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ANTHRAX IMMUNIZATION OF FREE-RANGING ROAN ANTELOPE *HIPPOTRAGUS EQUINUS* IN THE KRUGER NATIONAL PARK

by

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Abstract – An aerial method of immunization is presented as a feasible means of vaccinating free-ranging roan antelope *Hippotragus equinus* against anthrax in the Kruger National Park. The method is described in detail and the results, obtained after two consecutive years of application, are noted, tabulated and evaluated. A helicopter and a fixed wing aircraft were successfully utilized in the location of widely dispersed roan antelope herds and to bring the operator within effective firing range of the animal to be darted. A disposable projectile syringe, which simultaneously administers vaccine and effectively marks the animal for later identification, is considered a vital part in the successful implementation of the aerial method of immunization.

Introduction

The significance of anthrax as a limiting factor of the Kruger National Park (K.N.P.) roan antelope population was dramatically demonstrated during the 1959, 1960 (Pienaar, 1968a) and 1970 (unpublished data) anthrax epizootics. During these outbreaks a minimum of 83 roan antelope were found to have succumbed to the disease. This represents a fair proportion of the estimated 250-odd roan antelope for the K.N.P. and 300 to 350 total for the Republic of South Africa (Joubert, 1970).

By virtue of a regular yearly incidence and seasonal occurrence, the Pafuri area of the K.N.P. has attained the reputation of being an enzootic anthrax region (unpublished data). The disease sporadically spreads from the lower lying Pafuri area onto adjoining regions to set up foci of infection, which may flare up as epizootics, such as happened during 1970 (unpublished data). The areas adjoining Pafuri, popularly known as "high risk anthrax regions", unfortunately also overlap to a great extent with the northern portion of the preferred roan habitat, which, incidentally, is also their most favourable habitat in the K.N.P. The only remaining roan population of any consequence within the Republic of

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South Africa, therefore, is exposed to the constant and dreaded threat of anthrax. A research programme was, therefore, initiated, with the object of devising practical and effective means to protect these animals from the ravages of the disease. One of the first and most important considerations was to investigate possibilities of prophylactic vaccination.

Literature on wildlife diseases seems to be in agreement that immunization of wildlife is largely impractical (Davis, Karstad and Trainer, 1970). The majority of workers maintain that the problems involved in vaccinating a widely dispersed herd of animals in the wild are extremely difficult to overcome, if not insurmountable. Choquette (1970), however, maintains that with herd animals which can be coralled, such as bison (*Bison bison*), vaccination can be a feasible procedure. In 1965 and 1966, respectively, 4 291 and 4 164 Canadian bison were vaccinated against anthrax in this manner. The feasibility of this technique for African conditions is enhanced by spectacular successes obtained in the capture of wild African herbivores by means of net-and-plastic funnels and corrals (Oelofsen, 1969; Pienaar, *in press*). Kruger National Park animals, which lend themselves towards this type of manipulation, are those which tend to maintain group-formation, *inter alia* Burchell's zebra (*Equus burchelli*), blue wildebeest (*Connocheates taurinus*) and African buffalo (*Syncerus caffer*). The extensive dispersal pattern of roan antelope within the K.N.P., however, does not favour this procedure. Harthoorn and Lock (1960), on the other hand, succeeded in vaccinating a very limited number of free-living buffalo against rinderpest, by first immobilizing them with drugs delivered by darts and then injecting them with the vaccine. A high degree of disturbance and an inevitable increased vulnerability to predation in the immediate post-capture phase ruled this technique out as impracticable. Speculative ideas of mass vaccination per os or by means of inhalation have been advanced (Davis *et al.*, 1970; Pienaar, 1961, 1968). If these theories can be put into practice they could well prove to be the ultimate solution to the problem and are worthy of further investigation.

With the literature advancing no practical solution for the particular problem, a new method of administering vaccine had to be devised. It was thereupon decided to combine darting and disposable dart syringe principles and to use a helicopter as a means to bring the operator within firing distance of the subject animal.

It was also decided to use an avirulent spore vaccine developed in South Africa, and which is now used with excellent results in many parts of the world for all species and breeds of domestic animals (Sterne, 1959). In spite of its use in large scale annual precautionary vaccinations of chiefly domestic bovines in South Africa (Mansvelt, 1965) and in several thousand bison in Northern Canada in 1965 and 1966 (Choquette, 1970), the position with regard to African wildlife was still vague at the commencement of the project. Sterne (1939) found that under field conditions swellings were provoked in domestic goats. Neitz (1936) also demonstrated from a test on a limited number of animals that blesbok (*Damaliscus dorcas*) are more susceptible to a weak anthrax vaccine than are goats. The intramuscular deposition of the vaccine, which had to be used in lieu of the conventional subcutaneous method, was still another unknown factor which had to be contended with. It was, therefore, thought advisable to test the safety of the vaccine on a variety and representative sample of wild game species prior to its application in the field.

This report documents the results of investigations which are aimed at obtaining a practical, effective and safe method to prophylactically immunize free-ranging roan antelope within the Kruger National Park. It is hoped that this study will contribute positively towards promoting the survival of the species.

Materials and Methods

Study area and animals

Immunization activities were restricted to roan antelope occurring in a known high risk anthrax region in the northern sector of the Kruger Park, north of the Shingwidzi River. Within this area, operations were further limited to the preferred habitat of roan antelope, comprising approximately 1 150 square kilometres in an inverted L-shaped strip alongside and more or less parallel to the eastern border of the Kruger Park (Lebombo Mountain range) and Bububu River banks (see Pienaar, 1963, for detail). It consists mainly of an open savanna vegetation in which mopani (*Colophospermum mopane*), either in scrub or tree form, predominates. This area is further traversed by an extensive network of relatively wide, shallow and poorly drained grassy valleys which could be described as miniature "dambos" and in which *Lonchocarpus capassa* and *Hyphaene crinita* are the dominant tree and shrub species. Boreholes with concrete reservoirs and troughs, distributed throughout the area, provide the permanent water supply.

An enclosure of 260 hectares was erected in the northern part of this area with the object of holding a nucleus herd of roan antelope for breeding and study purposes (Pienaar, 1968; Joubert, 1970). The camp held 15 and 21 animals during the 1971 and 1972 phases of the operation respectively.

Based on continued surveillance and aerial censuses during 1971 and 1972, it is estimated that the numbers of roan antelope do not exceed a total figure of 100 for the operational area. This provides a density figure of approximately one roan antelope per 14,5 km^2 for the area which had to be covered outside the roan camp.

Darting equipment

A Palmer Cap-Chur gas-powered rifle was used to propel the dart or projectile syringes. The rifle has a single shot action and the gas-chambers were recharged after ten shots had been fired.

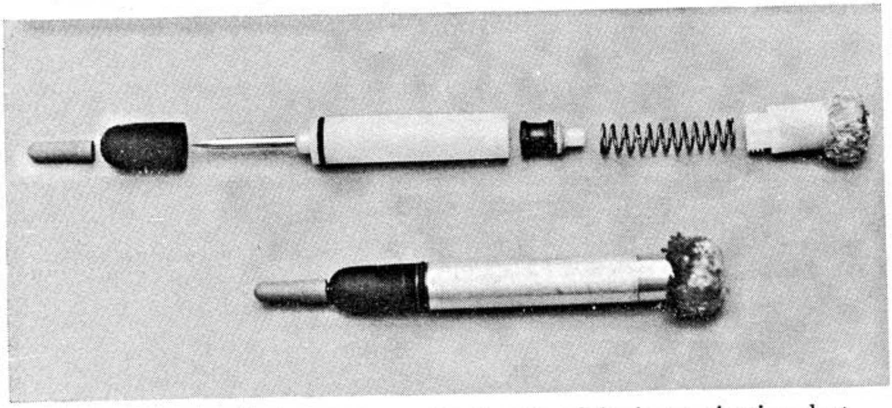

Fig. 1. Assembled and disassembled parts of the immunization dart.

Two types of dart syringes, which were used during the project, were developed by one of us (G. L. v. R.) and differed mainly through the principle by which the plunger was moved forward. In the one, the gas-explosive principle was applied, whilst the other utilized a spring mechanism which pressurized the fluid (vaccine) in the enclosed, rubber stoppered, chamber in front of the plunger. Figure 1 depicts the assembled and disassembled parts of the dart. On impact the rubber stopper is pierced by the sharp point of the needle, setting the contents of the dart free.

In accordance with the aerial procedure of immunization, spontaneous retraction of the projectile syringe after deposition of its contents, was considered a prerequisite to the success of the operation. To conform to this disposable principle, a smooth needle shaft, without a thickening or barb, was utilized. This, however, caused the dart to be retracted immediately after impact, and raised questions as to whether the full dosage was delivered. In an attempt to allay doubts on this issue, the effectiveness, or administering capacity, of both types of darts, were tested on ten impala (*Aepyceros melampus*), utilizing immobilizing drug mixtures and normal dosage rates for the species, as advocated by Pienaar, Van Niekerk, Young, Van Wyk and Fairall (1966) and Pienaar (1968 b).

Marking and subsequent identification of vaccinated animals were effected through the use of a marker device. As depicted by Figure 1, each dart needle was fitted with a hollow rubber cuff forming a compressible compartment around the shaft. The rubber material was rigid enough so as to obviate distortion and inevitable loss of stain solution at the moment of firing and during flight. The receptacle was filled to capacity (0,85 ml) with a stain solution (Fig. 2). To provide a high degree of contrast against the reddish-grey haircoat of the roan antelope, a concentrated alcoholic solution of gentian violet was utilized. The rounded part of the rubber cuffs was perforated with slight slit-like openings, the theory being that on impact and with penetration of the needle, sudden pressure is exerted on the cuff and its contents, resulting in a forced spray-out of the dye through the holes and onto the hide of the vaccinated animal.

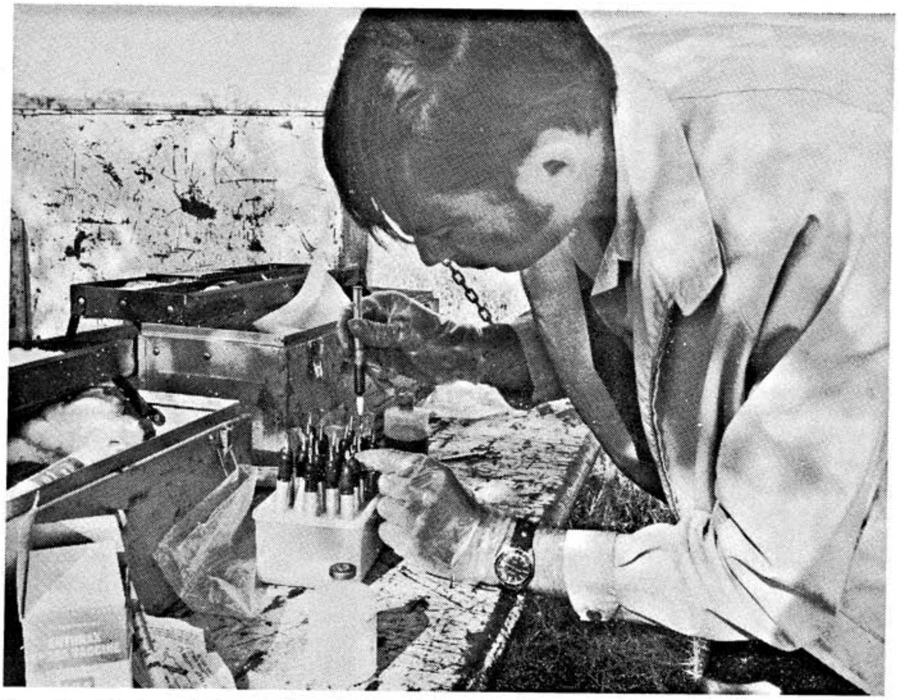

Fig. 2. Stain solution being injected into the receptacle of the marker device.

The dart capacity allowed for a volume of 1,25 ml and was filled with an avirulent uncapsuled spore vaccine which was manufactured and supplied by the Veterinary Research Institute at Onderstepoort, South Africa.

Locating and darting roan antelope

A helicopter was used as a means to bring the operator within firing range of the subject material (roan antelope). The services of two types of helicopters were utilized; a three seater Hiller 12E helicopter during 1971 and a three seater Bell 47G3B2 helicopter for the 1972 campaign. Reconnaissance flights were done exclusively by helicopter during 1971, whilst a six seater Cessna 206E Stationair took over the major portion of this work in the following year. A helicopter crew consisted invariably of a pilot and an operator (marksman) whilst the fixed wing aircraft was filled to capacity with observers.

Very high frequency (VHF) radios and a two way walkie-talkie (Motorola Handie-Talkie FM Radiophone) system were used as means of communication between the helicopter and fixed wing aircraft.

Results and Discussion

Projectile syringe

Table 1 provides data on the testing of the efficacy of the immunization darts. From these results it can be deduced that immobilization was affected on first attempt in 10 impalas, loading the darts with normal drug dosages as advocated by Pienaar (1966). Normal reaction times were recorded. This can only be interpreted as proof that sufficient volume of the drug mixture must have entered the body of the animal before withdrawal of the dart was completed. In view of the smooth needle shaft

Table 1

Testing the administering capacity of two types of anthrax projectile syringes through the responses afforded by adult impala (Aepyceros melampus) *to normal drug immobilization dosages.**

Projectile syringe		No.	Sex	Dosage level (Total dose in mgm)		First signs of ataxia (min. after darting)	Recumbency (min. after darting)	Remarks
				Etorphine ** (M99) mg	Acetylpromazine *** mg			
Propulsion of drug affected by:	Spring pressure principle (Fig. 1)	1	♂	0,5	5	2,5	6,5	
		2	♂	0,4	4	5	16	On first signs of ataxia aggression by other adult males were exhibited towards the affected individual, which resulted in pursuit and harassment and kept the animal in an excitable state.
		3	♂	0,4	4	3	15	
	Gas explosion principle (Detonator)	4	♂	0,3	3	2	5	
		5	♂	0,25	3	4	20	Dart penetrated skin fold at flank region and drug was obviously deposited subcutaneously.
		6	♂	0,3	3	4	7	
		7	♂	0,3	3	?	18	Chased by other animals, same as "2,3". Lost sight temporarily.
		8	♂	0,3	3	3,5	8	
		9	♀	0,3	3	2,5	6	
		10	♀	0,3	3	?	?	Lost sight of animal. Found in a recumbent position after 18 min.

* *Dosage levels as advocated by Pienaar* et al. (1966) *and Pienaar* (1968b).
** *M99: Reckitt and Colman (Africa) Ltd.*
*** *Acetylpromazine: Boots Pure Drug Co. Ltd.*

(Fig. 1) being used, the delivery of the drug must be virtually instantaneous on impact. It is conjectured that the small drug volume (1,25 ml) in relation to the relatively thick needle (10,5 gge), ensured deposition of the bulk of the drug within the fleeting instant between impact and withdrawal of the dart.

On impact each dart left an identification mark through the principle outlined above. The dye that was used (gentian violet) showed up well against the pale greyish haircoat of the roan antelope, and in some cases marks were still recognizable after 14 days. A variable amount of homogenous and heterogenous licking of the marked area was witnessed, which sometimes accounted for earlier disappearance of the mark.

The identification mark enabled the operator to recognize previously immunized animals; an aid which subsequently played a vital part in the successful completion of the project. The conspicuous nature of the mark greatly facilitated identification so that split second decisions could be made by the airborne team. In this way the immunization of all individuals in herds was ensured, despite flight reactions and scattering of individuals provoked by the helicopter.

The normal prescribed procedure of administering the vaccine is one ml subcutaneously. However, due to the length of the marking device the needle cannot be shortened sufficiently to ensure subcutaneous deposition without increasing the chances for possible error through loss or spilling of vaccine. The bulk of the vaccine is therefore invariably deposited in muscular tissue. Prompt responses by impala to the immobilization drug mixtures delivered by these dart syringes (see Table 1), corroborates the intramuscular deposition hypothesis.

Vaccine

Immobilization drug dosages which could be incorporated in the available dart space are considered much more critical than anthrax vaccine quantities needed for immunization purposes. The Onderstepoort vaccine as described by Sterne (1946) is still in use today. It consists basically of at least 10 million spores from avirulent uncapsulated *Bacillus anthracis* strains per ml, and these are suspended in a glycerine-saline mixture with saponin added as an adjuvant (Sterne, 1946). The dart syringe capacity allows for 1,25 ml, which provides for 12,5 million spores per dose. Formerly, as described by Sterne (1939), 300 000 and 600 000 to 1 200 000 spores per dose were used for sheep and cattle respectively. This elicited an immune response which was retained at least a year (Sterne, 1939). It is, therefore, assumed that the dose carried in the dart represents 10 to 12 times the minimal dose which is required for effective immunization, and provides sufficient compensation for possible loss of vaccine during the darting process. Whether the degree of immune response is subject to the route of administration, is still an unknown quantity. Until this point is clarified, the assumption is made that an intramuscular deposition of vaccine elicits an adequate protective immunity response in the host animal.

No untoward effects were detected in the seven wild animal species that were inoculated with anthrax vaccine under controlled conditions, utilizing the dart syringe method. The vaccinated animals which were kept under observation for months afterwards, included ten buffalo, four nyala (*Tragelaphus angasi*), eight impala, three Burchell's zebra, three blue wildebeest, twelve roan antelope, five warthog (*Phacochoerus aethiopicus*) and two baboons (*Papio ursinus*). The vaccine provoked no discernible swellings at the injection site, or debilitating effects in the subject individuals. McCulloch and Achard (1965) also reported no untoward effect after the vaccination of three giraffe (*Giraffa camelopardalis*), nine wildebeest, three topi (*Damaliscus korrigum*) and four eland (*Taurotragus oryx*) with anthrax, haemorrhagic septicaemia and blackquarter vaccines. On the strength of these observations and mass vaccination of bison which was carried out in Canada in 1965–66 (Choquette, 1970), the uncapsulated spore vaccine was declared safe for use in roan antelope under field conditions. The validity of this assumption was borne out by subsequent results that were obtained after the trial aerial run of vaccination during 1971. The death of a young roan antelope female 4 days post vaccination, however, marred an otherwise unblemished record. Typical *Bacillus anthracis* organisms was demonstrated microscopically in the bloodsmears, but unfortunately the carcass was destroyed before isolation and bacteriological identification of the causal organism could be attempted. Consistent negative findings in the other immunized animals minimize the probability of the vaccine strain being responsible for the death. Furthermore, an anthrax case was diagnosed in the area of operation immediately prior to the commencement of immunization activities. A plausible explanation, therefore, seems to be that the animal in question contracted the disease naturally, from a foreign source, before immunity could be effected by the vaccine. In other words, vaccination was carried out within the incubation period of the disease. Judging from the single case, it is conjectured that in the roan antelope an effective immunity is probably not set up in less than four days post vaccination. Sterne (1946) maintains that in domestic bovines protective immunity is effected in under a week whilst in horses it may take a month or six weeks to develop. Sterne (1939 a) also demonstrated the very early development of immunity in guinea-pigs. Considerable species differences are therefore in evidence.

During an epizootic outbreak of anthrax the effectiveness of the vaccine as a control measure is limited by the imminent time lag before protection is afforded. This hypothesis was borne out during an anthrax epizootic which ravaged the northern parts of the Kruger Park during 1970. During the time it was attempted to curb the spread of the disease within the roan enclosure referred to above. Vaccine alone had little effect, whilst vaccine combined with high dosages (20 ml) of a long-acting antibiotic (150 000 units benathamine penicillin and 150 000 units procaine penicillin G. per ml)* effectively arrested mortality in treated individuals (unpublished data).

Locating roan antelope

Locating roan antelope within the danger area proved to be a major undertaking. This was mainly due to a low density of the animals within the area and the excellent camouflage afforded by an animal sporting a dull grey haircoat against similarly shaded background with long dry grass predominating. In open veld the animals usually moved off at a brisk trot on perceiving the presence of the aircraft. This tendency greatly facilitated "spotting". However, with readily available cover in the form of trees, some instances were observed where a "freezing" posture was assumed under cover of overhanging foliage. For this, and other obvious reasons, reconnaissance flights had to be intensified in areas of denser vegetation.

It was, however, possible to take advantage of available knowledge on the normal daily and seasonal activity pattern of roan antelope and to arrange search flights accordingly. As indicated by Joubert (1970) roan antelope have a rhythmic pattern of activity in accordance with prevailing climatic conditions. Late winter months and early spring, i.e. the period June to September, usually present arid conditions with an influx of roan antelope towards permanent watering points. With the first substantial summer rains the animals typically disperse from these perennial waterholes, a pattern which is maintained as long as natural veld water is available. Joubert (1970) further maintains that during dry winter months, these animals normally frequent permanent drinking spots with an almost predictable regularity between 10 h 00 and 11 h 00 of each day of each day. The validity of these observations was borne out by subsequent results of this project.

During the 1971 phase of the operation dry conditions typical for the period (August/September) were experienced. The animals were invariably found in the vicinity of perennial watering points and consisted of individuals and herds of up to 17 animals (Table 2). A total of 13 encounters were needed to immunize 63 animals, utilizing the helicopter only during the entire operation.

In 1972, on the other hand, the rainy season, preceding the time of operation, was characterized by extremely heavy and prolonged precipitation. This accounted for conditions of lush grazing and an ample supply of veld water which still persisted at the commencement of operations (August). The animals were mostly far afield and found as individuals or small groups along the fringes of their traditional winter range, a distribution pattern typical of summer conditions (Joubert, 1970). This extensive dispersal pattern forced the operators to adopt a parallel strip search by the fixed wing aircraft, covering all possible areas. Depending on the

*"*Compropen*", *as distributed by Glaxo-Allenburys S.A. (Pty) Ltd.*

Table 2

A summary of the results obtained during the aerial immunization of roan antelope in the Kruger National Park during September 1971 and August 1972.

Particulars (Specified)	Immunization campaign	
	1971	1972
Average group size of roan antelope which were encountered outside the roan camp	5,15	3,65
Largest group of roan antelope which were encountered outside the roan camp	17	10
No. of encounters	13	22
No. of animals immunized	63	83
No. of darts used	85	147
No. of darts used per animal successfully immunized (darting rate)	1,35 (85/63)	1,77 (147/83)
Total flying time taken to complete operation: Helicopter: Fixed wing:	9,6 hrs. —	17,1 hrs. 22,2 hrs.
Flying time expended during positioning and reconnaissance flights: Helicopter: Fixed wing:	8,7 hrs. —	14,5 hrs. 22,2 hrs.
Helicopter flying time expended during the actual darting procedure, after contact with the animals has been established	55,5 min.	160 min.
∴ Helicopter flying time per animal successfully immunized during actual darting procedure	54 sec. (55,5/63)	1 min. 50 sec. (160/83)

terrain the strips were spaced 0,5 to 1,5 kilometre apart and actual flight ceilings were 90 to 250 metres above ground level. Higher flight levels and widely spaced strips were successfully implemented over flats, whilst the denser woodland fringes necessitated a lower and more closely spaced flying pattern. A relatively low indicated airspeed of 130 to 150 kilometres per hour was maintained throughout. Once the quarry was sighted and the helicopter crew notified of the position, the fixed wing aircraft spiralled up to about 300 metres, keeping the animal/s in sight. This was done in order to minimize the disturbance factor before the arrival of the helicopter. From that height the helicopter was directed towards the site and further assistance given in the ensuing darting operations by way of radio communication. The helicopter was, therefore, used for only limited reconnaissance flights, positioning flights and the actual darting procedures. In this manner 20 encounters resulted in the immunization of 64 animals outside the roan camp. It also explains the vast difference in reconnaissance flights which were needed during the respective years (Table 2). This also represents a considerable increase in the costs of the immunization campaign (see below). It should, however, be mentioned that the operational base from which flights were undertaken every day were situated within the operational area in 1971, whilst 20 minutes flying time separated the base from the area in 1972. A total of 40 minutes per day was therefore wasted for positioning flights for both aircraft during the latter year.

The success which was attained by the fixed wing aircraft in spotting procedures, is ascribed mainly to a relatively low airspeed and the additional number of observers which could be used. Six persons, which invariably comprised the aircraft crew, present excellent scanning possibilities.

Administering the vaccine

Essentially stereotyped reaction patterns were observed when roan antelope were disturbed by the approach of the helicopter. It was found that roan antelope do not maintain their group formation and invariably disperse when approached from the air. Two basic types of flight reactions were established. On a sudden approach from directly above, a herd would take fright and scatter in all directions. On the other hand, an unconcealed and relatively slow approach from the side invariably provoked an explosive flight reaction to the opposite side, with the herd maintaining a semblance of group formation only until a difference in pace of individual animals forced a stringing out of the group. At this stage the leading animals on the periphery also veer sharply off to left or right, forming a fan-shaped dispersal pattern. Circling and interception of the group by helicopter does not counteract this dispersal tendency, as is possible in the case of buffalo and elephant (*Loxodonta africana*), and may even cause more confusion. The result is that a group of roan cannot be held intact while working on one of its members. Attention therefore has to be focussed on one animal at a time. To complicate matters still further, an individual, when hard pressed, exhibits an extremely weaving running pattern, taking very little heed of the position of the helicopter. On the flats it was found that they usually follow a straight line for only six to 10 metres, then veer off to left or right, irrespective of the position of the helicopter. This was even more pronounced amongst denser bush, as is found on peripheral areas bordering the flats. The best results were invariably obtained with the helicopter positioned five to six metres from ground level and about six to eight metres from the target animal. To achieve this shooting position, pursuit invariably had to be undertaken until a break in the vegetation permitted a swoop on to the quarry, allowing for only a split second in which to aim and fire. This called for excellent manoeuvrability of the aircraft and a good understanding between the pilot and marksman. In actual practice, the respective operators and pilots during the 1971 and 1972 immunization campaigns quickly developed a mutual understanding and achieved a remarkable degree of success, as reflected by the results which are outlined in Table 2. With a new helicopter crew the 1972 campaign started off disastrously with 29 darts being used to immunize five animals in 35 min. 5 sec. Difficulties were, however, quickly straightened out, and the operation ended with the excellent results of nine darts used for nine animals in 6 min. 40 sec. during the last encounter, and an overall successful darting rate of 1,77 darts per animal for 1972. A closer analysis of the 1972 results also indicates a darting rate of 2,45 for the period 8–10/9/72 as opposed to 1,32 for the latter half of the operation.

The success of the operation is, therefore, to a very great extent dependent on the degree of understanding and cooperation as well as individual skills of members of the helicopter crew. The success obtained by two different crews and helicopters, however, indicates a high degree of feasibility for this phase of the operation.

The single shot action of the rifle hampered operations slightly. The multiple shot principle could be used advantageously and research is presently being conducted to perfect a dart gun with magazine action.

Postvaccinational phase

The disturbance factor created by the darting procedures was found to be of short duration. This observation was verified on most of the groups by resightings of darted (marked) animals. It was found that they almost invariably re-established their normal herd size, pattern and routine within 24 hours after the encounter. The temporary dispersal of individuals of a herd seemed to have no untoward effect on their vulnerability towards predators and was reflected by an unblemished survival rate in the immediate post vaccination period. Due to the small sample this should, however, be stated with some reservation.

Costs

Relevant details of costs are provided in Table 3. In the evaluation of these results it should, however, be borne in mind that this report covers mostly the experimental phases of the project, with costs being somewhat of a side-issue.

Figures that were obtained indicate all-inclusive costs per animal successfully immunized of R14,06 and R28,10 for the 1971 and 1972 periods respectively (see Table 3). The higher figure for the latter year is ascribed mainly to greater difficulties in locating roan antelope (see above), with an inevitable increase in time expended for positioning and reconnaissance flights (see Table 3). The flights by helicopter and fixed wing plane were responsible for the major proportion of the overall immunization costs, i.e. amounting to 63,8 per cent and 70,2 per cent during the 1971 and 1972 campaigns respectively. Working on less elusive animals or on a higher density population, it is foreseen that a considerable reduction in flight time and concomitant costs will be brought about, bringing the method into the scope of a much wider range of animals.

The bodies of the experimental darts were constructed of aluminium, which accounts for the relatively high cost of an item which has to be discarded. With the proposed advent of mass produced moulded nylon dart bodies, the cost per projectile syringe is not expected to exceed R0,50.

Table 3

Relevant detail of costs involved in the aerial immunization of roan antelope in the Kruger National Park during September 1971 and August 1972.

Particulars (Specified)	Immunization Campaign	
	1971	1972
PROJECTILE SYRINGE Manufacturing costs of aluminium darts, including costs of material and labour (per dart)	R3,08	R3,54
∴ Costs of darts per animal successfully immunized: Manufacturing costs × darting rate (see Table 2) = Sub total	R3,08 × 1,35 = R4,16 (29,6%)	R3,54 × 1,77 = R6,27 (22,3%)
AIRCRAFT FLIGHTS Helicopter flying expense (per hour) Fixed wing (Cessna) flying expense (per hour)	R65,00 —	R67,00 R30,00
Costs expended for positioning and reconnaissance flights: Flying expense × flying time (see Table 2): Helicopter:	R65,00 × 8,7 = R565,50	R67,00 × 14,5 = R971,50
Fixed wing:	—	R30,00 × 22,2 = R666,00
Total:	R565,50 (63,8%)	R1 637,00 (70,2%)
Total flying costs	R565,50 + R58,50 = R624,00	R1 637,00 + R174,00 = R1 811,70
∴ Flying costs per animal immunized: Total flying costs/number of animals immunized (see Table 2) = Sub total	R624,00/63 = R9,90 (70,4%)	R1 811,70/83 = R21,83 (77,7%)
VACCINE Avirulent anthrax spore vaccine was provided free of charge from the Veterinary Research Institute, Onderstepoort*	—	—
TOTAL COSTS PER ANIMAL IMMUNIZED Subtotals added	R4,16 + R9,90 = R14,06	R6,27 + R21,83 = R28,10

Percentage figures in parenthesis denote percentages of total costs.

* Ordinarily and in trade, anthrax vaccine is available at 0,5 cent per dose. Taking this into account, the vaccine cost × dart capacity × darting rate $\left(0,5 \times 1,25 \times \frac{1,35 + 1,77}{2}\right.$ = 1 cent) should be added to the gross total.

This is a more realistic price for a disposable dart syringe and lends further support to the idea of extrapolation to other species and circumstances.

Extrapolation

Comparative, albeit limited, trial runs indicate a high degree of feasibility of the aerial immunization procedure for various animal species, the relative degree being in the order of: elephant (1), buffalo (2), eland (3), Burchell's zebra (4), tsessebe (*Damaliscus lunatus*) (5), roan antelope (6) and blue wildebeest (7). The elephant can be described as a lumbering giant with virtually no means to evade an approach from the air. Buffalo maintain their group formation to a large extent and can actually be herded from the air. It has even been found possible to cut out consecutive groups of 30 to 50 animals from the main herd. In this way it is deemed feasible to immunize by darting all animals in herds substantially larger than roan herds, expending no more than 15 seconds per animal. Eland normally adhere to a pattern of straight running, presenting a relatively large target. Zebra also exhibit little evidence in the way of evasive tactics and can be darted easily. Tsessebe present a running pattern which is only slightly less devious than that presented by roan antelope. The exaggerated weaving pattern of blue wildebeest in flight provides for a most elusive target.

Working at random or on higher density populations, and using mass-produced moulded plastic darts, a considerable reduction in costs is anticipated (see "costs"). This, naturally, would widen the scope of application. In the event of an epizootic outbreak of highly infectious diseases such as anthrax or rinderpest among wildlife, aerial immunization can now be applied as a prophylactic measure, and will at least ensure the survival of breeding nuclei of rare species.

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