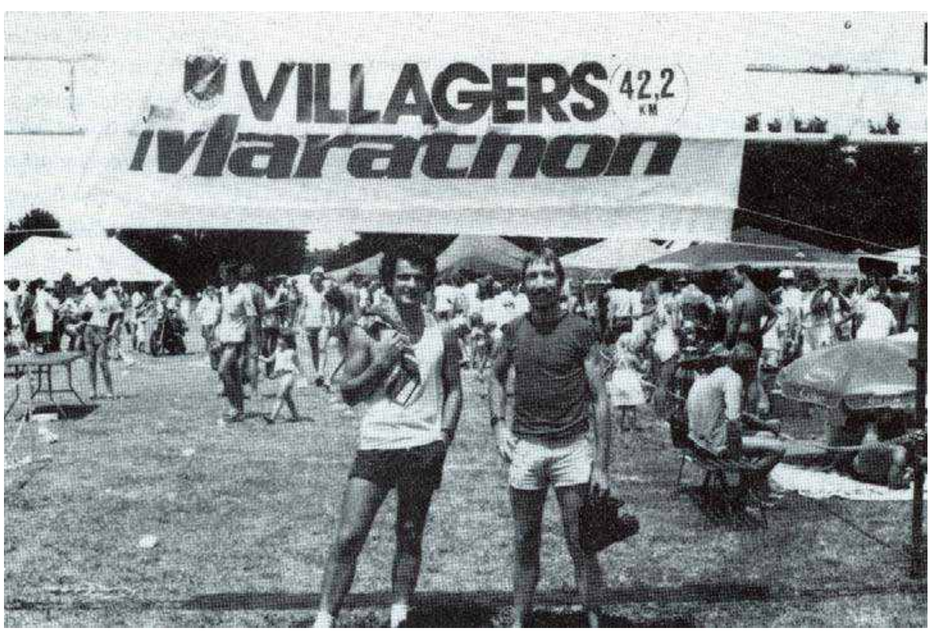
People in Swaziland were always friendly and welcoming. The barbecue or "braai" is a way of life in Swaziland, and many pleasant hours were spent socialising outside in the evening while a warm fire gently cooked supper. Lunchtime "braais" were also popular, and in the back yards of the many butcheries in the country, a fire was always burning, so that an instant meal could quickly be cooked.

New Year's Eve, Burn's Supper and St. Patrick's Day celebrations were undertaken with unrivalled enthusiasm in Swaziland. There was even specially imported haggis at the Burn's Supper, although it was disappointing to learn that the piper in full Highland Dress had never been within a thousand miles of Scotland! The Swaziland Veterinary Association was very kind to expedition members, who were their guests on a number of occasions, including a very memorable annual dinner and an interesting visit to the Onderstepoort Veterinary Research Institute.

5. Coronation

At the very end of their stay in Swaziland, team members were lucky enough to witness the coronation of the new King of Swaziland, King Mswati III. The last King, Sobhuza II, had reigned from 1921 until his death in 1982, and so the coronation was an occasion for national celebration on a scale not seen for decades. Most of the population donned their spectacular traditional dress and descended on the national stadium where the new 18 year old King gave his first address to his people. The stadium arena was packed with thousands of warriors shaking shields and spears as they danced their allegiance to their new ruler. Then thousands of women joined in, dancing and singing with joy. Exciting displays of a similar type, on a smaller scale, were repeated unofficially time after time throughout the country during the coronation period.

These were scenes which will never be forgotten, and both team members were delighted to be able to join in with the celebrations. Bayethe!



Pete and Brandan after winning a marathon

Tim and friends after completing the fun run

Vervet monkey

Impala

Swazi warriors

Sponsors and Acknowledgements

We gratefully acknowledge the following sponsors for their financial support, without which the expedition could not have taken place.

	£
Bank of Scotland PLC	50.0
Biological Council	50. 00
British Veterinary Association	250. 00
Carnegie Trust for the Universities of Scotland	1,500.
Clydesdale Bank (Pty) Ltd.	50. 00
Coopers Animal Health (Pty) Ltd.	50.00
Edinburgh University	270. 00
European Economic Community	1,809.
Fenella Johnstone	50. 00
Gillian Johnstone	200. 00
Pfizer Ltd.	1,500.
Rogerson, Baird, Wain & Partners	300. 00
Royal Society of Tropical Medicine & Hygiene	200. 00
Scottish Metropolitan Branch of the B.V.A.	25. 00
Smith Kline	25. 00
Tropag Consultants	200.00
Wellcome Foundation	500. 00

We would like to thank the following companies for their donation of equipment to the expedition

Arnolds Veterinary Products Ltd.
Bayer UK Ltd.
Beecham Animal Health
Boehringer Ingelheim Ltd.
Coopers Animal Health Ltd.
Crown Chemical Company Ltd.
C-Vet Ltd.
Duphar Veterinary Ltd.
Elanco Products Ltd. Ethicon Ltd.
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Hoechst UK Ltd.
Millpledge Pharmaceuticals
Norbrook Labs (G.B.) Ltd.
Parke-Davis Veterinary
Syntex Pharmaceuticals Ltd.
Upjohn Ltd.
Willows Francis Veterinary

Special thanks are due to Pfizer's Ltd. for their generosity in loaning an excellent pick-up truck to team members for the duration of the expedition.

In addition to those people acknowledged for their assistance in the individual projects, we would like to extend our sincere thanks to the following:

For their help in getting the expedition off the ground
Archie Hunter
Dr. Roger Purnell of Pfizer's Ltd.
The Expedition Advisory Centre
Administrative and secretarial staff at the CTVM
University of Edinburgh Expeditionary Society

For their patronage
Professor D.W. Brocklesby, Director, CTVM
The late Professor J .T. Baxter

For their overwhelming hospitality
Brendan McCartan and family
Reinhard Baer and family
Mike Maher

For their invaluable assistance with the field work
Sipho Hlatshawyo
David Ngwenya
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The field veterinary officers including Mohammed Abdulai, Emanuel Mbise, Bonaface Mburimburiwe, Ron Nxumalo, Nick Short and Godwell Tofa
The many Animal Health Inspectors and Veterinary Assistants, too numerous to mention individually

For their official support
The Ministry of Agriculture in Swaziland
Dr. N.J. Gumede, Director of Veterinary Services
Dr. J .G. Dube, Senior Veterinary Officer

For their friendship, help and hospitality on our travels
Dr. D.A. Davies, Ms Brigid Coetzee and staff at Coopers Research Station, Kwanyanga
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Library staff at the Onderstepoort Veterinary Research Institute
Members of the IVS and Peace Corps organisations

For their essential assistance with the preparation of this report
Jeanette MacDonald
Chris McKinnell

The University of Edinburgh Veterinary Expedition to Swaziland 1985

Income And Expenditure Account

Accounts covering the period from February, 1985 to 31st May, 1987

Income			£5,220.00
Sponsorships and Donations (Note 1) Bank interest			191.08
Personal contribution by participants			600.00
			£6,011.08
Expenditure			
Travel Expenses		£1,940.18	
Stationery & Postage		160.05	
Freight Charges		612.53	
Living Expenses in Swaziland		1, 565.09	
Vet. Assistant Expenses		197.14	
Sundries		130.78	
Motor Expenses	£1,968.45		
Less amount received from E.E.C. through Swaziland Government	(1,809.61)	158.84	
Currency Exchange difference		13.22	4,777.83
Surplus being balance held on Deposit with the Clydesdale Bank			£1,233.25

Note 1. Sponsorship and Donations:

£ 500	Wellcome Foundation
250	B.V.A.
270	Edin. University
200	Miss G. Johnstone
200	Royal Society of Tropical Med. & Hygiene
50	Miss F. Johnstone
50	Coopers
50	Bank of Scotland
50	Clydesdale Bank
50	Biological Council
25	Smith Kline
25	Scottish Met. Branch of B.V.A.
1,500	Pfizer's
1,500	Carnegie Trust
200	Tropag
300	Rogerson, Baird, Wain & Partners
£5,220	

Note 2. Currency Exchange rate based on £1 / E3.5000.
6 The Square, Kelso. 16th July, 1987
We have examined the books and papers of the University of Edinburgh Veterinary Expedition to Swaziland 1985 and have prepared the foregoing Income and Expenditure Account from the information given by the participants.

(Sgd) WELCH JOHN J. AND CO.
Chartered Accountants

TREASURER'S REPORT

At the time of issuing this statement, there remains outstanding the cost of producing and distributing the report. Any surplus funds below the value of £200 will be returned to Tropag, in agreement with the terms of their sponsorship.

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Further copies of the Expedition Report can be obtained from Professor D.W. Brocklesby
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