CARBON MONOXIDE

the bright side to the pollution coin

Four-year-old Kathy Schneider of New York City wears an air pollution mask to dramatize the need for cleaner air. The mask does nothing, however, to filter out carbon monoxide. The earth's total vegetation, represented by Kathy's peony, releases far more of this gas —during growth and decay— than all man-made machines. (United Press Photo)

by Edward J. Olsen

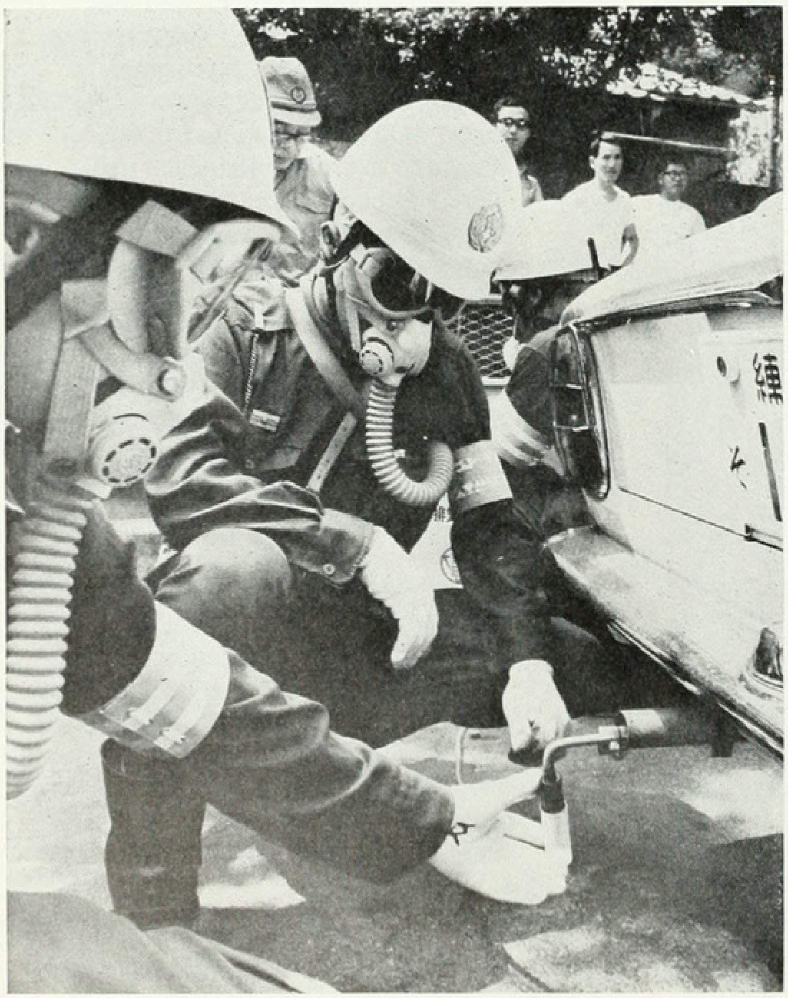
From the outset of the environmental preservation movement in the United States we have been repeatedly badgered by statements and statistics that worry and frighten us over the current quality of our lives—with gloomy prognoses unless decisive action is taken. Most people feel helpless in the face of statements in the media that warn of noxious chemical compounds, about which they know little or nothing and over which they can exercise practically no personal control. On the face of it, it seems as if there is nothing but horrendous statistics and "bad guys."

Environmentalism was, a few years ago, an "in" thing, especially popular among the young, who formed hundreds of chapters of "Earth Clubs" nationwide. Most of this youthful enthusiasm has of course drained away leaving, as usual, a hard nucleus of individuals in universities, government, and private sectors who have continued in methodical fashion to tackle the difficult problems and gradually effect changes where necessary. One of the results of the research of such groups has been the measurement and accurate assessment of pollutants, replacing the often inaccurate "guess-timates" of earlier environmentalists.

Dr. Edward J. Olsen is curator of mineralogy

Some years ago we were horrified to hear the more vocal (and emotional) environmental advocates tell us that we were releasing, annually, 270 million tons of the gas carbon monoxide (CO) into our atmosphere. The atmosphere was carrying an amount of some 530 million tons. Thus, man was creating an annual input of about 51 percent of the amount the atmosphere was holding—a truly frightening figure! Most of this gas can be directly attributed to automotive exhausts, for CO is produced by the incomplete combustion of gasoline in auto engines. It is also produced in most industrial fuel burning and from home heating plants. CO is, as we all know, a highly poisonous gas. Thus, it appeared we were pumping the major percentage of a highly toxic gas into the atmosphere; the implied result was clear.

Beyond these few superficialities we knew little. We did not have records of the CO content of the atmosphere over long spans of time, especially from pre-automotive and pre-industrial times. We did not know of any major producers of this gas on earth other than ourselves. The first major effort was an attempt to reduce CO emissions from auto engines, as well as other auto exhaust gases. The result has been, as we all know, several yards of tubes and pipes, plus other makeshift gadgetry on newer auto engines, that cause them to balk and lurch, and to reduce mileage by two or three miles per gallon. The new equipment has, however, reduced CO emissions along with a large variety of other noxious gases. These measures have turned a basically polluting engine into a less polluting one, at the price of poorer efficiency and operation. The point was to buy time until a clean and efficient engine could be developed.

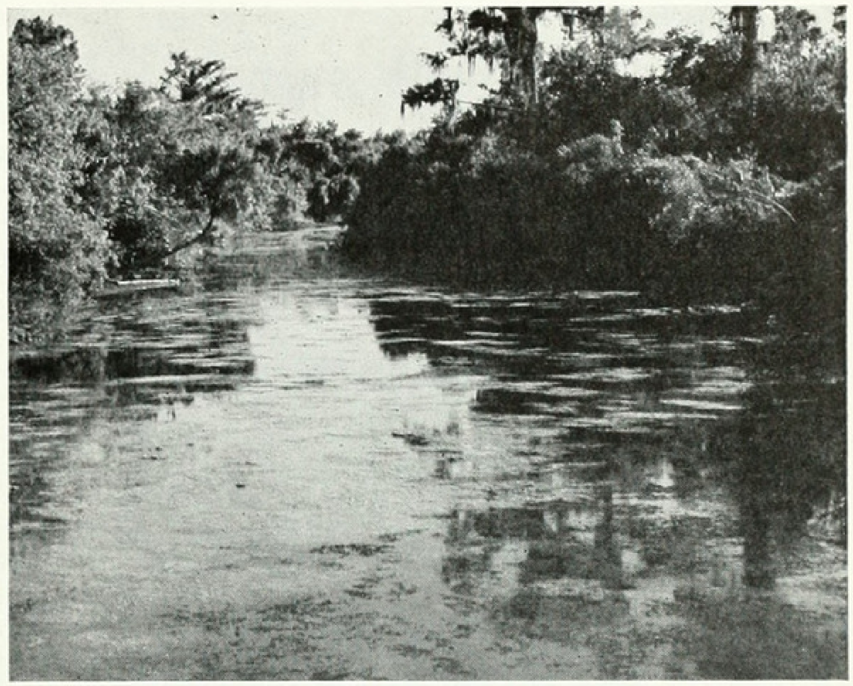


Japanese policemen measure CO content of auto exhaust in downtown Tokyo. Emissions from autos and other man-made sources account for only about 6.5% of the CO produced on earth. (United Press International Photo)

Several years ago it became obvious that good quantitative values for sources of CO were needed. Two research groups at Argonne National Laboratory, headed by Drs. Charles M. Stevens and Henry L. Crespi, began the difficult task. The compound CO consists of one carbon atom attached to one oxygen atom. It has been known for a long time that a small percentage of natural carbon atoms weigh slightly more than others: most weigh 12 units of weight, but some weigh 13 units. These are called "carbon-12" and "carbon-13," respectively. Similarly, oxygen comes in several natural weights of which oxygen-16 and oxygen-18 are the most important. Thus, it is possible for CO to have four different molecular weights—28, 29, 30, 31—depending on whether the carbon atom weighs 12 or 13 and the associated oxygen atom weighs 16 or 18. A given source of CO can produce different combinations, or mixtures, of these four weights and the research teams hoped to be able to associate specific sources with measured mixtures.

Air samples were collected in a wide variety of places: swamps, farmlands, air-collecting bags clamped over living tree branches, within cities, in forests, etc., and at different times of the year. Although the air analysis procedure was fairly straightforward it was extremely tedious, which is certainly one of the reasons it had never been accomplished before the environmental hue-and-cry began.

The results were rather startling. It turned out that five mixtures were identifiable with distinctly characterized CO. Two of the mixtures are found everywhere in the world and may be attributed to the formation of CO from methane (CH_4), popularly known as "swamp gas." Methane is produced by vegetation not only in swamps but



Above, *swamps, rice paddies, and other places where vegetation decomposes in wet or moist conditions produce methane which, in turn, reacts with air to yield about 3 billion tons of CO each year—about 73% of the total put into the earth's atmosphere. (United Press Photo)*

Left, *the living leaves of green plants produce about 200 million tons of CO annually—about 4.9% of the total put into the earth's atmosphere. (United Press International Photo)*

also in damp forests, wet fields, and wherever plant matter decomposes under still water or highly moist conditions. One acre of rice paddy, for example, produces about 3,000 pounds of methane each year, and this will react with air to produce over 5,000 pounds of CO. On a worldwide basis *over 3 billion tons* of CO are produced in this way.

A third mixture appears to result from the living leaves of green plants. This accounts for about *200 million tons* of CO each year, all of which is generated during the summer months.

A fourth mixture occurs as a burst of CO during the autumn months, producing up to *500 million tons* in a six-week period. This mixture is identified as the CO produced by the decay of chlorophyll when the autumn leaves turn brown and fall.

A fifth mixture can be definitely related to the CO produced by automotive gases and other man-made sources. This mixture accounts for about *270 million tons* each year, and is especially enhanced during the winter months by the burning of oil, gas, and coal in the heating of homes and larger buildings.

If you have been keeping score you will have already come to an unexpected conclusion. From the five mixtures we can account for the production of about *3.9 billion tons* of CO annually. This is certainly an underestimate because the study did not include sampling of production by the myriad microorganisms that populate the waters of the open oceans. The Naval Research Laboratory of Washington, D.C. estimates the annual production from this source at *150 million tons.* Thus, the grand total is close to *4.1 billion tons,* of which human sources account for only 270 million tons or only 6.5 percent! Therefore, man's production of this gas has only a small effect on the total CO balance of the earth's atmosphere.

The balance is clearly related to larger natural forces. The atmospheric load of CO is, as stated earlier, about 530 million tons. This balance is called the "steady state" of CO. The steady state can perhaps best be explained by comparing it to a normal five-gallon bucket, with a hole in the bottom. If you let water trickle into the bucket it will trickle out the hole just as fast, and the actual water content of the bucket will be zero. If, however, you let the water pour in at a higher rate, the rate at which it pours out the hole will keep increasing until the outflow rate exactly equals the inflow rate. The bucket will then have a constant depth of water. This is called the steady state amount.

Let us suppose, for example, this amount is four gallons. Let's further suppose the inflow rate (= outflow rate) is three gallons per minute. The inflow rate is equal to 75 percent of the steady state amount each minute. Thus, the inflow can be a large percentage of the content of the bucket. It can even be many times greater than 100 percent depending on the inflow rate and the size of the hole out of which the water is pouring. This is analogous to the annual man-made production of about 51 percent of the steady state content of CO in the atmosphere. The percentages appear impressive, but they do not tell the whole story.

It is clear that if 4.1 billion tons of CO are being put into the atmosphere each year, and the steady state amount is only 530 million tons, then around 3.6 billion tons of it are being broken down each year. The fate of the CO molecule is its conversion to carbon dioxide (CO_2), which is a nontoxic gas. The chemical processes in the atmosphere that convert CO to CO_2 are extremely fast—faster than imagined heretofore. The life expectancy of an average CO molecule depends on the season, about 40 days in the winter and only 10 days in the summer.

The man-made production of CO, then, is an insignificant factor in the amount of this toxic gas in the atmosphere. It is controlled primarily by the natural biological environment, and the steady state amount in the atmosphere would be little different if mankind ceased to exist. It is clear now that man himself evolved in an environment that contained about the same steady state amount of CO, and his tolerance for it in that amount and its seasonal variations must necessarily be a part of his evolutionary heritage.

This is not to say that CO is not a hazard under many circumstances. Before it disperses and decomposes it can be concentrated in toxic or near toxic amounts. Certainly during rush hours at street level on major avenues in the "canyons" of Chicago, New York, and other large cities CO can temporarily rise to serious levels. Weather conditions can occasionally retard the dispersal of auto exhaust for several days. These are the smog alert periods cities experience so often, especially in the summer months. For this reason the emission controls on automobiles are desirable.

It should also be mentioned that the conversion of toxic CO to nontoxic CO_2 is only a mixed blessing. Man, as we have seen, is putting very little of the total CO into the atmosphere, and the conversion of this small input to CO_2 is correspondingly small; 270 million tons of CO will ultimately produce only about 420 million tons of CO_2. Natural biological sources are producing over 6 billion tons of CO_2 from CO each year.

The problem arises, however, that man is directly adding major amounts of CO_2 to the atmosphere, *not* by the CO route. The same fuels that produce CO also produce many, many times more CO_2; it is a product of complete combustion of fuels. Consequently, the CO_2 content of the atmosphere has shown a continuous rise of about 0.2 percent per year for almost two decades. Clearly, the input rate is exceeding the rate at which CO_2 can be itself removed, mainly by plants, absorption into soil, and absorption into oceans and lakes. A steady state amount has not been attainable. This is analogous to pouring water into our leaky bucket at a rate faster than the leak can possibly let it out—it turns into a runaway state in which the bucket overflows. CO_2 is not toxic; however, it has other effects.

CO_2 acts to retard the radiation of heat from the sun's rays back into space. This could mean a gradual build-up in heat in the atmosphere, the so-called "greenhouse effect." The ultimate result could be a gradual worldwide climatic change that would

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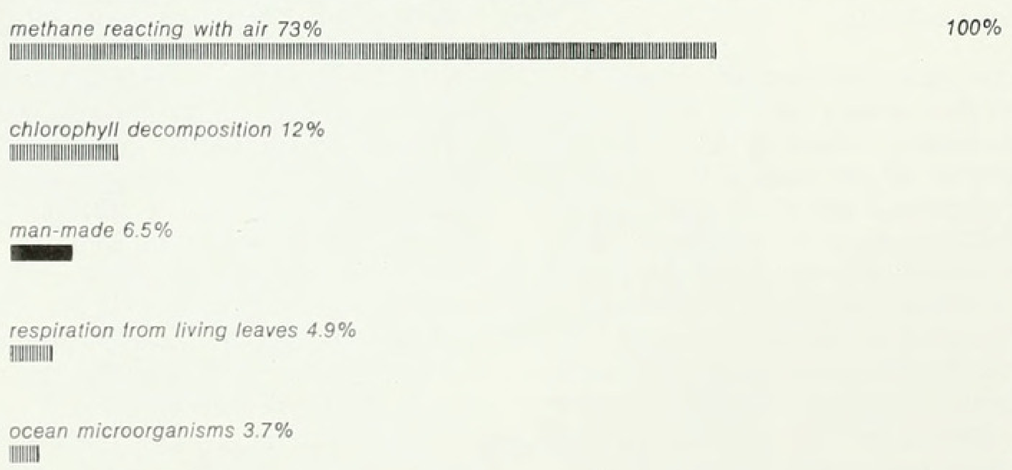
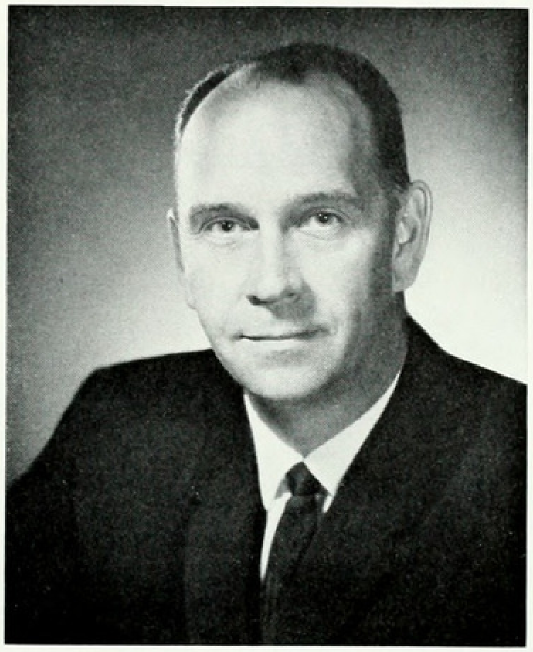
Sources of Carbon Monoxide in the Earth's Atmosphere



Yarrington Elected 7th Museum President

Blaine J. Yarrington, Field Museum trustee since 1970 and chairman of the Corporate and Foundation Division of the Museum's $25-million Capital Campaign, was elected president of the Museum by the Board of Trustees at its meeting January 21. He succeeds Remick McDowell, who is retiring.



Yarrington

Yarrington, president of Amoco Oil Company, a subsidiary of Standard Oil Company (Indiana), is a native of Albany, Missouri. Just before his 20th birthday, in 1938, he joined Standard at St. Joseph, Missouri. After advancing through a series of positions, he was named district manager at Joliet, Illinois, in 1960.

In 1961, Yarrington became New York Regional Manager for American Oil Company (now Amoco). Three years later he returned to the General Office in Chicago and in 1965 was elected a vice president of Standard, responsible for world-wide coordination of marketing, distribution, transportation, crude oil and product supply, and purchasing.

Elected executive vice president of American Oil in 1967, Yarrington was responsible for marketing, manufacturing, transportation, purchasing, and traffic. After becoming president of American Oil in 1970, he was elected a director of Standard Oil Company (Indiana).
In addition to serving as president of the National 4-H Service Committee, Inc., Yarrington is a member of the boards of Continental Illinois National Bank and the Continental Illinois Corporation, the Bank and Trust Company of Arlington Heights, the Chicago Association of Commerce and Industry, Illinois Manufacturers Association, Chicago Metropolitan Area of the National Alliance of Businessmen, and the Community Fund of Chicago. He is also a member of the Business Advisory Council of the Chicago Urban League, among his other associations.

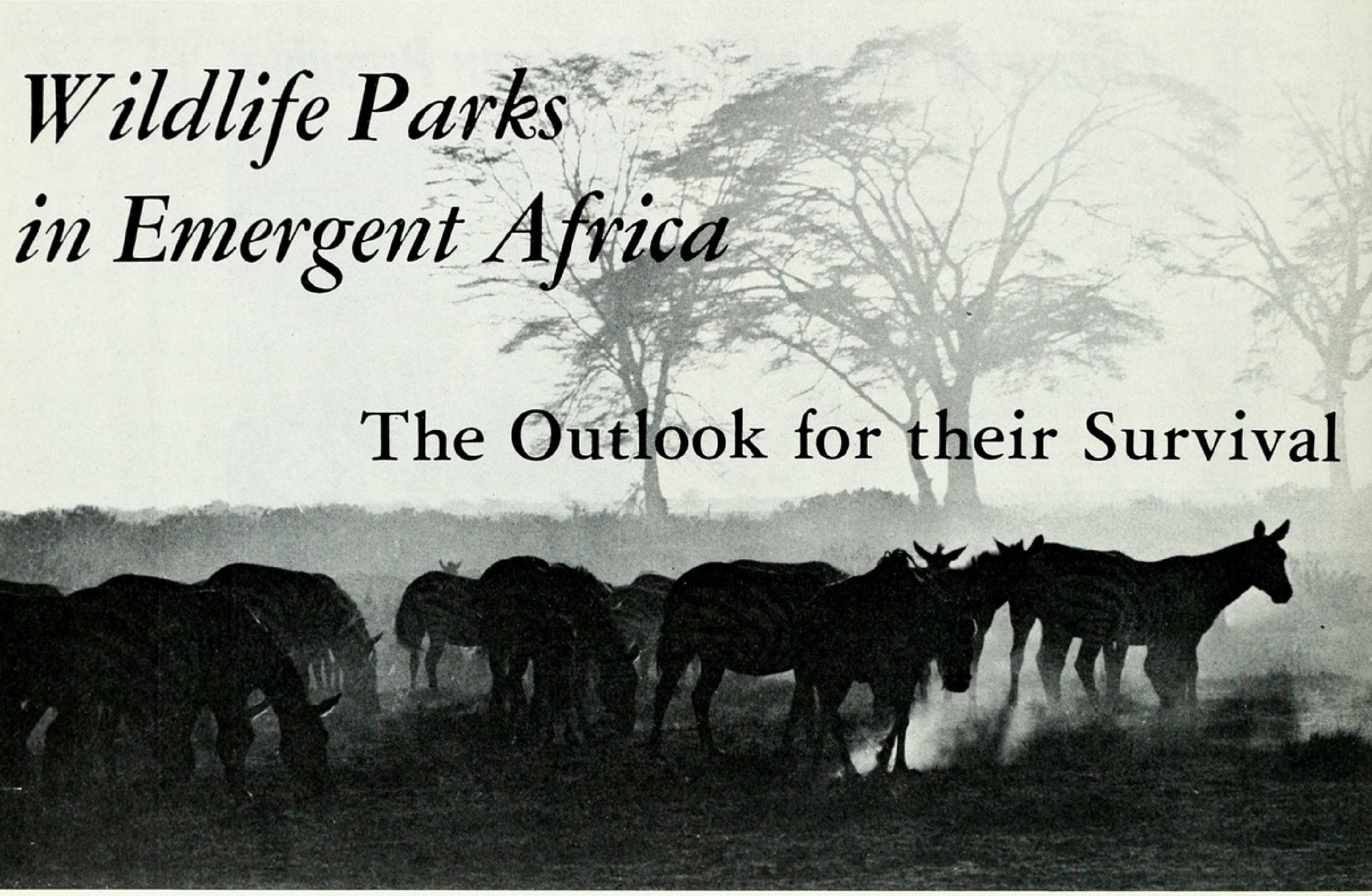
McDowell

McDowell, who has served as president of the Museum since 1969 and trustee since 1966, also retired last month from his position as chairman of the executive committee of Peoples Gas Company. He will continue as a trustee of Field Museum.

Other officers elected at the Museum's annual meeting include the following vice presidents: William G. Swartchild Jr., for program planning and evaluation; Bowen Blair, resource planning and development; Thomas E. Donnelley II, public affairs; Julian B. Wilkins, facilities planning; and William L. Searle, internal affairs. Also elected were Edward Byron Smith, treasurer, and John S. Runnells, secretary.

Wildlife Parks in Emergent Africa

The Outlook for their Survival



Photographs by the author

Naturalists have for years attempted to preserve samples of natural ecologies in order that man in his eagerness to "develop" our planet would not, in the process, destroy all natural systems. In the developed countries such destruction has proceeded almost unabated. Usually this process has occurred without our having any understanding of what was being destroyed—let alone whether it might be to man's advantage for it to be left alone. We have come to realize that most of the world's ecological systems are so intricate and extensive in their inter-relationships, and in such delicate balance, that merely isolating relatively small segments of the earth's surface and thus attempting to preserve them will not alone suffice. Furthermore, those few areas that have been in all good conscience set aside are forever subject to man's unique penchant for "development."

Dr. Norman Myers, an ecologist and a consultant in conservation biology in Kenya, is eminently aware of these problems. He proposes some unusual solutions. While unconventional and contrary in some respects to traditional approaches, his proposals are worthy of consideration. He has expounded his ideas at length in an essay in Science *(Dec. 22, 1972). This article so intrigued me that I sought out Dr. Myers while in Kenya last year to see if he might provide Museum members with some further perspective on wildlife conservation via the Museum* Bulletin. *His thought-provoking essay which appears here is necessarily lengthy, for the subject is complex and the attendant problems awesome. But nature lovers must have an intelligent awareness of all sides of these problems if solutions compatible with their interests are to be found. Those who wish to pursue Dr. Myers' ideas further will find his* The Long African Day *(Macmillan, 1972) of interest.*

—Dr. William D. Turnbull, curator of fossil mammals by Norman Myers

Yellowstone National Park was founded just over one hundred years ago, and together with most other parks of North America it stands a good chance of lasting another hundred years. But the outlook for parks and reserves in the savannah areas of Africa can scarcely be so hopeful. Indeed, one must ask whether they will survive this century.

Nowhere outside Africa is there such a large remnant of the tremendous panoply of mammals that roamed during the Pleistocene (1,000,000 to 10,000 years ago), which in turn comprised the most spectacular array of mammal life the planet has known. The new nations of Africa have been working hard to protect their wildlife heritage. Tanzania, for example, expanded during its first decade of independence (acquired in 1961) its network of parks from one to eight; another three are on the drawing boards. It has been spending a greater slice of its national income on parks than does the United States, and does it with a total annual budget of less than what Californians spend each year when they go sport fishing.

The parks of savannah Africa cover some extensive tracts. In eastern Africa (Kenya, Tanzania, Uganda, and Zambia) the parks total 38,000 square miles—an area the size of New England. Outside this main region, other parks comprise an additional 40,000 square miles. Similar parks have been set up in western Africa, but they are not as significant for conserving wildlife as the great chain of parks along the eastern side. Most African parks are in savannah zones, though other parks protect mountain and marine biotopes. Tsavo Park in Kenya and Kafue Park in Zambia are both over 8,000 square miles in area, Kruger is over 7,000, Serengeti 5,000, Wankie 5,600, Luangwa Valley 5,000, Ruaha 5,000, Kalahari-Gemsbok 8,030, and Virunga (formerly known as Albert or Kivu) 3,000. For comparison, Yellowstone—the largest park in the United States—is 3,400 square miles in area. A number of game reserves in eastern Africa afford adequate protection to wildlife, the most notable being Selous in Tanzania with 15,000 square miles.

"Wildlife Parks in Emergent Africa" is in part adapted from Dr. Myers' "National Parks in Savannah Africa," which appeared in Science, *Vol. 178, pp. 1,255-63, Dec. 22, 1972.*

Parks not large enough

But these parks and reserves for the most part are still too small. Their borders were generally established in response to political expediency rather than ecological requirements, with scant regard for the year-round needs of wild herbivores. The huge throngs of wildebeest, zebra, gazelle, and other large mammals now total almost two million in Serengeti Park alone, and the park should be enlarged by one-third or two-thirds in order to meet the long-term needs of its ecosystem. During a recent drought, for instance, the wildebeest migrated 25 miles beyond the park's perimeter in search of fresh grazing and water.

In October, 1973, Nairobi National Park totaled 26,000 herbivores for its 44 square miles, in contrast to its usual population of only 4,000 herbivores. The massive influx came from the hinterland territories, ten times larger than the park itself. Thus, Nairobi Park's ecounit totals almost 450 square miles, and without protection for this wide stretch of the life-support system, the park will not be permanently viable. Nairobi Park, in common with Tsavo, Wankie, Kruger, and a number of other parks, has constructed dams and pumping stations to provide water for wild herbivores during the dry season, hence the seasonal fluctuations in numbers.

In the past, these variations have not mattered much because adequate *lebensraum* was present in the support zone of the environs of the parks. But now savannah Africa is experiencing the biological and economic pressures of its human population, and the response of the two processes in combination is much greater than the arithmetic sum of the two if they worked in isolation. The most fertile areas of Africa now frequently support at least 500 human cultivators per square mile, and in some areas 1,500 to 2,000. In spite of high mortality rates, population growth rates in black Africa are among the highest in the world. This means a human spillover from the fertile territories into less suitable but more spacious biomes, notably the savannah grasslands. The process is taking place at extraordinary—and accelerating—rates. Uganda has seen the amount of land available to elephants decline from 70 percent of

Drought in the Serengeti: Gazelles strip leaves from low branches.

the country in 1929, to 17 percent in 1959, to less than 10 percent by 1974. While the overall number of elephants in Uganda is diminishing, the number of elephants in the parks is increasing through immigration.

Complexity of African parks

Moreover, there is some justification for saying that a park in savannah Africa could hardly ever be large enough. In North America and elsewhere in the temperate zones, a wildland ecosystem is generally not so complex or so integrated as those in tropical Africa. A disruption of the workings of Yellowstone or Yosemite, whether within the protected zone or outside, does not set off such significant repercussions throughout the system. An African park, by contrast, features an extreme diversity of animal and plant life; this is what makes it unique. Precisely because of these dynamic aspects, parks in Africa lend themselves much less readily to being put behind "fences," whether on the ground or on a park warden's maps or in the minds of international connoisseurs of parks. An African park ecosystem is more open-ended than the relatively "static" parks in the temperate zones. In addition, North American parks are frequently established to protect wild landscapes as much as to protect wild animals. Not that these factors should be considered merely as limitations on functional management; they can also serve as constraints on creative policy.

In the medium-term, let alone the long-run prospects for parks in Africa, the survival parameters will depend on the extent to which ecological determinants are balanced with socioeconomic factors. This equilibrium must be established and maintained at the interface between "nature's world" and "man's world" (to use two rather imprecise and disputable terms—man is, after all, of "nature," and "nature" is a human concept—but these terms nonetheless serve to point up the two sides of the argument as frequently perceived). In Africa, a reconciliation between ecologic and economic factors must recognize that tropical environments feature great productivity and great vulnerability. In addition to these two aspects to be safeguarded, there are often a dozen additional interests arising from man's immediate and future needs: the needs of human communities in emergent Africa, the needs of conservationists outside Africa, the needs of tourists, of the biotic associations, of the physiographic background, and so forth. When once the conflict is recognized as comprising not merely two sides in direct opposition, but as constituting a spectrum of activities to be accommodated in common accord, then conflict could give way to coordination, allowing the exceptional potential of savannah ecosystems—for meat and money as well as spectacle and science—to be mobilized for man's benefit.

Issues affecting park survival

To tackle this situation, a prerequisite contribution rests in park policy: what is a park supposed to be? what purposes should it serve? One central issue concerns the extent to which park policy at the national level should be permitted to conflict with what is unique to a particular area. Tsavo Park affords a refuge for one of the last great aggregations of elephants and the only great aggregation of black rhinoceros left on earth. Should it not therefore be managed as a park for these two species, instead of as a duplicate of the spectrum of plains herbivores to be seen in a dozen other parts of Kenya alone? Not, of course, that Tsavo should protect the elephants whatever the cost to other creatures; the first to suffer would probably be the rhinoceros, since it is the only other large browser without a regurgitatory digestive system for extracting as much protein as possible from the plants that it eats. Perhaps the objective should be to aim at as large a number of elephants and rhinoceros as possible, in conjunction with protecting the park's ability to support a variety of "high interest" species and communities.


Serengeti leopard with its kill.

A second issue deals with the notion that wilderness is to be protected from the interfering hand of man, especially modern man. According to this approach, African parks should constitute areas of the earth on which man can look without seeing the reflection of his own image. But in many instances, a policy of excluding man would imply that this should be the first occasion in a very long time that an area has been freed of man's influence. Man is a component, if not the dominant component, of most ecosystems in Africa. The Uganda parks were the scene of human habitations for centuries (if not millenia) until the early part of this century. The site of Nairobi Park was used as a military training ground, for growing wheat, and for leisure riding, until its designation as a park only 25 years ago. Potsherds dating from the time of Christ have been found in Serengeti Park. Indeed, some of the grassland areas with their tremendous throngs of herbivores may have arisen as a result of the extensive practices of pastoralist man, burning away bush to increase forage areas for his livestock, during only the past 5,000 years. The immense concourse of Serengeti animals, two million strong, is a spectacle that was probably afforded to very few of our primitive ancestors of Africa.

To this extent, then, parks should be established not merely to guard against something, namely man and his unwanted works. More positive justifications for parks include the values to science. Ecologists and ethologists can investigate them as "reference points" against which man can measure the effects of his activities in other parts of his living space. All the more is this pertinent when the wildland phenomena to be protected constitute exceptional instances of nature's works.

Supporting parks through tourism

Serengeti Park illustrates the conflicts facing those who frame policies for parks. The park serves a range of overt and covert purposes: encouraging tourism, stimulating the regional economy, serving science, reflecting the national need for revenue or prestige or both, matching the local need for meat and money, serving the world's needs for irreplaceable spectacles, among others—not all of which purposes are compatible. Throughout the 1960s, Tanzania was fortunate in having its network of parks extended, with great energy and foresight, while there was still time and space to do so. But during the 1970s, significant socioeconomic changes are overtaking the country, changes as

"It is not only the African lion that is a marvel of nature in Africa, it is the African ecosystem within which the lion exists in its own distinctive manner."

far-reaching for Serengeti in five years as those that took fifty years in times before the park was established. By the 1980s, there could well be ten times as many visitors to Serengeti as the present 70,000. They would be bringing enough foreign exchange into the country so there would be little doubt as to the most profitable use for Serengeti, provided of course that tourist revenues could be more equitably distributed around the region.

Yet, in the interim, some arrangement is needed to bridge the critical period of the next ten years. As with many other aspects of contemporary life, society badly needs broad-scale schemes to induce people to regard parks as long-term investments: pay now, benefit later. Areas such as Serengeti might well qualify for what the rest of the world could contribute in the way of "cost difference compensation," especially when the rest of the world is insistent that what is at stake is not the Africans' heritage alone. Compensation along these lines might eventually be available under the World Heritage Trust system of parks, protected areas being formulated by the United Nations Educational, Scientific, and Cultural Organization (UNESCO).

Furthermore, tourism as a support for parks is subject to serious criticisms, by the man living in the park hinterlands or within a game reserve itself. With a monthly income perhaps totalling what a single busload of tourists pays at the park entrance and with a waistline that reveals different nutritional problems from those of the visiting foreigners, he is little interested in foreign exchange. He is little likely to be any more impressed by tourism's impact on the economy than is the American rancher who sees his rangeland disrupted by the Yellowstone elk herds. The African peasant knows a leopard not as a splendid subject for the camera viewfinder but as a beast that may ravage his livestock.

The gate fees of most parks go to the national exchequer, although a portion is sometimes diverted to the district treasury. Game reserves are usually run by the local council, which gets most, if not all, of the revenues. Safari lodge owners and other concessionaires in parks and reserves generally pay a bed levy and various other taxes, some of which go to augment local funds. But these allocations of revenue are rarely what the local man thinks of as local. Amboseli's central sanctuary of 30 square miles has been producing well over half the total income for the 8,000-square-mile district. These profits should allow for dispensaries, schools, and cattle dips all across the landscape for those Masai who have been particularly deprived by tourists' needs; hitherto they have benefited but little from tourist contributions to the district treasury.

Support through game cropping

A more favorable prospect for the local man, as well as for park administrators with an excess wildlife population, is game cropping. The ecological merits of cropping have been documented in detail, and the economic potential of turning wild creatures into meat and trophies is considerable. Cropping, like tourism, need not be an exclusive activity, since it can prove complementary to subsistence or commercial livestock ranching. It can also support rather than conflict with park policies, even if these policies are seen as protecting wilderness for its aesthetic, cultural, and scientific values alone, while on the other hand, cropping is a purely commercial activity. During the 1960s, 20 million pounds of elephant and hippopotamus meat from park cropping projects were put on the market in Uganda. Butchers came from 100 miles away for a product which they knew had a ready market. Presumably the customers with protein-poor diets had few qualms about whether the meat was poached or legally shot, whether it derived from conservation management or from commercial exploitation; they gladly left such deliberations to wilderness moralists.

Cropping can also be highly profitable. An elephant—the most frequent candidate for projects aimed at reducing excess park populations—is worth at least $250. A reduction campaign of 10 percent for the surplus elephants in Tsavo Park would double the present financial allocation for all of Kenya's parks, while a substained-yield harvest of 5 percent per year would triple the total wildlife research budget. (Natural mortality accounts for 7 percent in a stable population.)

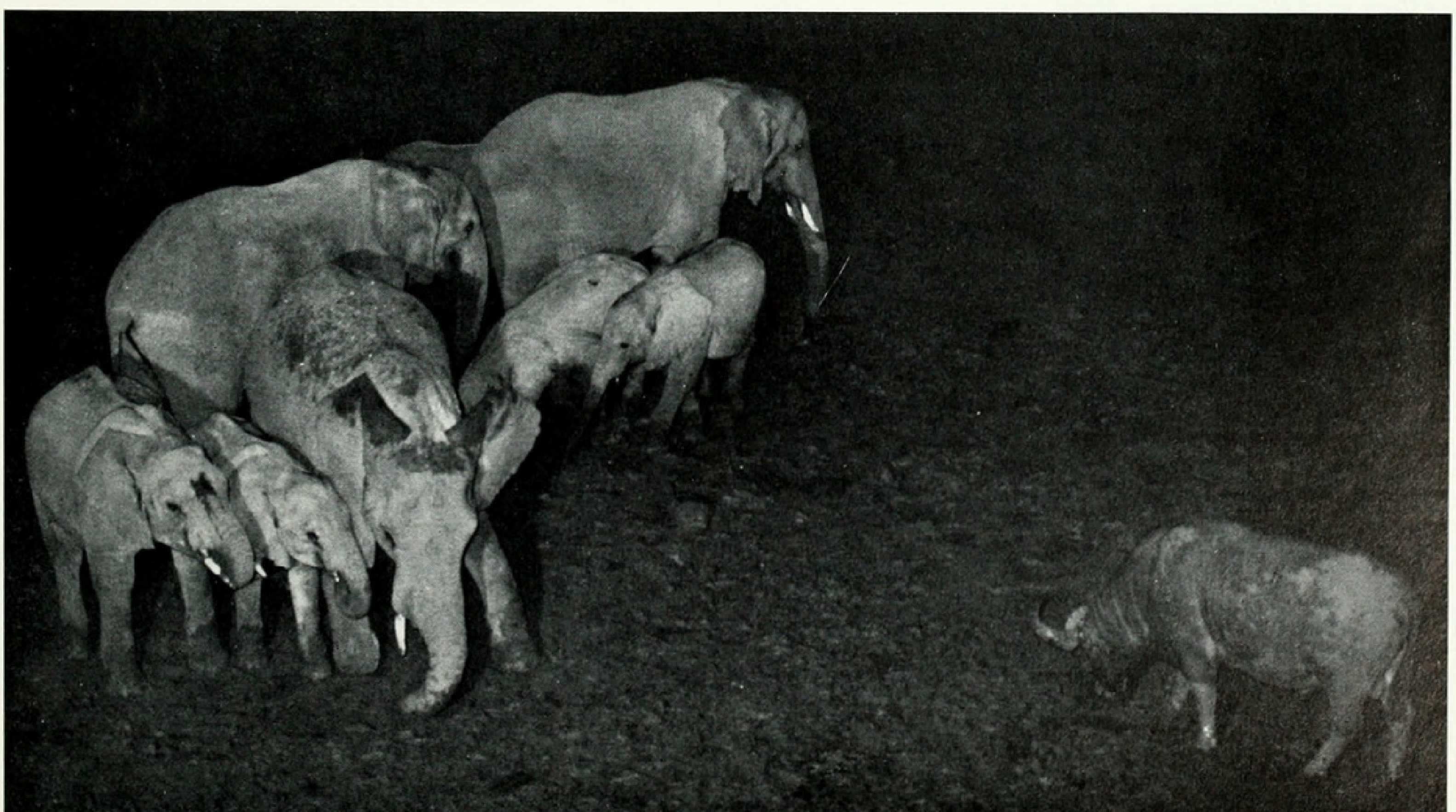
These possibilities emphasize the need to view parks as no more than heartlands within broad ranges of supporting territory to permit genetic exchange; to provide protection against disease, and to allow scope for the various dynamic and compensatory factors which constitute what is ultimately unique about African parks. It is not only the African lion that is a marvel of nature in Africa, it is the African ecosystem within which the lion exists in its own unique manner.

The strategy of multiple use of land, as implied by these policy perspectives, is being attempted at the 3,200-square-mile Ngorongoro Conservation Unit in northern Tanzania. Here, a broad range of resources and an integrated strategy attempt to cater not only to wildlife-based activities but to cultivation, pastoralism, and forestry as well. The framework allows for several purely protective practices, such as watershed management. Major objectives are directed at tourism and game cropping, as well as protecting the supreme spectacle of Ngorongoro Crater. The water tables of the 100-square-mile crater are dependent on catchment areas 20 miles beyond its rim, hence the forest resources are exploited in a manner compatible with the crater's interests. This conservation unit thus allows man to manage ecosystems for the two returns he needs from his environments, namely simplicity of food production and enough variety in land forms to protect his own living space. The largest share of the unit's revenues comes from tourism, and that resource base in turn is protected to ensure tourism's continued contributions to the local economy. If the crater were declared a national park, the income would mostly go to the national exchequer in Dar es Salaam, 400 miles away. The conservation unit enjoys virtually all the advantages it did when it was part of Serengeti Park, and seems better fitted to meeting the pressures of the future by being integrated with surrounding land uses. However revolutionary the Ngorongoro strategy may seem to conservationists who like their sanctuaries in neat packages, it is not so very extraordinary to local people who have long combined various forms of land use. What seems revolutionary to them, if not regrettable, is the idea of parks in segregated segments.

For single park authority

Those wildlife tracts which are already designated as parks could receive better protection if the park were integrated with a regional management plan, operating under a single conservation authority. The hinterland would constitute a buffer zone where game cropping and sport hunting could take place. The environs would thus afford the park a breathing space, instead of a no-man's land "noose" constricting the park's life-support systems. Radiating from the park at the center, with its policy of minimal interference by man, would be zones of increasingly intensive subsistence and commercial activities, such as those now threatening the ultimate survival of the parks. The park itself would continue, with little modification of its basic purpose other than

Elephants and a water buffalo share a water hole.



Viewing parks as natural resource ecosystems, rather than as places of refuge, would allow a start on the mobilization of all exploitable resources for local human communities of emergent Africa. This measure would anticipate the times when such huge tracts of land as parks and reserves in savannah Africa will have to justify their existence by meeting local needs. This stage will arrive soon enough, and parks must accept the new situation, if they are not to vanish altogether within a few decades. Multiple-purpose units, such as are proposed in this article, would still leave scope for the purist spectator to experience wild nature, undefiled by man's hand.

In the main, the institutional framework known as "national park" does not allow park managers to deploy the full range of conservationist techniques for protecting wildland resources. But a park must be considered a regional as well as a national entity. In Africa a park could never have perfect boundaries, since the ecosystems show too much flux in their workings from one season to the next. Human institutions, by contrast, tend to be inflexible, to emphasize boundaries of local authority and to encourage administrative autonomy. Man must strive to interfere as little as possible with "given" ecological factors such as the locality of the Serengeti migration. But wildlife parks are, like any institution contrived by man, subject to changes dictated by his biological and economic requirements. All the more, then, should park boundaries be flexible in concept in order to match the dynamics of park ecosystems.

CARBON MONOXIDE *(from p. 6)*

result in the atmosphere becoming intolerably hot. There would be many associated repercussions—for example, the surface would be drier with much water held in permanent clouds, creating worldwide drought.

Since CO_2 is considered today to be a "clean" product of fossil fuel burning, the development of engines that more completely burn fuels and generate more and more of it, though nontoxic in itself, will not be a blessing in the long run. Use of fossil fuels must reach a plateau, preferably a lower one than at present, and other energy sources that produce no carbon-bearing compounds must be developed.

The facts about CO are, nevertheless, of immediate interest. The earlier environmentalists were wrong in their estimates of the importance of the man-made input of it into the atmosphere. They served, however, a useful function in raising the cry against it. The research that followed has laid to rest the large-scale and long-term effects of CO as a pollutant (except on a local scale for short periods, as mentioned above). Were it not for the environmental concerns of the few, specific figures on the various sources of CO might never have been forthcoming.

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