viding also in the future needs of the present population numbers. It must be remembered also that this was the particular area where elephants again obtained a foothold in bygone years (1905) and slowly increased in numbers with the passing of time.

It may well be considered then as the cradle of the elephants' population history in the Kruger Park and as an area that is particularly well suited as an elephant habitat.

Throughout the intervening years elephants in this area gradually multiplied in numbers, but in delicate balance with the other competing grazing- and browsing species in the habitat, their predators and the available food- and water resources, in other words, epitomizing a natural process of recolonisation.

Since the early thirties however, an ever increasing number of elephant began moving out of the original habitat, northwards at first, but later, during the forties, also southwards, where other areas were colonised. This process has progressively increased in magnitude and tempo and is still going on today.

It is expounded in this manner that the saturation process of an uninhabited area is a gradual one, and is not completed within a season or two, but may take many years, provided there is ample space in the area surrounding the original population-centre to absorb the surplus numbers. The saturation process in respect of elephant within Area C may thus be safely assumed to be of considerable duration yet while there still exists enough "Lebensraum" in under-populated areas in the Park. Only when the surrounding areas also become saturated, will population pressure augur serious destruction of the habitat.

If the number of elephant per square unit in Area C be considered then as a "safe" natural saturation level during any time within the next year or so, this may serve as a realistic basis for calculating also the carrying capacity for elephant of other areas in the Park. The limitation of population growth within Area C during the coming year will naturally leave considerable scope for natural increase of other competing herbivorous species — which is very desirable in the case of the rarer forms.

In order to obtain a practical basis for the comparison of present conditions in respect of population numbers, grazing potential and other features of Area C with other areas in the Park, a map was compiled (vide Map No. 4) distinguishing the following zones:—

(i) Areas inhabited by concentrations of elephant (mainly breeding herds) during the dry season.

(ii) Areas inhabited mainly by groups of or single bachelor bulls during the dry season.

(iii) Areas which are available as winter-habitats but which are poorly, if at all, utilised by elephant.

(iv) Areas which are primarily utilised by all elephant during the rainy season.

An indication of the relative grazing pressure exerted by each grazing or browsing competitor, as well as the whole herbivorous community, is also necessary. The only realistic approach here is not a comparison with domestic animal units, but rather a calculation of the biomass on each of the respective areas. The surface area of each particular zone was established planimetrically and to each species a figure denoting mean body weight (in lbs.) was allocated. By multiplying the number of animals with the mean body weight, the relative biomass of the species in the particular area was obtained. This can be further converted to a figure in lbs./unit area (square mile) by dividing the total biomass for the species by the total surface area of the zone in question.

The accompanying series of tables provide the required data for each area, and constitute a sound basis for comparison of heavily populated with sparsely populated areas.

The mean body weights for the respective species have been so calculated as to also make provision for the large numbers of young and subadults which are present in any community, and in this respect we believe that our figures are more realistic than those proposed by other workers.

Species	Mean Body Weight in lbs.					
	Pienaar et al.	Grzimek & Grzimek (1960)	Petrides (1956)	Bourlière (1960)	Petrides & Swank (1955)	Lamprey (1965)
Elephant	7000	7000	—	7000	7000	4700
Hippopotamus	2500	—	—	2800	3000	—
Buffalo	1100	1000	—	1000	1000	1100
Roan antelope	500	—	—	—	—	—
Sable antelope	350	—	—	—	—	—
Eland	1000	1000	1000	—	—	1200
Tsessebe	200	—	—	—	—	—
Giraffe	1500	2400	2500	—	—	1700
Waterbuck	450	300	450	300	450	470
Wildebeest	400	450	450	—	—	500
Zebra	475	650	650	—	—	550
Impala	90	150	150	—	—	110
Kudu	380	—	—	—	—	—
Nyala	120	—	—	—	—	—
Square-lipped rhino	3000	—	—	—	—	—
Reedbuck	120	—	—	—	100	—
*Others	50	—	—	—	—	—

* Includes steenbuck, duiker, Sharpe's steenbuck, bushbuck, warthog, bush pig, mountain reedbuck, red duiker, suni, klipspringer and oribi.

	Vegetation type	Size of area in sq. miles.	Annual mean density./sq. mile.	Biomass in lbs./sq. mile.	Source of Reference.
Nairobi National Park, Kenya.	Acacia-Themeda savanna grass land (heavily grazed).	11	134	47,000	Petrides (1956)
Nairobi National Park, Kenya.	Acacia-Themeda savanna grass land (average grazing).	—	80-90	25,000-30,000	Petrides (1956)
Albert National Park, Congo.	"Steppe".	—	200-225	43,281 and 116,967	Bourliére and Verschuren (1960)
Albert National Park, Congo.	"Steppe" and savanna with thicket.	—	49	57,099	Bourliére and Verschuren (1960)
Albert National Park, Congo.	Wooded savanna.	—	46	88,949	Bourliére and Verschuren (1960)
North Rukwa plains, Tanzania.	Grassland.	c.300	15	—	Vesey-Fitzgerald (1960)
Central Rukwa plains, Tanzania.	Grassland.	c.500	8	—	Vesey-Fitzgerald (1960)
Ngorongoro crater.	Grassland.	c.120	c.100	c.35,000	Lamprey, 1965
Tarangire game reserve, Tanzania. Transect area.	Acacia savanna.	12	117	70,000	Lamprey, 1965
Tarangire game reserve. Total area.	Acacia savanna.	c.6550	c.10	c.6,000	Lamprey, 1965
Masai steppe.	Grassland and Acacia savanna.	c.8000	c.2.5	c.1,250	Lamprey, 1965
Doma-Mikumi controlled area, Tanzania.	Acacia savanna and Brachystegia woodland.	c.800	c.10	c.6,000	Lamprey, 1965
Serengeti plains, Tanzania.	Grassland and Acacia savanna.	c.4600	c.80	c.21,000	Grzimek & Grzimek (1960)
Serengeti plains.	Grassland and Acacia savanna.	c.6500	c.140	c.36,000	Stewart & Talbot (1961)
Serengeti-Mara.	Grassland and Acacia savanna.	—	—	70,000-100,000	Talbot & Talbot (1963)
Henderson Ranch. S. Rhodesia.	Open Mopani woodland.	—	—	26,500	Dassman & Mossman (1961)
Queen Elizabeth National Park, Uganda.	Open plains with scattered forested areas.	—	—	200,000	Swank & Petrides (1958)
South Kivu area, Congo.	Forest-savanna.	—	—	34,000	Pirlot (1956)
Kruger National Park.	Predominantly Mopani-, Acacia- and Combretum-woodland and savanna.	7,340	38.59	*10,529.6	This study.

* The relatively low biomass per unit area obtained for the Kruger Park may be partly due to the lighter mean body weights allocated to the respective species. The modification was thought necessary to obtain a more exact result, but even when employing the same standards as the other workers, it is evident that the Kruger National Park with its rich variety of herbivorous species and vegetational types, has nowhere reached saturation level in respect of grazing potential, and the impression is corroborated that the real limiting factor which stifles population growth is a lack of adequate water supplies.

If the total live weight (i.e. biomass) of ungulates per unit area of the Kruger Park as a whole is compared with that of a number of well-known game habitats elsewhere in Africa, it becomes abundantly clear that we are by no means experiencing the grazing pressure (at any time of the year) that is prevalent in the majority of these areas. Even our most densely populated areas (the Lebombo flats of Crocodile Bridge section, the Lower Sabi-Skukuza riverine strip, as well as Pafuri, during the winter months), do not as yet carry the game numbers of many other areas in Africa with a weaker grazing potential. (Vide Table below).

In the light of all the available factual data, and with Area C (which supports a biomass of 14,402.5 lb./sq. mile) as basis, it now becomes possible to adjudicate the different seasonal feeding grounds (as expounded in Map No. 4) on merit, and to provide some indication of where and why elephant may yet be allowed to reproduce in an uninhibited manner, and for how long.

Area A. (Biomass 47,180 lbs./sq. mile).

This is the area which supports the greatest animal mass/unit area in the whole of the Kruger Park, and the grazing pressure here is most acute during the winter months.

Although mortality as a result of food shortage or starvation is the exception here — this region encompassing dense stands of a variety of shrub forms such as *Azima tetracantha, Macrorungia formosissima, Anisotes sessiliflorus, Capparis tomentosa, Acacia tortilis, Ziziphus mucronata* and others, as well as a leafy tree-stratum which provide sufficient food during the winter-months when leaves and seed pods are shed—it is obvious that we are dealing here with one of the few really overpopulated areas in the Park. Distinctive indications of such a state are the almost total disappearance of the grass cover and the inability thereof to recover completely even during favourable wet seasons, deficiency diseases amongst local game animals, a lack of sufficient predation, erosion, heavy parasitic infestation and epidemic diseases (including anthrax), and lastly, extensive damage by elephants to trees and shrubs during the winter months.

This area is floristically unique since it represents the only strip of really typical tropical riverine forest which is accessible for tourist traffic, and also contains the most beautiful fever tree forest and a magnificent collection of large baobab trees and Mlala palms. It is also the outstanding nyala habitat, and these animals are seldom encountered by tourists elsewhere in the Park.

Elephants invade this area only during the winter months, and through the years their numbers have increased to such an extent that at one stage during the recent severe drought close on one hundred of these pachyderms were concentrated here.

It is evident from the census data that these seasonal visitors were all bulls, of which at least some are probably temporary immigrants from Mocambique and Southern Rhodesia.* Others move in from the arid sand-

* Since the writing of this paper this has been proved by a marking campaign whereby 12 elephant bulls were captured and marked at Pafuri during July 1965.

veld regions in the south when the water in the pan-country dries up.

It seems possible that the majority of these marauders, who for several months during the dry season wreak havoc amongst the trees and shrubs at Pafuri, could be withheld from their bad practices if sufficient permanent water were made in their traditional home ranges in the sandveld, since it has been found that they leave Pafuri immediately after the first rains. As yet the search for artificial water in the sandveld has been fruitless however, and if the vegetation of Pafuri is to be preserved in its present state, appropriate measure will have to be taken against the elephants here (which may be regarded as representing the surplus bulls in the Park).

Concurrently, the numbers of grazing species (and here particularly impala) will have to be drastically culled in order to provide the necessary respite for the grass cover to re-establish itself.

With the object of barring completely the entry of elephant, the possibility should be considered of setting up a simple cable fence south of the present main road to the W.N.L.A. quarters, all the way from the Tula-mila ridges, and closing the gap along the eastern boundary between beacon No. 11 and the Levubu-Limpopo confluence, with an entrance gate at Tambye drift.

In the meanwhile, further attempts should be made to augment the water shortage in the sandveld. At least half, but preferably three-quarters of the impala at Pafuri should be translocated or destroyed.

After complete recovery of the vegetation in this area, the carrying capacity of this isolated river valley will in all possibility be one of the highest in the Park, and small numbers of elephant will then, as in the days of yore, do no appreciable damage.

Area B. (Biomass 9,127 lbs./sq. mile).

This region, which covers primarily the area between the Shingwidzi- and Mphongolo rivers, is potentially as suitable an elephant habitat, if not more so, than Area C. Lack of adequate water supplies is a classic limiting factor in this area however, and in view of the several large breeding herds already roaming these parts ,the natural water supplies in the two large seasonal rivers particularly, but preferably also in the Phukwane, should be stabilised by building a number of weirs at strategic sites, as well as the large Mbomene dam in the Mphongolo.

The artificial water resources of this area would never suffice in the needs of the large elephant- and buffalo herds here, should the natural watering points dry up completely during any future period of drought.

Such a critical situation was imminent during the recent severe drought, and the rains brought relief only in the nick of time.

Provided that the water resources be safeguarded in this manner, and it is essential that this is done in any event, this area could support with

ease a further 350 elephant (which would then represent the same biomass per unit area as Area C, calculated according to the differential percentage of the biomass of each species).

The present difference in biomass/sq. mile between Areas C and B = 14,402.5 — 9,127.0 i.e. 5,275 lbs./sq. mile. This figure multiplied by the total surface area (i.e. 930 sq. miles) provides an indication of the potential biomass that the area may support above the present total. Elephant represent 47.7 per cent of this total and if the adjusted figure for potential biomass is divided by the mean body weight of elephant (7,000 lbs.), the total number of elephant which the area could support in addition i.e. 334, is obtained.

Area C. (Biomass 14,402.5 lbs./sq. mile).

The huge area (1,030 sq. miles), lying mainly between the Letaba- and Tsende rivers, serves as standard of a "naturally saturated" zone in respect of elephant (particularly in the northern mopani veld).

Elephant control may be instigated here at any time in the immediate future and the consequences of such cropping can only be beneficial to the population, as well as to the whole animal community and their habitat.

Area D. (Biomass 12,141.4 lbs./sq. mile).

The total biomass/sq. mile of this area is rapidly approaching that of standard Area C, but despite the fact that large tracts in this region is covered by *Combretum-Acacia* savanna or woodland, which certainly has a lower carrying capacity for elephant than the northern mopani veld, there remains some scope for further development. The stabilising and supplementing of artificial water resources in the interior regions between the Letaba- and Olifants rivers by the proposed Hlanganine dam and the boreholes along the Mulalane spruit, make accessible a much larger grazing area throughout the year, and will also affect Area (e), which is at present hardly utilised at all.

These measures would, when completed, enable Area D to support a further 100 elephant with ease, particularly in the northern mopani covered parts. In this respect it will also be necessary to devote attention to the leaking Shisakashangondzo dam, so that it might function as the permanent watering point for which it was originally intended.

Area E. (Biomass 18,117.2 lbs./sq. mile).

An area of some 230 square miles that follows the course of the Nwaswitsontso river. Judged strictly on total biomass, it would appear that the saturation level has already been exceeded here when compared with standard Area C. In reality, however, the two areas are hardly comparable in view of the fact that the grazing (grass cover) of Area E has a higher carrying capacity than the mopani veld of most of Areas B, C, and D, and the high biomass here is mainly represented by the very much larger number of grazing species which utilise this particular food stratum.

The total number of elephant (62) of this area is in fact relatively

small, and only represents 10.4 per cent of the total biomass. Should this number even double itself, they would still not contribute a menace to the vegetation of this area or to the competing ungulate species which are dependant on it. Water resources must be further safeguarded here by the sinking of a borehole in the immediate vicinity of the Ngwenyene dam.

Area F. (Biomass 31,215.5 lbs./sq. mile).

Although this region (420 sq. miles in extent), which comprises mainly the riverine strip along the Sabi east of Skukuza, is one of the most densely populated areas in the Kruger Park, there is as yet little indication of serious overgrazing, except the normal localised trampling of the riparian grazing during the winter months. The number of elephant here (161), which represents only 8.6 per cent of the total biomass, and utilise primarily the dense scrub of the Nwatimhiri bush as well as the riverine vegetation during the dry season, would normally not be considered as a serious destructive force in the habitat, even if they should double or treble their number.

In view of the very heavy tourist traffic however, particularly during peak periods in the dry season, between Skukuza and Lower Sabi and along both riverbanks, it would be unwise, for safety reasons, to allow the present number of elephant further scope for increase. It must be remembered that although this area accomodates only one-seventh of the elephant population of Area C, the only four serious clashes between elephant and tourist cars in the history of the Park, have all recently occurred in this area.

It would in fact be desirable to keep these animals away from the Sabi river banks for as long as possible, and a large dam in the headwaters of the Munweni spruit and the stabilising of the Mlondozi dam as a permanent water resource, should contribute significantly to this end.

Area I. (Biomass 4,713.1 lbs./sq. mile).

This area (mainly that part of the Lebombo flats between Shingwidzi and Klopperfontein) harbours an elephant population during the dry season which is made up almost entirely of bachelor bulls, and is potentially (vide biomass of Area III) one of the richest and most suitable elephant habitats in the whole Park. The serious lack of ample, permanent watering points rules it out of bounds for the larger breeding herds during the winter months, and the present series of windmills just can not provide in the needs of so many large animals.

Wherever permanent watering points with sufficient capacity have been established in this region, elephants in considerable numbers (even breeding herds) were soon attracted. This has been proved beyond doubt by the Mpenza and Manyeleti dams, and will, we feel, be confirmed also by the Hlamalala- and Stangene dams, once they are discovered.

Elephant (even in their hundreds) can only have a beneficial effect on the Lebombo flats with its very luxurious grass cover, and will probably contribute greatly in limiting further encroachment by scrub mopani, which,

in turn, would make the area more accessible and acceptable for flats loving or grassland species such as the rare roan antelope, eland, tsessebe, ostrich, wildebeest, etc.

With this end in mind, it would be highly desirable to conduct a proper survey of the Lebombo flats (also towards the south), to ensure optimum utilisation of this potentially rich game area through the building of an additional series of strategically placed large earth dams. Until such time as more adequate water supplies are established here, elephant breeding herds will continue to shun the Lebombo flats as a dry season habitat, and the situation may be left unaltered.

Area 2. (Biomass 13,951.3 lbs./sq. mile).

A region which encompasses the Nwambiya and Machai sandveld areas. In this arid country, where Malonga spring and the weak Machai borehole are the only permanent watering points, only a small number of elephant can survive during the winter months when the water in the seasonal pans dries up. The rest have to move out in search of water, and the majority migrate northwards to Pafuri.

For several years now we have tried without avail to augment the water resources here by means of one or two boreholes. Not only would this help in drawing a number of elephant away from Pafuri, but it would also relieve the intense pressure on Malonga spring during the dry season. If further drilling attempts are indeed successful, the number of elephant here will have to be strictly limited in view of the rare and unique flora of this area, and the large amount of water consumed by elephants at the expense of smaller and less common species.

Areas 3 and 5. (Biomass 9,935.1 lbs./sq. mile and 5,338.0 lbs./sq. mile).

Both these areas, which at present harbour only lone or groups of bachelor bulls during the dry season, may be developed, as in the case of Area 1, into important elephant habitats and to the advantage of the community as a whole, by the establishment of adequate permanent water supplies in addition to the existing chain of windmills. The possibility of constructing a large earth dam in each of the Shawu and Dzombo valleys should be investigated.

Areas 4, 6 and 7. (Biomass 3,914.0 lbs./sq. mile, 4,782.3 lbs./sq. mile and 12,094.0 lbs./sq. mile).

All of these relatively small areas are only visited and utilised by a few nomadic elephant bulls during the dry winter months, and nothing will be achieved by disturbing the present status quo.

Area 8. (Biomass 10,761.3 lbs./sq. mile).

This extensive area (400 sq. miles), which covers mainly the *Bothriochloa* infested grazing regions around the borehole complex of Satara section, may be regarded as a region that lends itself to further development as an elephant habitat. In spite of the fact that the Gudzane dam, which is the largest and most permanent of its kind in the Park, is situated in this area

and was built many years ago, the number of elephants has remained relatively constant. The reason for this apparent anomaly would appear to be the fact that the great majority of fodder trees in this area is deciduous, and sufficient browse is thus not available during the dry season, in contrast with the mopani veld, where even the dry mopani leaves, twigs and bark are eagerly sought out by elephant during this time.

Although a higher density of elephant in this area is desirable in all respects (vide the extensive bush encroachment during recent times), it is doubtful whether these animals will react favourably on any programme of development.

Areas 9 and 10. (Biomass 20,663 lbs./sq. mile and 20,183.2 lbs./sq. mile).

These two areas comprise respectively the Sabi riverine strip west of Skukuza and the winter grazing along the Crocodile river, between Boulders and Crocodile Bridge.

Both these areas harbour only a small residential elephant population during the dry season, consisting almost entirely of bachelor bulls. In view of the high population density of other species (particularly impala) in both areas (Area 10 is in fact the only region in the whole Park where a number of animals often succumb, directly or indirectly, during drought periods for lack of food), and the vulnerability of the border fences along the rivers, where intensive agricultural development encroaches on our borders, it is undesirable to encourage increased numbers of elephants here. The new boreholes in the mountainous country of Malelane section, and along the Nwashitsaka at Mklari, may possibly be instrumental in keeping elephants away from the perennial rivers during the winter months.

Areas i, ii and iii. (Biomass 5,445.8 lbs./sq. mile, 9,148.0 lbs./sq. mile and 36,240 lbs./sq. mile).

All these areas are potentially accessible to elephant during the dry season, but of the three, it is probably only Area ii (the tall grass savannah and woodland of Pretoriuskop section) where elephant may eventually settle in significant numbers, and where their presence will have a beneficial effect on the habitat.

Except for Area iii, elephant are at present seldom encountered in these regions during the winter months, and then only odd nomadic bulls.

Area i is apparently unacceptable topographically and it would be undesirable, in an yevent, to allow large numbers of elephant along this boundary river with its exceptional riparian vegetation, nearby bush-clad ravines and rare Msimbit forests.

Area iii is, like Area 8, probably unsuitable as winter feeding ground for numbers of elephant, in view of a lack of abundant evergreen trees and shrubs, or for that matter, species which retain their leaves for a longer period during winter than those of the knobthorn-marula association of this area.

Should elephants penetrate the tall grassland around Pretoriuskop during future dry seasons, this would not be an alarming phenomenon in such a sparsely populated region, and they may even actively contribute in revoking the open savanna aspect of bygone days.

Areas (a) — (j). (Biomass fluctuates from 204.3 lbs./sq. mile to 3,984 lbs./sq. mile).

These are all primarily summer feeding areas of elephant which are utilised during the rainy season by breeding herds as well as nomadic bulls, and in the case of Areas (f) and (h) in the Central district, also by the masses of migrating wildebeest and zebra.

Under no circumstances should these areas be tampered with, and particular care should be taken against the establishment of permanent water supplies in such summer habitats.

To recapitulate, it may be stated that elephant have attained the safe "natural" saturation level in respect of water, food supply, living space, associated herbivora and tourist traffic, in Area C of the northern district, and with the exception of Area ii, also south of the Sabi river.

Elsewhere in the Park (except in the case of Pafuri, where control measures have become imperative), elephants may be allowed to multiply naturally until the population peak is reached which is prescribed above for the respective areas, provided of course that the concomitant furnishing of additional water supplies has been successfully completed.

The systematic culling of elephant numbers in the areas indicated above, may commence at any time, and should be conducted along the lines which will be subsequently discussed.

ELEPHANT CONTROL AND CULLING OF SURPLUS NUMBERS.

Having decided where control should be exercised, the topical question now is how and when to impose the culling scheme.

In a sanctuary such as the Kruger Park, where elephants have for so many years only sporadically been destroyed, and in small numbers, it is most essential that the present amicable relationship between man and beast, and particularly between tourist and elephant, be preserved at all costs. Where necessary, elephants have to date been shot with a heavy calibre rifle, but control measures have been almost exclusively limited to marauding bulls, which have caused damage, singly or in groups, to the border fence or adjoining private property, or which have been badly injured in fights or as a result of poaching activities.

Not once during the 60 years since elephants have returned to the Park, has any form of quantitative control been conducted, and the breeding herds have been allowed to wend their ways unmolested and to roam at will through their chosen habitats.

It is well-known that in all cases where these timid breeding herds have been hunted intensively (in areas outside the Park), this had a most

disturbing influence on the animals. These sagacious beasts will initially attempt all in their power to dodge the hunters and will move hither and thither over large and even foreign areas. If the hunters keep on the trail however, the animals become extremely vicious and develop vindictive traits. A whole herd would then often charge their persecutors with murderous intent in the event of one of their comrades being shot. (In this respect reference might be made to the case of the elephants in the Addo bush, where even today, more than 30 years since the campaign of destruction by Major Pretorius, the survivors do not tolerate the presence of human beings, and will charge on the least provocation).

The terror that will follow in the Park on a general cropping of breeding herds with rifles can well be imagined, and such a situation will not only be fraught with grave danger to the officials in charge of this unenviable task, but will be equally hazardous to our heavy tourist traffic.

Not only will the animals scatter over wide areas, and may even cross the borders in considerable numbers, but where the rifle is used, elephant will inevitably be wounded, thus creating an additional source of danger to both officials and visitors. In cases where the herd displays aggressive tendencies the hunter may be forced to shoot his way out of a difficult situation (if indeed this is possible!), and there can thus be no question of selective control.

The recent advances in the field of game immobilization with drugs however, solves also this thorny problem, and makes the selective culling of elephant breeding herds in a Park with heavy tourist traffic a practical proposition. Preselected animals may be destroyed, silently and efficiently, from a distance of 100 yards or more, by the humane method of administering an overdose of certain narcotic or paralysing drugs. For this purpose dart-syringes of 3-10 ml. capacity can be used, which are projected from a safe distance by means of a powerful and very accurate crossbow.

There is very little disturbing influence amongst the herd, provided they are properly stalked, and another decided advantage of the method is that it is technically impossible to wound a beast. (Pienaar and Van Niekerk, 1963).

In the event of mal-function of the dart-syringe, the darted animal is none the worse for wear, and rubs off the dart against the nearest tree or shrub. Otherwise the affected beast will collapse silently and without disturbing the rest of the herd.

We would then recommend most strongly to the Board that all culling of a selective or quantitative nature should be conducted along these lines in future, and that only nomadic bulls be shot as before with rifles.

A dose of 10-15 ml. of Succinyl-choline chloride at a concentration of 500 mgms./ml. would be ample to immobilize even the largest elephant bull and would kill it within minutes after effecting collapse. The meat of the animals destroyed in this manner is fit for human consumption, but the one disadvantage is the large and heavy dart-syringes necessary to

contain the full dose. This would mean that the effective distance between marksman and target would be cut down to about 50 yards.

The advent of the new highly potent morphine analogues of the M-series (Oripavine derivatives) eliminated this problem. Only 8 mgms. of the drug M-99 is necessary to immobilize completely for several hours the largest elephant bull, and the subsequent destruction of such a beast presents no difficulty. The effective dose of the drug is easily contained in even a 3 ml. capacity dart-syringe, and animals can therefore be darted from distances up to 120 yards.

This would, in our opinion, be the drug of choice and although the meat of such animals may not be fit for human consumption (an aspect which will have to be investigated), it may nevertheless be cooked, minced and dried, and distributed as fertilizer.

For establishing an assized basis for quantitative culling, it will be necessary to obtain an indication of the relative percentage of the different age groups in the population. As an acceptable and visible indicator of a particular age group, the tusk length or size may be utilised.

It is true, of course, that the tusks of some elephants will develop more rapidly than in others, and that relatively younger elephant may carry larger and heavier tusks than older animals (Irwin, 1964), but as a general characteristic of age (particularly amongst the younger animals), which is visible from a distance, it is about the best that could be suggested.

Brooks and Buss (1962) and others have studied the tusk weights of elephant which have been destroyed in Uganda during the period 1947-1957, whether by hunters or natural causes. It was found that the tusk weight group of 0-10 lbs. represented 41% of a total of 16,237 elephants destroyed. The other tusk weight groups were indexed as follows:

11— 20 lbs.	—	34%
21— 30 lbs.	—	15%
31— 40 lbs.	—	5%
41— 50 lbs.	—	3%
51— 60 lbs.	—	1%
61— 70 lbs.	—	0.4%
71— 80 lbs.	—	0.3%
81— 90 lbs.	—	0.1%
91—100 lbs.	—	0.1%
101—110 lbs.	—	0.1%

Where the allowable culling ceiling is now known, it is a relatively simple procedure to calculate the number of each tusk weight group to be destroyed from the percentages provided above. All that remains then is that an equal number of males and females be shot and that a pro rata number be allocated to each area where culling becomes essential.

One could, of course, adopt the percentage proportions of the Uganda tusk weight groups for local applications, but it would be more desirable to

conduct a pilot cropping scheme (similar to that which was completed on the hippo-population of the Letaba river recently), whereby a predetermined number of elephant are destroyed at random. This would certainly provide a more accurate indication of the tusk weight groups obtaining in the Park. We have reason to believe that our elephants carry heavier ivory generally than those of Uganda, but this will soon be proved by the experimental scheme. One should also distinguish between the tusk weight classes of females and males.

Other measurements and weights of all the animals destroyed can be recorded at the same time, and from these one may even obtain a more exact criterion of age class. Valuable data could also be obtained in respect of the reproductive pattern — particularly such controversial aspects as the age of puberty, suckling period, time lapse between successive births, etc., as well as disease conditions affecting elephants, their daily food-intake per unit weight, etc.

It is clearly evident from the analysis of tusk weight groups in Uganda, that the heavy tuskers (i.e. the oldest age groups) are by far in the minority. Significant also is the fact that all the weight groups from 51-100 lbs. represent only 2 per cent of the total.

Since it will probably never become necessary to destroy more than 100-150 elephant annually in the Kruger Park, it is obvious that no more than 2 or 3 large adult bulls with tusks in the 51-110 lbs. group should be included. The outstanding specimens will not be destroyed in any case for aesthetic reasons, regardless of whether they still partake in breeding activity or not.

There are today few areas in Africa that can boast the large number of heavy tuskers which occur in the Kruger Park, and this is certainly a state that should be preserved with pride and at all costs.

At present, however, from 30-40 elephant in this tusk weight group are destroyed annually along our borders and elsewhere in the Park. Fortunately, a considerable surplus of bulls have accumulated through the years by continuous immigration from Moçambique, but the grave warning spelled by the present tendency, not only for the welfare of the population, but also for the whole preconceived scheme of selective cropping, is manifested by the fact that the entire Park today harbours not more than some 400 elephant in this tusk weight class.

At the present rate of destruction of these large tuskers serious inroads will soon be made on the natural population structure and the ultimate effects thereof can be most detrimental.

If culling of surplus numbers has to be conducted on a preconceived and sound scientific basis, it is of primary importance that there should be absolute control over the numbers of each age group that have to be destroyed. The whole scheme would otherwise be senseless and arbitrary, and the results unpredictable.

For this reason, we must impress on the Board the urgency of taking the necessary steps whereby the present vulnerable border fence (vide Map No. 4), is made elephant proof.

Only when this has been completed, will we have complete control over culling operations, and will elephants be destroyed *within* our boundaries when and where the circumstances demand such measures.

It would furthermore be advisable to check on the results of the culling campaign by means of regular aerial surveys. In this sense, one would be particularly curious to ascertain the possible disturbing effects of the scheme on the elephant population, and the adaptations that this may cause in the seasonal migrations or population translocations from one area to another.

Although not essential, it may be desirable to confine control activities to the summer months, when the elephants are scattered over a wide area and a more even crop may be obtained. Tourist traffic is also less active during this period and contact with breeding herds would be minimised.

Elephants which have to be marked, on the other hand, will have to be captured during the dry season in order that the desired results may be obtained.

RESUMÉ

As a guide to the Board, the following recommendations are suggested as a summary of our views:—

(i) At least one complete aerial census of elephants must be conducted during a suitable period in the rainy season, for obtaining an indication of the actual residential elephant population of the Kruger Park. All aerial surveys of this nature should in future be executed by means of a helicopter.

(ii) A number of elephant bulls of the bachelor or nomadic class must be captured and marked as soon as possible, in order to ascertain their future movements, and their possible rôle in breeding activity. This project should preferably be commenced at Pafuri.

(iii) It is also desirable that a number of individuals be marked in the various breeding herds of the respective winter feeding grounds, so that grazing range and seasonal migrations may be established with greater certainty.

(iv) More specialised research is essential in respect of reproduction aspects such as age of puberty, time lapse between successive births, mortality amongst calves and adults, etc.

(v) The region marked C on the accompanying map (4) may be accepted as an area which has become naturally saturated with elephant over a long period, without disturbances worth mentioning in the balance of these climax animals with the water resources, food and associated species in the habitat. Control of excess numbers may commence here at any time in the near future.

(vi) With the biomass per unit area of Area C as basis, a quota of elephant may be allocated to all the other seasonal habitats, with due consideration of such factors as the preservation of a virile population, their competition with other associated species in respect of food and especially water, the safety of the visitors to the Park, the undeniable rôle of elephants in the economy of nature, and possible future development of such areas.

(vii) Except for the tall grassland of Pretoriuskop section, where elephants can perform a useful function, they should be dissuaded from entering the area south of the Sabi river in larger numbers.

(viii) It is essential that a programme, whereby water resources is stabilised and augmented in underpopulated and potentially rich grazing areas, is systematically purveyed.

(ix) It is urgently recommended that the traditional feeding grounds of the large elephant breeding herds are not further invaded or encroached upon by tourist activities.

(x) Quantitative culling of elephant numbers should be conducted by means of the crossbow and drugged darts. This will rule out the danger element for official and tourist, and guard against disturbance of the seasonal rhythm of breeding herds. The potent morphine analogue M-99 is recommended for this purpose, despite the fact that meat of animals destroyed therewith may not be fit for human consumption.

(xi) Cropping should be conducted according to a controlled and standardised technique and must be limited to the area within our boundaries. A practical basis whereby culling of the respective age classes may be effected, is the tusk weight index.
It is desirable that a pilot cropping scheme be launched in a suitable area, whereby a predetermined number of animals is shot at random, to furnish the necessary exact data for compiling such an index, and in addition also information in respect of reproduction, food consumption, disease conditions, parasitic infestations, etc.

(xii) In order that the destruction of a larger number of big tuskers annually, other than is prescribed by the tusk weight index, may be prevented, it is imperative that the vulnerable portions of the boundary fence be made elephant proof. Until such time as this can be completed, shooting of bulls with large tusks should be strictly limited.

(xiii) The quantitative culling of buffalo numbers is not necessary at this stage, but the position on the Lebombo flats of Crocodile Bridge section should be carefully watched.

BIOMASS PER UNIT AREA FOR THE SEASONALLY DEMARCATED FEEDING GROUNDS OF ELEPHANTS IN THE KRUGER NATIONAL PARK.

AREA: Kruger National Park. SURFACE AREA: 7,360 sq. miles.

	Total Number	Density per sq. mile	Mean body weight (lbs.)	Biomass lbs. (Total area)	Biomass per square mile	Differential percentage of total biomass
Elephant	2,374	0.32	7000	16,618,000	2,257.9	21.45%
Hippopotamus	2,865	0.39	2500	7,162,000	973.2	9.24
Buffalo‡	10,614	1.44	1100	11,675,400	1,586.3	15.06
Roan antelope	351	0.05	500	175,500	23.8	0.23
Sable antelope	1,236	0.16	350	432,600	58.8	0.56
Eland	540	0.07	1000	540,000	73.4	0.69
Tsessebe	715	0.09	200	143,000	19.4	0.18
Giraffe	2,975	0.40	1500	4,462,500	606.3	5.76
Waterbuck	4,085	0.55	450	1,838,250	249.7	2.37
Wildebeest	13,035	1.77	400	5,214,000	708.4	6.72
Zebra	14,400	1.96	475	6,840,000	929.3	8.83
Impala	204,050	27.72	90	18,364,500	2,495.1	23.70
Kudu	6,875	0.93	380	2,612,500	354.9	3.37
Nyala	980	0.13	120	117,600	16.0	0.15
White Rhinoceros ...	87	0.01	3000	261,000	35.5	0.34
Reedbuck	1,210	0.16	120	145,200	19.7	0.19
*Others	17,950	2.44	50	897,500	121.9	1.16
TOTAL	284,342	38.59	273**	77,500,050	10,529.6	100.00

* Includes — Steenbuck, Sharpe's steenbuck, duiker, red duiker, warthog, bush pig, bushbuck, mountain reedbuck, klipspringer, suni, and oribi.
Stocking rate of Area K.N.P. is 38.59 animals (reresentative of a biomass of 10,529.6 lbs.) per square mile or per 302 morgen.

∴ 7.82 morgen per animal with a mean body weight of 273.0 lbs.
Grazing potential thus available for an imaginary grazing and browsing animal of 273 lbs.** would be 7.82 morgen per head.

** The mean body weight per head of a total 284,342 animals in the Kruger Park.

‡ Census total + 100 (50 Pretoriuskop area, 50 Lebombos, Crocodile Bridge area).

BIOMASS PER UNIT AREA FOR THE SEASONALLY DEMARCATED FEEDING GROUNDS OF ELEPHANTS IN THE KRUGER NATIONAL PARK.

AREA: A. SURFACE AREA: 25 sq. miles.

Species	Total Number	Density per sq. mile	Mean body weight (lbs.)	Biomass lbs. (Total area)	Biomass per square mile	Differential percentage of total biomass
Elephant	86	3.44	7000	602,000	24,080	51.0%
Hippopotamus	55	2.20	2500	137,500	5,500	11.6
Buffalo	80	3.20	1100	88,000	3,520	7.5
Roan antelope			500			
Sable antelope			350			
Eland			1000			
Tsessebe			200			
Giraffe			1500			
Waterbuck	50	2.00	450	22,500	900	1.9
Wildebeest			400			
Zebra	100	4.00	475	47,500	1,900	4.0
Impala	1,800	72.00	90	162,000	6,480	13.7
Kudu	150	6.00	380	57,000	2,280	4.8
Nyala	400	16.00	120	48,000	1,920	4.1
White Rhinoceros			3000			
Reedbuck			120			
*Others	300	12.00	50	15,000	600	1.3
TOTAL	3,021	120.80	390.5	1,179,500	47,180	99.9

* Includes — Steenbuck, Sharpe's steenbuck, duiker, red duiker, warthog, bush pig, bushbuck, mountain reedbuck, klipspringer, suni, and oribi.
Stocking rate of Area A is 120.8 animals (representative of a biomass of 47,180 lbs.) per square mile or per 302 morgen.

∴ 2.5 morgen per animal with a mean body weight of 390.5 lbs.
Grazing potential thus available for an imaginary grazing and browsing animal of 273 lbs.** would be 1.7 morgen per head.

** The mean body weight per head of a total of 284,342 animals in the Kruger Park.

BIOMASS PER UNIT AREA FOR THE SEASONALLY DEMARCATED FEEDING GROUNDS OF ELEPHANTS IN THE KRUGER NATIONAL PARK.

AREA: B. SURFACE AREA: 930 sq. miles.

Species	Total Number	Density per sq. mile	Mean body weight (lbs.)	Biomass lbs. (Total area)	Biomass per square mile	Differential percentage of total biomass
Elephant	579	0.62	7000	4,053,000	4,358	47.7%
Hippopotamus			2500			
Buffalo	1,228	1.32	1100	1,350,800	1,452	15.9
Roan antelope	70	0.07	500	35,000	38	0.4
Sable antelope	150	0.16	350	52,500	56	0.6
Eland	120	0.13	1000	120,000	129	1.4
Tsessebe	150	0.16	200	30,000	32	0.3
Giraffe	20	0.02	1500	30,000	32	0.3
Waterbuck	650	0.69	450	292,500	315	3.5
Wildebeest ...	120	0.13	400	48,000	52	0.6
Zebra	800	0.86	475	380,000	409	4.5
Impala	18,000	19.35	90	1,620,000	1,742	19.1
Kudu	950	1.02	380	361,000	388	4.3
Nyala	80	0.09	120	9,600	10	0.1
White Rhinoceros ...			3000			
Reedbuck	50	0.05	120	6,000	6	0.1
*Others	2,000	2.15	50	100,000	108	1.2
TOTAL	24,967	26.80	341	8,488,400	9,127	100.0

* Includes — Steenbuck, Sharpe's steenbuck, duiker, red duiker, warthog, bush pig, bushbuck, mountain reedbuck, klipspringer, suni, and oribi.
Stocking rate of Area B is 26.8 animals (representative of a biomass of 9,127 lbs.) per square mile or per 302 morgen.

∴ 10.3 morgen per animal with a mean body weight of 341 lbs.
Grazing potential thus available for an imaginary grazing and browsing animal of 273 lbs.** would be 8.2 morgen per head.

** The mean body weight per head of a total of 384,342 animals in the Kruger Park.

BIOMASS PER UNIT AREA FOR THE SEASONALLY DEMARCATED FEEDING GROUNDS OF ELEPHANTS IN THE KRUGER NATIONAL PARK.

AREA: C. SURFACE AREA: 1,030 sq. miles.

Species	Total Number	Density per sq. mile	Mean body weight (lbs.)	Biomass lbs. (Total area)	Biomass per square mile	Differential percentage of total biomass
Elephant	1,139	1.11	7000	7,973,000	7,740.8	53.7%
Hippopotamus	678	0.66	2500	1,695,000	1,645.6	11.4
Buffalo	2,230	2.16	1100	2,453,000	2,381.6	17.0
Roan antelope	123	0.12	500	61,500	59.7	0.4
Sable antelope	100	0.10	350	35,000	34.0	0.2
Eland	180	0.17	1000	180,000	174.8	1.2
Tsessebe	120	0.12	200	24,000	23.3	0.2
Giraffe	50	0.05	1500	75,000	72.8	0.5
Waterbuck	500	0.48	450	225,000	218.4	1.5
Wildebeest	120	0.12	400	48,000	46.6	0.3
Zebra	1,200	1.16	475	570,000	553.4	3.8
Impala	11,000	10.68	90	990,000	961.2	6.7
Kudu	1,000	0.97	380	380,000	368.9	2.6
Nyala	100	0.10	120	12,000	11.7	0.1
White Rhinoceros			3000			
Reedbuck	150	0.14	120	18,000	17.5	0.1
*Others	1,900	1.84	50	95,000	92.2	0.6
TOTAL	20,590	19.98	720.1	14,834,500	14,402.5	100.3

* Includes — Steenbuck, Sharpe's steenbuck, duiker, red duiker, warthog, bush pig, bushbuck, mountain reedbuck, klipspringer, suni, and oribi.
Stocking rate of Area C is 19.98 animals (representative of a biomass of 14,402.5 lbs.) per square mile or per 302 morgen.

∴ 15.1 morgen per animal with a mean body weight of 720.1 lbs.
Grazing potential thus available for an imaginary grazing and browsing animal of 273 lbs.** would be 5.7 morgen per head.

** The mean body weight per head of a total of 284,342 animals in the Kruger Park.

BIOMASS PER UNIT AREA FOR THE SEASONALLY DEMARCATED FEEDING GROUNDS OF ELEPHANTS IN THE KRUGER NATIONAL PARK.

AREA: D. SURFACE AREA: 870 sq. miles.

Species	Total Number	Density per sq. mile	Mean body weight (lbs.)	Biomass lbs. (Total area)	Biomass per square mile	Differential percentage of total biomass
Elephant	152	0.17	7000	1,064,000	1,223.0	10.1%
Hippopotamus	829	0.95	2500	2,072,500	2,382.2	19.6
Buffalo	1,164	1.34	1100	1,280,400	1,471.7	12.1
Roan antelope	8	0.01	500	4,000	4.6	0.03
Sable antelope	70	0.08	350	24,500	28.2	0.2
Eland	50	0.06	1000	50,000	57.5	0.5
Tsessebe	30	0.03	200	6,000	6.9	0.05
Giraffe	720	0.83	1500	1,080,000	1,241.4	10.2
Waterbuck	1,000	1.28	450	450,000	517.2	4.3
Wildebeest	550	0.63	400	220,000	252.9	2.1
Zebra	1,500	1.72	475	712,500	819.0	6.7
Impala	35,000	40.22	90	3,150,000	3,620.7	29.8
Kudu	900	1.03	380	342,000	393.1	3.2
Nyala	50	0.06	120	6,000	6.9	0.05
White Rhinoceros ...			3000			
Reedbuck	50	0.06	120	6,000	6.9	0.05
*Others	1,900	2.18	50	95,000	109.2	0.9
TOTAL	43,973	50.54	240.4	10,562,900	12,141.4	99.98

* Includes — Steenbuck, Sharpe's steenbuck, duiker, red duiker, warthog, bush pig, bushbuck, mountain reedbuck, klipspringer, suni, and oribi.
Stocking rate of Area D is 50.54 animals (representative of a biomass of 12,141.4 lbs.) per square mile or per 302 morgen.

∴ 6.0 morgen per animal with a mean body weight of 240.4 lbs.
Grazing potential thus available for an imaginary grazing and browsing animal of 273 lbs.** would be 6.8 morgen per head.

** The mean body weight per head of a total of 284,342 animals in the Kruger Park.

BIOMASS PER UNIT AREA FOR THE SEASONALLY DEMARCATED FEEDING GROUNDS OF ELEPHANTS IN THE KRUGER NATIONAL PARK.

AREA: E. SURAFCE AREA: 230 sq. miles.

Species	Total Number	Density per sq. mile	Mean body weight (lbs.)	Biomass lbs. (Total area)	Biomass per square mile	Differential percentage of total biomass
Elephant	62	0.27	7000	434,000	1,887.0	10.4%
Hippopotamus‡			2500			
Buffalo	405	1.76	1100	445,500	1,937.0	10.7
Roan antelope			500			
Sable antelope	33	0.14	350	11,550	50.2	0.3
Eland			1000			
Tsessebe			200			
Giraffe	350	1.52	1500	525,000	2,282.6	12.6
Waterbuck	250	1.08	450	112,500	489.1	2.7
Wildebeest	1,500	6.52	400	600,000	2,608.7	14.4
Zebra	1,000	4.34	475	475,000	2,065.2	11.4
Impala	16,000	69.56	90	1,440,000	6,260.9	34.5
Kudu	200	0.87	380	760,000	330.4	1.8
Nyala			120			
White Rhinoceros ...			3000			
Reedbuck	20	0.08	120	2,400	10.4	0.06
*Others	900	3.91	50	45,000	195.7	1.1
TOTAL	20,720	90.05	201.3	4,166,950	18,117.2	99.96

* Includes — Steenbuck, Sharpe's steenbuck, duiker, red duiker, warthog, bush pig, bushbuck, mountain reedbuck, klipspringer, suni, and oribi.
Stocking rate of Area E is 90.05 animals (representative of a biomass of 18,117.2 lbs.) per square mile or per 302 morgen.

∴ 3.3 morgen per animal with a mean body weight of 201.3 lbs.
Grazing potential thus available for an imaginary grazing and browsing animal of 273 lbs.** would be 5.4 morgen per head.

** The mean body weight per head of a total of 284,342 animals in the Kruger Park.

‡ The hippos in Orpen dam have not been considered in the above calculation in view of their comparatively small sphere of influence.

BIOMASS PER UNIT AREA FOR THE SEASONALLY DEMARCATED FEEDING GROUNDS OF ELEPHANTS IN THE KRUGER NATIONAL PARK.

AREA: F. SURFACE AREA: 420 sq. miles.

Species	Total Number	Density per sq. mile	Mean body weight (lbs.)	Biomass lbs. (Total area)	Biomass per square mile	Differential percentage of total biomass
Elephant	161	0.38	7000	1,127,000	2,683.3	8.6%
Hippopotamus	482	1.14	2500	1,205,000	2,869.0	9.2
Buffalo	1,270	3.02	1100	1,397,000	3,326.2	10.7
Roan antelope			500			
Sable antelope	110	0.26	350	38,500	91.7	0.3
Eland			1000			
Tsessebe	60	0.14	200	12,000	28.6	0.09
Giraffe	150	0.35	1500	225,000	535.7	1.7
Waterbuck	320	0.76	450	144,000	342.9	1.1
Wildebeest	7,000	16.66	400	2,800,000	6,666.7	21.4
Zebra	4,500	10.71	475	2,137,500	5,089.3	16.3
Impala	42,000	100.00	90	3,780,000	9,000.0	28.8
Kudu	450	1.07	380	171,000	407.1	1.3
Nyala			120			
White Rhinoceros ...			3000			
Reedbuck	50	0.11	120	6,000	14.3	0.05
*Others	1,350	3.21	50	67,500	160.7	0.5
TOTAL	57,903	137.80	226.5	13,110,500	31,215.5	100.04

* Includes — Steenbuck, Sharpe's steenbuck, duiker, red duiker, warthog, bush pig, bushbuck, mountain reedbuck, klipspringer, suni, and oribi.
Stocking rate of Area F is 137.8 animals (representative of a biomass of 31,215.5 lbs.) per square mile or per 302 morgen.

∴ 2.2 morgen per animal with a mean body weight of 226.5 lbs.
Grazing potential thus available for an imaginary grazing and browsing animal of 273 lbs.** would be 3.7 morgen per head.

** The mean body weight per head of a total of 284,342 animals in the Kruger Park.