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EDITORS' NOTE: This article by Daphne Sheldrick is an expanded and updated version of the one that appeared in 1993 in the book "The wilderness guardian"; it also includes an appendix of plants and animals noted in the paper. It has been edited for brevity.

VEGETATION CHANGES IN TSAVO NATIONAL PARK, KENYA, 1885 — 1996: ELEPHANT DENSITIES AND MANAGEMENT

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"Weird and ghastly is the aspect of the grayish coloured trees and bushes; for they are almost totally destitute of tender waving branch or quivering leaf. No pliant twig or graceful foliage responds to the pleasing influence of the passing breeze. Stern and unbending, they present rigid areas of formidable thorns as if bidding defiance to drought or storm. To heighten the sombre effect of the scene, dead trees are observable in every direction, raising their shattered forms amongst the living, unable to hold their own in the struggle for existence. Hardly a spot of green relieves the depressing landscape, and though it was now the wet season, only here and there could a tuft of grass be seen. A dreary silence reigned supreme, unbroken by the chirp of insect or the song of bird. No grass rustled; no leafy branch sighed or spattered like dropping rain. The wind hastening past, fresh from the ocean, raised only a mournful whistling or dreary creaking, 'eerie' and full of sadness, as if it said "here all is death and desolation".

This graphic description of *Commiphora* woodland was made in 1885 by the famous explorer, Joseph Thomson, in his travels to the Interior through the formidable 'Taru Desert'. Seen through the eyes of an Englishman accustomed to soft landscapes, this stark scene must have presented a staggering contrast from England's rolling green countryside, but it was typical of the type of vegetation that clothed the arid regions of low elevation at that time and stretched as an interminable gray wilderness from just beyond the Coastal belt across what was known as the Taru desert, now Tsavo National Park, northeast through Somalia up as far as the Gulf of Aden.

When Tsavo National Park first came into being in April 1948, the vegetation of this huge area consisted almost entirely of dense *Commiphora* woodland, which is, in fact, comprised of a specific plant community growing in association: an assemblage of very interesting, mostly deciduous plant species, mainly 3-4.5 meters (about 10-15 feet) high that have adapted over millennia to cope with arid conditions. At that time (1948) the elephant population, *Loxodonta africana*, in Tsavo was estimated at 15,000 in an area of 7,720 square miles (about 20,000 square kilometers), a density about two elephants per square mile, or less than one elephant per square kilometer.

The main component is a tree with peeling blue bark, *Commiphora baluensis* with related species such as the twisted *Commiphora rivaris*, intermingled amongst many different types of *Acacia*; the frankincense tree of the Bible, tangled and grotesque yet sometimes delicately beautiful when adorned with rosy 'Tsavo' lanterns and stunted evergreens such as *Boscia coriacea*. Beneath this general agglomeration of twisted branches, spikes and stems, smaller species compete for space, some of which are the staple diet of the desert dwelling gerenuk and lesser kudu. At a lower level, shrubs and legumes such as *Barlaria*, *Disperma*, *Indigofera*, *Sericocomopsis*, favored by rhino, *Tephrosia* and many others form a dense tangle. *Sansevieria* grows in dense clumps that make passage in the bush extremely difficult. The soil beneath lies bare and exposed, for the roots of these arid region plants all run close to the surface, inhibiting the growth of grass. Most of the park consists of rather poor red laterite soil resting to a depth of some 1-1.2 meters (about 3-4 feet) on a bed of limestone gravel. Only scattered clumps of the hardiest perennials such as *Aristida* can compete with such greedy surface feeders. Annuals appear as a brief flush following the rains, but die out with the onset of the dry season. For most of the year, the soil is baked to a hard pan and is devoid of ground cover.

Widely scattered larger trees projecting through the bush canopy are also a feature of this habitat. Prevalent is *Delonix elata*, with delicate yellow and white blossoms; *Cassia*, sometimes adorned with bright yellow flowers; the prehistoric looking *Euphorbia candelabrum*, or umbrella tree and, in certain places, *Melia volkensii*, or African mahogany, casting welcome shade in a hot and dusty land and spindly black trunked *Platycelyphiium voens* deceptively dull in a drought dormant phase, but capable of painting the gray nyika purple with splashes of jacaranda-like blossoms that fall to the ground and carpet the red earth for miles. Dominating the general scene is that giant of the nyika (thorn scrub), the baobob *Adansonia digitata*, more prevalent north of the Galana and Tsavo rivers.

Bordering the few permanent rivers and seasonal watercourses of the park, lusher riverine vegetation appeared as a thin green

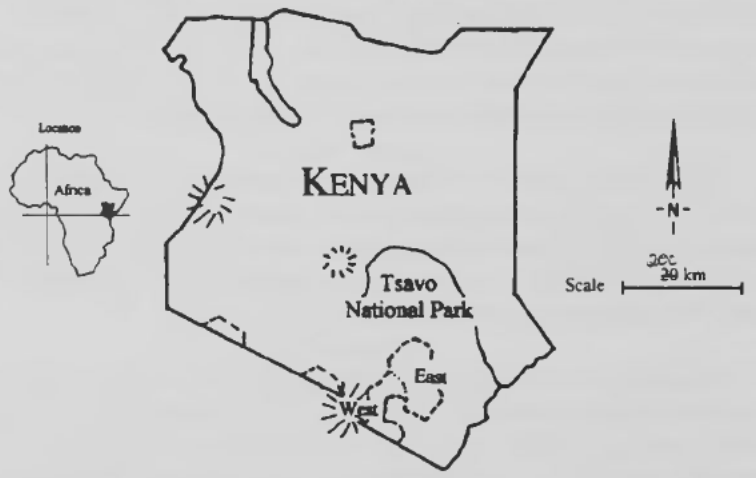

Figure 1. A map of Kenya indicating the location of Tsavo National Park (East and West) [artwork by Jann S. Grimes].

Figures 2 through 9 [opposite] depict an overview of various habitats in Tsavo National Park, Kenya, some with vegetation during wet seasons, others during dry seasons [all photographs by the author].

Figure 2. African elephants (*Loxodonta africana*) in a defoliated *Commiphora* woodland.
Figure 3. A baobob tree (*Adansonia digitata*) damaged by elephants.
Figure 4. Two elephants in a grassland.
Figure 5. Denuded open savannah in dry season.
Figure 6. *Ipomoea* aff. *mombassana* (morning-glory family) vines in hills near a roadside.
Figure 7. Emerging vegetation in an open savannah shown from the air.
Figure 8. A close-up of *Ipomoea* vines.
Figure 9. An aerial view of copse, a savannah thicket.

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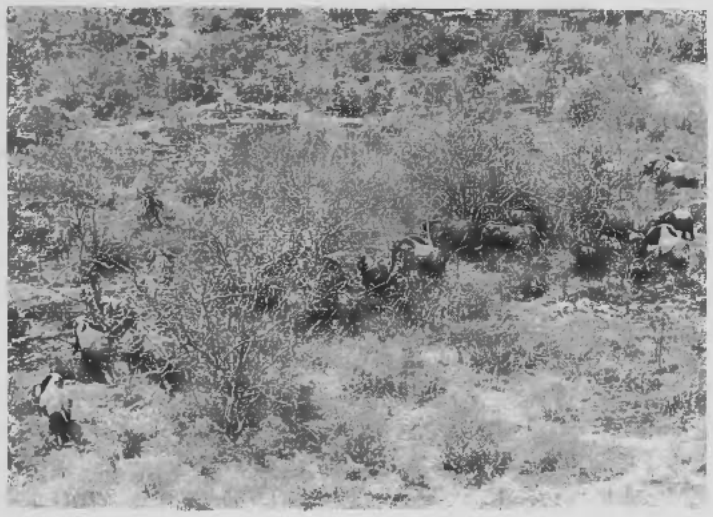

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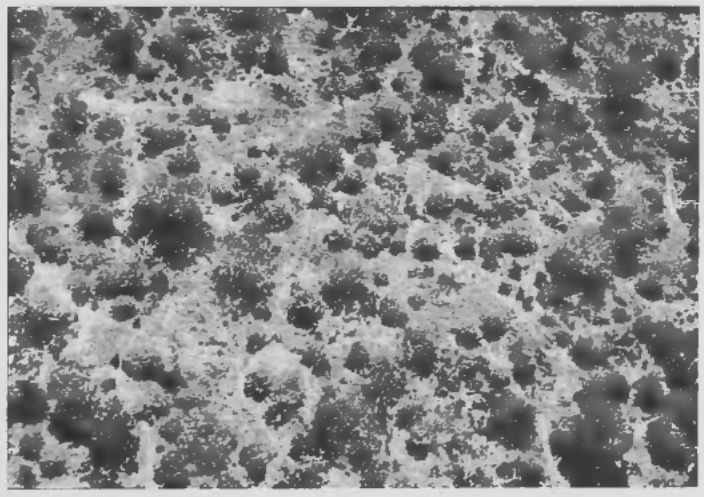

ribbon lending relief to the sea of interminable bushes. Here, trees such as *Acacia elatior* grew in dense stands; beautiful spreading tamarinds, *Newtonia hildebrandtii*, *Ficus sycomorus* and forests of swaying doums, *Hyphaene coriacea*. In 1948 stands of the Tana river poplar *Populus ilicifolia* were an impressive feature of the many islands of the Galana and Athi rivers, while dense thickets of the salt bush *Suaeda monoica* and the toothbrush bush, *Salvadora persica* clothed the more saline soils.

Areas of impeded drainage covered in black-cotton loams appeared as open 'mbugas' capable of supporting good perennial grasses and legumes rich in protein upon which the grazing animals depended heavily during the dry seasons. The habitat of Tsavo then was essentially for the bush-dwelling species; grazers had a very lean time.

Arid by nature, with rainfall that has always been low, unpredictable and erratic, periodic droughts have been a feature of Tsavo since time immemorial. Hot desiccating winds sweep across the bleak landscape to punish the country even further during the southeast monsoon. It is a harsh and inhospitable land, yet exciting in its spectacular contrasts: a barren wasteland one moment, silent and asleep; a veritable garden of Eden the next as the rain brings new life and triggers a burst of energy and color. The bush takes on a profusion of greens, myriad wild flowers carpet the earth. It was set aside as a national park not because it harbored a wealth of wild animals, which it certainly didn't, nor because of any spectacular scenic advantage, but simply because it was the only empty piece of land that could be spared, being unsuitable for other purposes due to aridity, a lack of permanent water sources, and the presence of trypanosomiasis [a disease caused by a parasite flagellate protozoan in blood of vertebrates]. The only people who penetrated that largely unknown chunk of Africa then were small bands of poachers from the Waliangulu and Wakemba tribes who made a living by hunting elephant and rhino, selling the trophies to illicit dealers in Mombasa. Joseph Thomson's vivid description of what the country was like under *Commiphora* woodland cannot be improved upon.

By fortunate accident, the park happened to incorporate two distinct faunal types: the Somali or northern races in the more arid habitat of the eastern sector and the Masai or southern races in the western. Thus Tsavo Park harbored the nucleus of a greater variety of large mammalian species than any other park in the world, though none, apart from the elephant and rhino, were found in significant numbers. *Commiphora* country does not support a large game population anywhere in Africa. The numbers in Tsavo were further restricted by the absence of permanent water and good grazing. One could drive all day through a tunnel of sweltering bush, and if lucky, catch sight of the rear end of an elephant or two, if they happened to be standing just beside the road, or get a fleeting glimpse of a dikdik or a kudu as it dashed across. Buffalo were seldom seen, and then only in small herds near the permanent rivers; zebra were extremely scarce and associated only in very small groups. Other plains species, apart from oryx, were few and very far between. The rangy Tsavo lions, well known for man-eating tendencies, had a hard time to fill their bellies and went around singly, or in pairs, with a lean and hungry look. No one, not even in a flight of wild fancy, could call the Tsavo as it was in 1948, covered in dense *Commiphora* woodland, a good faunal sanctuary compared to other areas of Kenya and Tanzania — good elephant and rhino country, perhaps, but even these animals were difficult to view because of the very dense cover.

It is difficult to understand, therefore, why the modification of the habitat has been the target of impassioned outbursts over the first 20 years. One wonders whether it was not premature to mourn the loss of the *Commiphora* so vociferously, because it is doubtful whether the park could have endured as a viable tourist attraction. Nevertheless, it was a viable ecological unit, unattractive enough to escape the attention of humans, and large enough to secure the long-term survival of a cross section of the fauna representative of the country in perpetuity. In a land with a rapidly rising human population, it represented probably Kenya's only hope of preserving the indigenous fauna for the benefit of future generations and should, therefore, always have been considered the most important wildlife asset in the country. It has, however, tended to be regarded as the park with the lowest priority.

Modification of the habitat was in progress even prior to the establishment of Tsavo, but it became more noticeable as time went on. In the mid 1950's, attention focused on the fact that elephants were destroying the *Commiphora* woodland over large areas, despite *Commiphora* comprising only a very small proportion of their diet. Yet the elephants seemed driven by some inexplicable impulse to push over these particular trees until skeletons of dead trees lay in tangled heaps on the bare, baked soil, and large areas of the park resembled a battle ground. Damage was worst in the Galana river valley, the north bank of the Athi river, and around permanent water supplies such as the Aruba Dam. Such large-scale destruction of the prominent vegetation of the area appeared very alarming at the time, for it was doubted whether the rainfall was adequate to promote perennial grassland in its place.

Experts were called in, and the consensus of opinion was that the elephant population had to be reduced by one third to halt destruction of the woody cover. Counting techniques were still very much in their infancy in those days (mid 1950's), nor were aircraft available. It was suggested that around 4,000 elephants would do. Ways and means of dealing with the surplus with minimum of disturbance to those left were discussed and re-discussed, for the only feasible method of cropping such large numbers lay in annihilating entire family units, as Uganda had done. This certainly did not offer a lasting solution to the problem and could even aggravate it by relieving some of the pressure on the vegetation, making life that much easier for the elephants that remained. As all the age groups within the population would still be intact, the result would be an increase in the breeding rate and a still rising elephant population that would continue to suppress the bush. A well known statistician pointed out that the true solution lay in removal of a cross section of young females that represented the reservoir for future recruitment. If these were selectively taken from specific age groups within each family unit, the population would be put into a natural decline. The killing of individual cows and calves within family units and within a national park presented insurmountable obstacles and would have inflicted unprecedented harassment on the elephants, possibly turning them savage, or even driving them out of the park to rampage through the settled areas beyond the boundaries. Before any decision could be taken by the Trustees, however, the heavy rains of 1961 triggered countrywide floods providing plenty of herbage for the elephants as well as for all other creatures. The pressure was off - but only temporarily.

Meanwhile the floods brought havoc to the riverine vegetation. Large stands of poplar were swept away by floodwaters, as were *Acacia elatior*, doums and many others. The Galana widened its banks by as much as 300 yards in some places. But the recovery of the formerly battered areas was spectacular. The climber *Ipomoea mombassana* covered the landscape in a protective bandage of white, providing not only a ready source of food for the elephants, which rested the woody vegetation, but also cooling the soil enabling seedlings and grasses to become established. Nitrogen fixers such as *Indigofera* and *Tephrosia* were very much in evidence, colonizing huge areas. Meanwhile even

the fallen *Commiphora* played a vital role, providing effective barriers against trampling by heavy animals. Perennial grasses rapidly spread to provide good ground coverage where before the earth had lain exposed. Among them were grasses such as *Chloris myriostachya*, a very valuable pasture grass; *Cenchrus ciliaris,* whose roots penetrate as deep as 6 meters (20 feet), *Eragrostis superba, Sporobulus* and *Digitaria*. *Acacia tortilis* seedlings appeared in thousands to replace the fallen *Commiphora* trees, promising a more open area of *Acacia*/grassland which would undoubtedly be far more productive than the old.

The authorities were confused. The changes brought by the elephants so far could in no way be called detrimental but rather appeared beneficial to the whole, though the rainfall had also been better than usual. Doubts were expressed as to whether in fact *Commiphora* woodland was the 'climax' vegetation in view of the poor soil cover and excessive run-off that is a feature of this type of vegetation. Nature does not normally endorse erosion and people began to speculate as to whether the woodland was not, perhaps, just a phase of a perfectly natural long-term vegetational cycle, in which plant succession came into play. Certainly, it was curious that all the trees that comprised the *Commiphora* community appeared to be of comparable age. Views of various experts differed and conflicted. It was obvious that no one really knew for sure on whose shoulders full responsibility lay, it was decided to play the sage and leave the question of the elephants in abeyance until the position could be clarified by further study. Knowledge of African ecosystems was still extremely limited. Action taken on the wrong advice could lead to far reaching consequences that might be detrimental to the park as a whole. Instead, the Trustees agreed to permit scientists to crop 300 elephants at Kowito to provide a sample that could form the baseline for a study of the population dynamics. It was hoped that from this would emerge specific data enabling the Warden and Trustees to come to the right decision.

Following colonization of large areas by perennial grasses and legumes, a rapid build up of plains animals became evident. Many species extended their former range. The impala, for instance, appeared for the first time in the Voi river valley; Peters gazelle, formerly confined to the area north of the Galana river, appeared on the south bank, as did the Somali ostrich; buffalo congregated into larger herds, likewise zebra, kongoni and other grazers. Oribi made their debut within the park boundaries. Even the rangy Tsavo lions formed large prides that looked sleek and fat; some began to sprout reasonable manes. And, with the continued good rains, even the elephants seemed to be doing fine.

A strange development accompanied the transition of bush to grassland in some areas of the eastern sector: the dramatic appearance of over 100 permanent springs and streams. At first, the heavier than usual precipitation of rain was thought responsible, but as the years passed, these streams and springs increased their flow. People began to wonder if this phenomenon could be connected in some way to the removal of the *Commiphora* cover. Now that an intricate network of grass roots had penetrated the hard pan, and excess run-off was held up by the presence of the grass, much more moisture was being absorbed into the soil. This possibly raised underground water table levels and had some bearing on the spring's appearance.

By this time (early 1960s), scientists working on the "elephant problem" produced a bombshell, stating the Tsavo elephants were, in fact, segregated into ten discrete populations, and, as the sample 300 was from only one of them, a further 2,700 elephants would have to be cropped to complete their studies, meaning a sample of 300 from each remaining nine populations. This hypothesis was strongly contested by the Warden, himself no mean naturalist, and began the long "elephant controversy". The Trustees, once again confused by conflicting opinions, decided the evidence produced was still inadequate to warrant a major policy decision with such far reaching ramifications. The scientist in charge of the research project resigned in high dudgeon.

Another factor now came into play - fires. Fires were unknown when the park was covered in *Commiphora*, the ground cover was too sparse to let them take hold. In the very early days, deliberate efforts to burn some areas to promote better grazing and open up the dense thickets were frustratingly unsuccessful. With the emergence of the new grasslands, fires took on major importance as they swept across the eastern boundary from Giriama (a Bantu tribe) country and also from the railway, devastating woody vegetation in huge areas of the park south of the Galana river at the onset of the dry seasons. A 75 mile firebreak was hurriedly put in along the entire eastern boundary, the road network was adjusted to partition the park into smaller blocks where fires could be contained by back-burning. All this took time and, in the interim, the damage to the woodlands exceeded anything the elephants could have done, opening up large tracts of land toward the eastern boundary. Of course, Tsavo's critics continued to blame the elephants.

Too much burning in arid lands is definitely undesirable, particularly when the rainfall is erratic and unpredictable. The red soils become pulverized, subjected to wind erosion and excessive wash once the protective hamper is removed. With almost total failure of the 1960 long rains and partial failure of the short rains, large areas of the arid eastern sector, particularly those subjected to fire, began to assume a desert-like aspect, where the only emergent tree appeared to be the stunted, evergreen *Boscia coriacea*, sclerophyllus, truly drought resistant and having the added bonus of being unpalatable to elephants. *Acacia tortilis* also continued as an emergent species, but many of the saplings were stripped and killed by elephants. Local populations of *Melia volkensii* and *Platycelyphiium voens*, both also not eaten by elephants, remained in specific areas. But the elephants suddenly started attacking the beautiful *Delonix elata* that formerly seemed immune.

The 1971 long rains again fell far short of expectations, and the situation worsened. Many people maintained that the park was being reduced to a desert and blamed the authorities for not having reduced the elephant population before. Tsavo's critics were now in full cry. The press took up the call as well, adding to the general confusion clouding the issue. Although periodic droughts were not unusual in Tsavo, this particular drought proved to be the worst in living memory and of the longest duration, with six years of well below average precipitation within the eastern sector.

With an annual average as low as 10-15 inches (25-39 centimeters) of rain at the best of times, anything well below is bound to result in extreme aridity, being within the accepted desert bracket. No one could possibly expect anything else. It was an Act of God, one of those quirks of nature that, when viewed against the backdrop of millennia can be likened to the flicker of an eyelid. Such catastrophes had happened in the past, and would happen again in the future. But to us who live in the middle of a long-term cycle and depart long before it has even progressed very far, let alone reached its conclusion, such events understandably take on a magnitude that is probably completely out of perspective. Some people went so far as to say, rather prematurely, that the park was finished. The parched red plains, born of excess burning, were blamed upon the elephants; the dust storms that enveloped the area during this period were blamed upon the elephants; even the color of the sea at Malindi which was

a result of erosion caused by humans way beyond the country of the elephants, and had nothing whatsoever to do with Tsavo - this, too, was blamed upon them.

Long term climatic and vegetation cycles in Africa are only now beginning to be understood. Under natural conditions, the health and optimum productivity of an area is brought about through the dynamic functioning of all kinds of balances and cycles, which are far too involved for us to fully understand, and which are calculated by nature to promote the most fruitful relationships between all physical, chemical, botanical, and zoological components of the living whole. Evolved to accommodate itself to harsh conditions and spare rainfall, the system continually moves towards amelioration and improvements, perhaps through the creation of niches for more efficient plant and animal species. The biomass may remain fairly consistent, but its composition must change, and this is a perfectly natural process that we should accept and not try to manipulate.

It was understood ever since modification of the habitat began in Tsavo, that the day would come when the elephant population would reach saturation point in terms of the carrying capacity of the park (between 10-20,000 elephants), particularly in a drought year, and when this point was reached, one of two things was likely to happen. Either the elephants would move out of the park *en masse* in search of new pastures, or they would remain and die in large numbers from starvation. No one knew which of these two alternatives would happen, for not enough was known of the elephants' seasonal movements and their fixation to home ranges. One fact emerged, however, from two years radio telemetry tracking of individual elephants — the hypothesis that the Tsavo population was comprised of ten discrete units was exploded. That was one point vindicating the Warden and Trustees, and, again, emphasized the wisdom of caution.

Legend has always depicted elephants roaming over vast distances and people tended to accept this. In fact, the elephant movements are triggered only by rainfall and, during the dry seasons, the same elephants return to the same dry weather haunts year in and year out. If those haunts happen to coincide with areas of minimal falls of rain, they are in trouble. It seems strange they make no attempt to move elsewhere, but the fact that elephants are so localized in the dry season is probably fortunate and has, no doubt, been ordained by nature to safeguard the environment from the depredations of a large roving population that would eat an area flat, then move on to devastate the next one. Nature has also seen to it that the two largest herbivores (elephants and rhinos), whose natural enemies are few, apart from man, are most susceptible to drought conditions, due to the nature of their physiology whereby an inefficient digestive system permits as much as 6% protein waste in the droppings.

It seems doubtful whether there is, in fact, such a thing as a "static dynamic balance" of large herbivores in any area other than perhaps in forest and particularly not in areas of low rainfall insofar as elephants are concerned. There is a real danger in keeping a population too high for too long, and the end result would be far more damaging. And, after all, who is to determine the level of this 'dynamic balance'? It now seems probable that violent population seesaws, traumatic as they are, are necessity in arid lands; that a build up of elephant numbers follows an increase in the woody vegetative cover during a cycle that is perfectly normal in this type of country, and that this build up continues to a point where the elephants overtake the vegetation, exist on the capital for a short time, trigger off the next stage of plant succession, and are finally subjected to a dramatic population crash in a drought year when the protein content of the herbage falls below the level needed to sustain their great bulk. This point was reached in Tsavo in 1970-71 when 5,900 elephants died of starvation in the eastern sector and when drought conditions persisted, a further 4,000 succumbed in 1975, bringing the total die-off from starvation to some 10,000 in all.

The removal of 10,000 large herbivores from the battered habitat was of great significance, but the selectivity of the natural die-off was the key issue. Those affected were adult females and a cross section from the young stock of the entire population — in other words, a radical adjustment in the potential for future recruitment had been wrought by the removal of animals from these specific age groups. This coincided with the recommendations of the statistician way back in the fifties. Nature had effectively provided the solution to the elephant problem quietly, without disturbance (and relatively painlessly) in a way that left large gaps in the structure of the elephant population and ensured a continued decline for many years as the adults gradually died of old age and were not replaced. Very few calves from interim age groups will be seen in the Tsavo population today, which is comprised mainly of adults and the very young who will not be in a position to breed for many years. The population will therefore fall to an extremely low level in years ahead, with the result that there will be an increase in the woody vegetation until the elephants repeat the cycle in our grandchildren's time. That is assuming, of course, that poaching does not push this declining population over the brink to extermination. Unhappily, this is not something that can be discounted.

Should elephants disappear entirely from Tsavo, the ramifications are endless. Tsavo would probably die as a faunal sanctuary, for the elephants are the key to its ecology. They are necessary for the diversification of the habitat, for opening up thickets to promote growth of grasses and necessary for provision of water in that thirsty land. By pudding the depressions that trap rain water in the wet season, they seal the soil so that it becomes impervious and capable of holding water well into the dry season. By rolling and bathing in puddles and carrying away large amounts of mud plastered on their enormous bodies, they create larger waterholes. By digging away the sand and tunneling with their trunks, they make subsurface water in dry riverbeds accessible to other less well endowed creatures, and by trampling, they can even raise the water table of the watercourses, bringing underground supplies to the surface for the benefit of all.

They are the pathfinders of the nyika, for their trails link the main watering points and feeding grounds, follow the best alignment over difficult terrain, lead the way over escarpments, through gorges, across plains and through woodlands. They are nature's gardeners. Uprooting, ringbarking, pruning, pushing and planting, they play a vital botanical role within the habitat, dispersing seeds over huge areas in their droppings. They also provide the fertilizer for the nyika by depositing approximately 1,000 tons of dung per day in the park, which is then carried beneath the soil by millions of dung beetles in the wet season and billions of termites in the dry season. More importantly, they are the only agents capable of releasing nutrients locked in wood so that these can be recycled within the habitat. Were the elephants not there to break down branches and make foliage accessible at a lower level, many smaller browsing animals would be adversely affected. Were the elephants not there to trample and crop the grass when it becomes rank, keeping it short and palatable for the grazing animals, they too would suffer, for rank grass is both undesirable and unproductive. No one in their right mind would wish to see Tsavo completely enveloped in *Commiphora* woodland again, as it was in 1948, or the herds of grazing animals replaced only by the fleeting glimpse of a bushdweller dashing

across a road, or a place "where the wind, hastening past fresh from the ocean, raises only a mournful whistling or dreary creaking, 'eerie' and full of sadness, as if it says 'here all is death and desolation." Yet, it will indeed be, should the elephants be allowed to disappear from Tsavo.

Poaching was a problem in Tsavo as far back as the fifties, but it was brought under control by tough measures taken by the Colonial Government and stamped out entirely during the sixties. For ten years Tsavo was a sanctuary in more than just name, and the Tsavo elephants went about their daily lives free from fear and completely unmolested by man.

In 1975 about 35,000 elephants survived the drought and remained within the Tsavo ecosystem in an area 16,000 square miles (about 40,000 sq. km) in extent, in 1975. Only three years later, a mere 8,000 were left. Unless poaching can be stamped out effectively and ruthlessly within the immediate future, the point of no return will be here. Those magnificent animals, which have survived through millennia, will disappear forever from Tsavo. Kenya's last bastion of wildlife and its hopes for the future will have been irreversibly ruined, and with it will go the tourist industry. This time, it won't be an Act of God, but an act of man; nor will it be the fault of the elephants; nor even the droughts, as some will try to suggest. Instead it will rest squarely on the conscience of those unscrupulous dealers, and on the last government who, despite repeated warnings of a worsening situation, did too little too late.

Those on the periphery who have consistently maintained that the habitat of Tsavo Park was beyond recovery and was reduced to a desert will have to retract their words. The protracted drought has broken at last, and the park has cast off its desert aspect with alacrity to become once again a veritable Garden of Eden, transformed by the heavy falls of rain at the end of 1977 and the beginning of the 1990s. Seeds from the old regime, which have been cradled within that bare red earth have remained viable, awaiting just such an opportunity, and today are popping up in the thousands all over the eastern sector, while large areas exposed and devoid of cover only a short time ago have now become recolonized by the perennial grasses everyone thought had disappeared forever.

Furthermore, the enclosures that were established in the park as part of the vegetational monitoring program have proved conclusively that once the browsing pressure of elephant has been removed, woody vegetation springs back, even though the nearest parent tree be 50 miles (80 kilometers) away. The resilience of plant communities greatly exceeds that of the animals and for a very good reason. In this way, nature insures against irreversible damage to the habitat with indigenous species if, of course, man does not intervene. We have merely witnessed the swing of the cyclical seesaw from its zenith to its lowest ebb. Now begins an upward curve again. However, nature also built elephants into the habitat, and we can only hope that some of these animals will be spared to balance the process in the years to come to ensure the diversification that is needed by other species.

Confucius said to study the past if you would define the future. Events in Tsavo have paved the way to a better understanding of natural processes and provide important guidelines for the proper management of animal populations in arid lands.

Recent studies of elephants and their habitat in Tsavo National Park (TNP) ecosystem help us to better understand long term changes in elephant numbers and vegetation. In 1988 Olindo *et al.* estimated the elephants population at TNP ecosystem at 6,000, a decline from 42,000 in 1969, mainly from poaching. A survey of the vegetation in TNP was reported by Leuthold in 1996. In this study photographs taken from fixed locations during the long dry season in 1970 and 1994 document the development of woody vegetation under changing ecological conditions over the twenty-five year period. The original vegetation was heavily influenced by both elephant and fire during the 1960s and 1970s. The elephant population has decreased substantially as a result of large scale poaching during the 1980s. Presumably, as a result, trees and shrubs have reappeared in large numbers at the majority of locations sampled. To assess changes in past diets of elephants in TNP, in 1989 Tieszen *et al.*, investigated stable carbon and nitrogen isotope ratios of bone collagen of elephants aged between 1 and 50 at time of death and found that elephants have maintained similar proportions of types of vegetation in their diet in spite of the fact that the woodlands appear to have been converted to grasslands over the past fifty years.

A summary of habitat changes, including that of elephant population, was provided by Chadwick (1992, pp. 102-131) who also discussed the "elephant controversy" and "elephant problem" of TNP. Below are selected thoughts, some directly quoted, from his book.

> 'The Kenya government is strenuously avoiding publicity over the shooting of several hundred elephants now taking place in Tsavo National Park... Because wildlife is a major source of income, the government doesn't want to draw attention to the shooting,' read one newspaper article. It was from 1968.

Events that led to the elephant controversy (to shoot or not to shoot the elephants) — should humans interfere with nature and apply a management program or should a laissez faire approach be employed — follow. Increased poaching and human settlement around the park drove the elephants into Tsavo's ecosystem in unprecedented numbers. The parklands might ordinarily hold from 10,000 to 20,000 elephants. By the late 1960s, the population, swollen with refugees, was approaching an estimated 42,000. "They were trampling the countryside into dust, degrading the range used by other wildlife along with their own." This situation led some authorities to believe a culling program was necessary. The opposition, led by Chief Park Warden David Sheldrick, believed that nature should take its own course. It appeared that neither side had enough information to evaluate long-term dynamics of the African ecosystem for a compelling argument. As a result, the elephants were left alone for the time being, and when drought struck between 1970 and 1972, about 6,000 elephants died of thirst and starvation.

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Appendix 1. Part A. Plant species, some are consumed by elephants, rhinoceroses, gerenuk, and other herbivores, in Tsavo National Park, Kenya. Part B. Animals mentioned in this article.

References consulted include Sheldrick (1993c, pp. 350-361) and those given in the key; page numbers are given inside square brackets. Absence of reference to a plant taxon imply it is the same as in Sheldrick (1993c). When known, taxa (genera and species) are grouped by genera. Key: B+=Bein *et al.* (1996), CP=Coates Palgrave (1977), S=Schmutterer (1976).

Part A — Plants

Acacia elatior, Acacia tortilis (acacia) [CP:252]
Adansonia digitata (baobob) [CP:587]
Aristida (a perennial)
Balanites sp. (torchwood) [CP:338]
Barlaria sp.
Bauhinia taitensis (bauhinia) [CP:282, for genus only]
Boscia coriacea (evergreen, shepherd's tree) [CP:185, genus only]
Boswellia hildebrandtii (frankincense tree of the Bible) [B+:94, for genus only]
Cassia sp. (cassia) [CP:287]
Cenchrus ciliaris (buffergrass)
Chloris myriostachya (pasture grass) [for genus only]
Combretum aculatum (combretum) [CP:662, B+:138]
Commiphora baluensis, C. rivaris [B+:144, for genus only]
Cordia [B+:150]
Delonix elata [B+:160]
Digitaria sp. (a grass)
Diospyros mespilliformis (African ebony) [B+:168]
Disperma sp.
Dirichletia glaucenscens [CP:842, for genus only]
Eragrostis superba (a grass)
Euphorbia candelabrum (African candelabrum) [S:320]
Ficus sycomorus (sycamore fig) [B+:212]
Grewia [CP:547, B+:222, for genus only]
Hyphaene coriacea (doum palm) [S:22]
Indigofera (river indigo, nitrogen fixer) [CP:305]
Ipomoea mombassana (morning glory family) [S:196]
Lannea [CP:459, B+:246, for genus only]
Melia volkensii (African mahogany) [CP:381, for genus only]
Newtonia hildebrandtii (tamarind) [CP:256]
Platycelyphiium voens
Populus ilicifolia (Tana river poplar) [PC:91]
Premna resinosa [B+:318]
Roseia coriacea (evergreen)
Salvadora persica (toothbrush bush) [B+:350]
Sansevieria (sisal) [S:344]
Sericocomopsis sp.
Sporobulus sp. (a grass)
Sterculia rhynchocarpa [B+:366, for genus only]
Suaeda monoica (salt bush) [B+:372]
Tephrosia (nitrogen fixer) [CP:308]
Terminalia orbicularis [CP:679, for genus only]

Part B — Animals

beetle, dung
buffalo
dikdik
elephant
gazelle, Peters
gerenuk
impala
kongoni
kudu, lesser
lion
oribi
oryx
ostrich, Somali
rhinoceros
termite
Trypanosoma (parasite)
zebra