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FIG. 1. Greater kudu on green burn, Hluhluwe Game Reserve, Natal South Africa.

Fire and Animal Behavior

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THE REACTIONS and relationships of animals to fire, the charcoal black burn, the straw-colored and later the green vegetation certainly attracted the attention of primitive man and his ancestors. In "Fire—and the Ecology of Man" I proposed that man himself is the product of a fire environment—"*pre-man primates as well as early man inhabited fire environments* and had to be 'fire-selected' . . . to live in such environments." (Komarek, 1967). Therefore, man's ultimate survival, as had been true with other animals that live in fire environments, depends upon a proper understanding of fire and the relationships of animals and plants to this element.

Modern literature, particularly in the United States, has been so saturated with the reputed dangers of forest fires to animals that he has developed a deep seated fear of all fires in nature. In this nation, the average individual is only beginning to realize the proper place of fire and fire control in forest, grassland and field. Unfortunately, much knowledge on fire and animal behavior that was common information to the American Indian, pioneers, and early farm and ranch people has been lost though in some parts of the world a large body of this knowledge still exists. One of the purposes of this discussion is to stimulate others to record such information; not to dismiss it as folk-tale or fantasy.

Many years of experience and close association with forest and grassland fires and the environmental change they evoke has caused

me to ponder the remarkable behavior of animal life upon encountering fire and its effects. Suddenly, fire alters ecological conditions affecting the animals and plants; the habitat, predation, availability of food, visibility, etc. Yet many animals live with fire as a frequent environmental factor and require it to condition the habitat in which they live. As an example, *annual* fires are a virtual necessity in the management of high populations of the bobwhite quail in certain areas of the deep Southeast. Fire as a cause of adaptive animal behavior is an interesting if difficult field of study.

K. D. Roeder in the Introduction to Niko Tinbergen's *Animal Behavior* (1968) contends that:

> The study of animal behavior began with early man's first attempts to draw conclusions and make predictions from his observations of the creatures around him. Yet today it remains as one of the most complex and challenging branches of science. In fact, at present we seem closer to understanding the origins of life itself than we are to how and why most living things behave as they do.

This is particularly true of the study of fire and animal behavior because the idea that all fire is destructive has permeated the minds of the general public and the scientific community. A recent example of this kind of information demonstrates this propaganda of fear while reflecting a desire to condition the general public to requests for more and more funds to fight bigger and bigger fires. The following extracts from the *American Forests Magazine*, the official publication of the American Forestry Association exemplify such information:

BLACK FRIDAY–IDAHO STYLE

> September 1, 1967 was Black Friday literally and figuratively for Idaho's verdant forests. On that never to be forgotten day the ancient enemy, forest fire, was destroying 640 acres of mountain timberland every three to six minutes. . . .
>
> The fire had no intention of being stopped! A wall of flame swept over the divide into the Pack River drainage and by 10:00 p.m. had unmercifully devoured another 35,000 acres in seven and and one half hours. . . .

> As the wind lessened . . . this fiery giant lay back eager to explode on the coming day. (Wylie, 1968)

And, in a "Fire Fighter Views The Sundance Fire":

> . . . The inferno had been so hot that it hadn't left the usual islands of untouched trees. . . . If atomic bombs ever desolate the earth, it will surely look something like this. Smoke, charcoal, and ashes. Black. With such silence. No movement, no sound.
>
> Then we found tracks of returning wildlife. It was incredible. Bear, deer, and rabbit. Animals coming back to search for the only home they had known. They wouldn't find it. Nor would they find food. They would wander helpless, hungry, lost. The lucky ones might stay in a straight line and eventually come into a green and living world. The others. . . .
>
> My eyes stung. These wild things, frightened, trapped, and driven as they had been . . . and now these tracks, like refugees returning . . . (Gorsuch, 1969)

The fire burned a strip 3½ miles long and less than a mile wide. On this area of 55,910 acres were focused the activities of over 500 men and over 100 machines from September 1st to the 9th. It was all this activity that frightened the animals, not the fire. It was not mentioned that the burned area contained logging debris and total fire exclusion had been practiced for many years resulting in a uniform blanket of highly combustible litter. This constituted a concentration of more fuel than would normally occur in nature, except in unusual instances. A student of animal behavior in relation to fire must be aware of the tremendous number of such highly emotional accounts in United States literature.

ANIMAL BEHAVIOR

Tinbergen (ibid) points out that in a study of animal behavior one "tries to find out as exactly as possible 'what makes animals tick;' why animals behave as they do." Scott (1968) has put it rather succinctly:

> . . . The most important things about an animal is *what it does;* and when we have described this, it is possible to go ahead and

> analyze the environmental changes which cause it to act, the structural and physiological peculiarities which modify its behavior, and the various and individual consequences of its reactions.

And Roeder (ibid) has written:

> The complexity of animal behavior study does not depend on elaborate mathematical treatments, on delicate instruments or giant computers—the paraphernalia that people usually associate with science. Although these devices have their place, they are after all *only a means of wringing facts from nature,* and an *experienced* student of animal behavior armed with binoculars and hidden in a blind can gather in a few hours enough facts about his subject to keep him pondering for a year. The challenge is mainly to the intellect, to the judgment and patience of the observer rather than to his technical ingenuity. (italics mine)

This discussion is primarily concerned with how animals behave when confronted with the fire itself, the smoke, the burned area and the resulting "greening" burn. An analysis of the "environmental changes . . . the structural and physiological peculiarities" will be made wherever possible. A reasonable, but far from complete, literature search has been made. This is quite difficult as relative information is sparse and widely scattered. There is considerable fragmentary data in older publications before the advent of forest fire prevention policies. An attempt has been made to compile many different facets of information on many animals. I will appreciate any references not listed in regard to animal behavior and fire.

BACKGROUND

It may surprise many that animals do not have an innate fear of fire. Fire is a natural part of the environment of many animals—even *annual fire*. Because people, including scientists, have for two generations been bombarded by highly emotional and undocumented reports that fire is not only destructive to wildlife generally but that animals had an inborn fear of fire, I find it necessary to partially document my activities in the field of fire and animal ecology. Some of these are discussed in "Lightning as a Sculpture of Life" (Lear,

1966). My investigations in fire and animal behavior have largely been empirical with relatively few sophisticated experiments. However, as *experience* is a very important and critical factor in any behavior study, a short summary of my experience follows.

As mammalogist for the Chicago Academy of Sciences I was engaged not only in ecological life history and taxonomic studies on mammals but also was involved in considerable work with birds, reptiles and amphibians. This included a comprehensive survey of mammals of the present Great Smoky Mountains National Park (Komarek and Komarek, 1938). As a youth I had studied coleoptera and worked on the H. Psota Coleoptera collection.

From 1934 to 1943 I was an ecologist with the Cooperative Quail Study Association, Thomasville, Georgia (Herbert L. Stoddard, Director and Henry L. Beadel of Tall Timbers Plantation, Secretary). The association, primarily a research and consultant group in game management, had a membership of over 100 hunting plantations averaging about 10,000 acres in size which were scattered from North Carolina to Arkansas with a concentrated membership in the Thomasville, Georgia—Tallahassee, Florida region. The purpose of these plantations was to hunt the bobwhite quail and wild turkey and *annual fire employed as the principal management tool.* We were also engaged as consultants with many governmental agencies concerned with wildlife, range, field and forest. Throughout this period well over 25 burns were conducted by us per year or a total of over 225 on Sherwood Plantation, the experiment station for the Association. In addition we observed many thousands of acres of burns on the lands of our members and others.

Some of this study was conducted from 1943–45 in my Farm and Game Service, a consulting business, with further experimentation on Birdsong Plantation. We (my wife, brother and I) had acquired Birdsong in 1938, and our major objective was to reclaim 565 acres of heavily brush-choked lands caused by total fire exclusion and turn it into a modern cattle farm while integrating wildlife management. In later years our children (Ed, Jr. and Betsey) assisted us. Since they grew up with fire and had not been "conditioned" that all fire was destructive as had we, their bright eyes caught many a facet of fire ecology that we otherwise might have missed. From

1937 through 1958 we averaged well over 20 small fires per year or a total of about 200 fires.

In 1945 my brother and I took over the management of Greenwood Plantation (owned by John Hay Whitney), 18,000 acres in Thomas County, Georgia with instructions to fully develop the property for hunting purposes, assist in the development of southern agriculture, and to put the forest on a modern management basis integrated with wildlife management. This led to the development of hybrid corn for the south in cooperation with the Georgia Coastal Plains Experiment Station, Florida Experiment Station, and the U.S. Department of Agriculture (Komarek, 1951; Hayes, 1963). In all three phases of management, wildlife, forest, and farm, *fire has been a primary tool.* Over most of the lands this has meant *annual* control burning. We had to train our own personnel to do this properly. This has been an admirable opportunity to study the relationships of fire to animal behavior.

My studies in animal and fire ecology have also carried me to all the states of the union; all the provinces and territories of Canada with the exception of New Foundland and the Northwest Territory; to ten states in Mexico. These have been achieved by car or camper and tenting and were studies in the field. In addition I have had the opportunity to study fire ecology in Africa (Kenya, Tanzania, Zambia, Rhodesia, Natal, South Africa) and in Australia (Western Australia, Victoria and the Northern Territory) with investigators most of whom have spent most of their lives in the "bush." The opportunity to lecture or give seminars on fire ecology throughout the United States, Canada, Mexico, Africa, and Australia has also been of great benefit to this study. In addition the chairmanship of the past nine Tall Timbers Fire Ecology Conferences has given me an excellent chance to discuss and review studies in fire ecology with many informative and able associates.

METHODS

In 1959 my interests were focused intensively on lightning fires (Komarek, 1958–59), and I began to realize that natural or lightning fires occurred only from late April to October in this region. In

game management we had been concerned primarily with "man-made" fires during the late fall, winter, and early spring months. By 1964 I was experimenting with summer fires on Birdsong, noticing behavioral differences in certain insects, particularly in two species of grasshoppers (Komarek, 1965).

In the early spring of 1968, Ed, Jr. observed that many kinds of insects appeared to move out ahead of certain kinds of fires in a more or less regular pattern. That stimulated us to devise a system of "simulated" lightning fires. In this procedure a fire would be lit with either one match or a very short line of fire from a drip-torch. These spots were then marked, and in most cases photographed, with a white stake and numbered. We would stand by quietly and observe what was happening among the animals ahead of the fire, in the smoke, and on the smoking burn. Later we would carefully examine the burn for dead or alive animals. After the burns "greened" further observations were made. If possible animals were collected for identification. In the summer of 1968 (from May 25 through September 6), 69 such experimental burns were made in grass and forest vegetations. Other such burns were also conducted at Tall Timbers Research Station with the help of University students. Between 1964 and 1969 well over 100 experimental summer burns were carried out. Many of these were executed during thunderstorms, some were terminated by rain, some were quite activated by thunderstorm gusts, and in three instances we were forced to leave because of intense lightning activity.

AVOIDANCE RESPONSE TO FIRE AND SMOKE

Since my connection with the Cooperative Quail Study Association (Komarek, 1937, 1939; Stoddard, Beadel and Komarek 1961) I have been intrigued by the behavior of animals in response to fire and smoke, particularly their ability to avoid death or injury from a dangerous agent such as fire. My wife and I attempted to kill cotton rats with grass fires without success and found that these rodents somehow "sensed" the oncoming fire in time to take precautions for their safety (Komarek, 1963). In recent years I have been interested in studies on the escape behavior of such mammals.

Cotton Rats:—After examining hundreds of recently burned or burning cotton rat nests during the breeding season of these rodents, I have wondered how their juvenile escaped death for I have yet to find a single nest with dead or injured young. The squeaking of cotton rats are quite often heard ahead of oncoming fires. These sounds have been attributed to juvenile rodents. However, while conducting our simulated lightning fires, Ed Jr. noted that these squeaks were coming from adult rats although they appeared to be the excited squeaking of young. In specially designed burns over a small but prolific cotton rat area it was observed that these rodents removed their young in advance of the flames. On July 17, 1969 shortly after a fire was set and backing into the wind with a line of flames over 18 inches high I heard the familiar squeaking call. I was stationed along a firebreak near the edge of the oncoming flames. Suddenly, squeaking continuously and excitedly, an adult cotton rat came within 6 feet of me. It stopped, looked at me attentively, and continued. I then noted a well worn runway, which went across the plowed firebreak and into vegetation on the other side, between me and the rodent. While I watched, the cotton rat "herded" a young juvenile into the runway from the surrounding grass. As soon as the juvenile rat was in the runway the adult chased it a short distance away from the flames and returned to repeat the same process with two other young. These young were about 2 or 3 weeks of age and as soon as they were safely across, the adult disappeared and no further sounds were heard.

A few days later, under similar circumstances, I watched an adult cotton rat carry away from the flames four very young rats (eyes still closed). They were carried one at a time, by the scruff of the neck, and deposited somewhere in dense vegetation across the firebreak from the burning grass. In both instances, apparently, I saw only the final stages for these rodents usually have six or more young per litter. The squeaking sounds heard as the flames approach are apparently calls to the young. These rodents can sense the fire, and from which direction it is coming in sufficient time to rescue their young. Presumably, they place them in shallow pop holes or in areas away from the flames.

Frequently we have seen cotton rats run across the line of fire,

apparently finding a weak spot in it, and return to the smoking burn without injury. However, under certain circumstances, in certain types of cover, they are occasionally singed or killed. In burning ungrazed pasture of tall bahia grass (*Paspalum notatum*) where the ground was hard from over 25 years of grazing, I was able to trap and kill cotton rats by encircling with fire. However, in the part of the pasture where there were a number of old imported fire ant (*Solenopsis s. richteri*) mounds in which the rodents had burrows, they easily escaped the fire. In such areas I was unable to kill any cotton rats by fire encirclement.

Cotton rats in the Deep South live in a fire environment which is necessary for the maintenance of their habitat over a period of years. By utilizing behavior patterns that have evolved by natural selection they seem to have fully adjusted to fire.

Rabbits:—For many years Mr. H. L. Beadel conducted an annual rabbit hunt on Tall Timbers Plantation for his employees after the property had been partially burned over in late February or early March. Twenty to thirty employees armed with "throwing sticks" about 18 inches long and about 1 to 2 inches in diameter, along with their nondescript dogs would hunt over a certain section of the plantation. The remaining unburned spots would be set afire during the hunt. When the barking dogs or fire flushed a rabbit all would follow, whooping and yelling, until someone's throw would kill the rabbit. For over 25 years I attended these hunts and examined the rabbits for disease, parasites, breeding data, etc. Two species of rabbits were involved; the Florida cottontail (*Sylvilagus f. floridanus*) and the marsh rabbit (*Sylvilagus p. palustris*). As many as 80 rabbits would be killed in one hunt (almost all cotton-tails); however, I never examined a cottontail that was burned, scorched, or killed by fire. Although no more than 12 marsh rabbits were taken in a year, at times some were found to be partially burned or singed, and, in a few instances, totally burned. Apparently the behavior patterns of the cottontail under these conditions made it much less prone to injury from fire than the marsh rabbit. In some years the hunt took place while both species of rabbits had suckling young in the nest. Although I was particularly watchful during those years no juvenile rabbits were ever found singed or burned in nests. In fact, very few

were found by hunters or dogs. It should be noted that the singed marsh rabbits probably had to choose between the actions of man, his dogs, and fire and elected the latter.

Large Mammals:—Mammals of varying sizes including elephants, have been reported killed or injured by catastrophic fires. Where there are heavy accumulations of fuel creating the possibility of fire storms the danger to mammals must be great. However, rarely is there any mention of the activities of man that might have caused these deaths. Considering the many millions of acres burned every year in North America, Africa and Australia such deaths are unusual, even rare. Somehow, mammals have the ability to sense the fire, smoke, and the direction it travels. These animals do not panic and flee ahead of a wind driven fire, but they usually escape along the sides or flanks. I also believe that panic from fire only in rare instances and under unusual conditions occurs in animals. My associates and I have observed Virginia deer (*Odocoileus v. virginianus*) quietly watching a fire at night while slowly moving away from the flames. My livestock (cattle and horses) show no fear of a fire racing across a pasture. In fact, a few times I was afraid that they might be caught by the flames but with no particular concern they simply move. Horses, cattle and dogs have been seen warming themselves quite near moving flames.

A week before we arrived at the Kruger National Park in South Africa a lightning-set fire burned over nearly 300 square miles in about 4 days. We could find no record of any large mammal trapped by this fast moving fire, though many species of large mammals inhabited the burned area at the time of our visit. The personnel in national parks and game refuges in the United States, Canada, Australia, Kenya, Tanzania, Zambia, Rhodesia and South Africa were of the opinion that only in rare instances are large animals trapped, even in catastrophic fires. Reports of such deaths have been built up by foresters, conservationists, and the news media far beyond their actual occurrence. Consequently, some sensing mechanisms and behavior patterns certainly must give warning in sufficient time for large animals to move out of the way of hot fires, particularly if man with his fire-fighting activities does not disrupt or interfere with such escape. Phillips (1965) asserts that elephants in certain kinds of

vegetations become quite nervous when fire is near; whereas in other areas they pay little attention to it.

Reptiles:—There are 500,000 or more acres in the Thomasville, Georgia—Tallahassee, Florida hunting lands that are burned over annually. The southern diamondback rattlesnake (*Crotalus admanteus*) inhabits these areas. The annual burning does not seem to have reduced the number of such snakes, and I have not seen a rattlesnake killed by fire, and only rarely heard of such an occurrence. A typical sight on a cool spring morning is that of rattlesnakes sunning themselves in front of an old stump hole or burrow on a fresh, blackened burn. I have only found two water moccasins (*Agkistrodon piscivorus*) killed by fire on the many acres of marsh I have investigated. They were found where a fire had encircled them in a deep tidal marsh while the tide was out. These snakes are also abundant on the previously mentioned hunting lands around

FIG. 2. Diamondback rattlesnake on fresh burn swallowing small cottontail rabbit. Photo by E. V. Komarek, Jr.

lakes, ponds and low wet areas, and rarely have I heard of one of these being killed by fire. Likewise striking, is the lack of any evidence to show that any other species of snakes are killed by fires, consequently it must be of rare occurrence.

Many species of snakes, if not all, find their prey by heat sensing pits and it may be that these same organs can respond to the infra-red radiation (or other radiations) of fires. I do not know of any experimental evidence, however, in this regard, but it certainly should not be a difficult experiment to conduct in a laboratory. Fire killed lizards also seem to be of rare occurrence.

Amphibians:—I have also wondered about the few amphibians that one finds on burns so the following observations are relevant:

> On July 14, 1969 (burn KB-11) I watched a green tree frog (*Hyla cinerea*) move ahead of backing fire—took photos—moved about 25 feet then got into wet leaves and soil in a small depression fire went around this—at one time the fire was crackling within 1 foot of the frog—it did not seem to be particularly scared. (EVK field notes)

This frog kept about 1 to 2 feet ahead of the fire which was backing into the wind about 100 to 200 feet per hour and flames flared to about 2 feet high.

On January 21, 1969, I set a fast moving fire in tall grasses of several species that were standing in water, in which a chorus of spring peepers (*Hyla crucifera*) was in full swing. At times the flames were over 6 feet high as the wind drove the fire across the water. The frog chorus hushed as the fire swept overhead but commenced immediately after the fire had passed as if nothing had occurred. Careful examination of the area showed no evidence of any injured or killed frogs.

Insects:—Various responses and reactions of several species of insects have been noted throughout our experimental burns and our annual control burns. Usually fire causes a steady exodus of insects varying in behavior according to species and to the kind of fire. A fire burning dead grass mixed with a heavy growth of green grass in summer produces little flame but large amounts of dense white smoke. Under conditions where there is little green vegetation and much dead dry debris, the flames are large and the small amount of

smoke is blackish colored. Certain insects react differently to the two kinds of fire. In the former, the Carolina grasshopper (*Dissoteria carolina*) has a tendency to crawl up stems or twigs into the dense smoke and remain motionless. In the latter conditions, particularly, such as a backing fire in cool weather, it will hop, crawl, and make short flights just ahead of the flames. Space limitations make it possible to only record a few of my observations at this time.

The green katydids (*Amblycorypha oblongifolia*) and (*Pterophylla camellifolia*) will sometimes take flight as much as 25 yards or more in front of a wind-driven head fire. With a backing fire into the wind they are apt to remain in the grass until the fire is much nearer. The red-legged grasshopper (*Melanopus femurrubrum*) usually does not start to move in numbers until the flames are closer; with a backing fire they will stay just a few feet ahead of the fire, moving as it does. However, under certain conditions they will take wing in large numbers. There are times when these insects and many other species come flying ahead of a fast moving fire in a spectacular, cloud-like manner.

These observations, however, do not mean that these species are not trapped by certain kinds of fire. Ed Jr., and I found that we could kill relatively large numbers, particularly of the latter species, by manipulating the fire along with the vagaries of the wind and fuel. At times we found many dead grasshoppers cooked to a pink color and sometimes lightly charred in our fires; at other times few were to be found.

Several species of Crickets (*Gryllidae*), but particularly the common garden cricket (*Acheta* sp.) also was found to advance several feet ahead of the fire in large numbers at certain times. It was also evident that although many might be killed by the fire, others had taken refuge under debris, in the soil, etc., for they are frequently seen crawling over the still warm burn.

At times one of the most striking events is the movement of spiders ahead of the fire, particularly the common wolf spider (*Lycosa rabida* Walckenaer). They are also found crawling, apparently foraging, immediately after the fire has passed. At times the amount of spider webs found the morning after the burn is quite spectacular, particularly when the web is wet with dew. Sometimes spider webs

so closely woven over the burned ground give the impression of a mesh-like covering.

Dr. William B. Peck (pers. comm.) informed me that in April 1967 he had found heavy wolf spider concentrations on a burned over savanna "just south of the village of Cuajinicuilapa, on the Guerrero-Oaxaca state line" in Mexico and "The fire certainly had not majorly depleted the populations of several species that I found."

Although fire is used in the control of the two-lined spittle bug (*Prosapia bicinta*) in coastal bermuda pastures the froth-masses of certain species of the spittle bugs are in evidence on the blackened burn within a day or so after the fire in native grasslands.

Smoke has been used as a deterrent to many species of insects obnoxious to man. Thus, our children Betsey and Ed Jr., found that they could easily keep black flies (*Simuliidae*), gnats, and mosquitoes away, at least temporarily, from the entrance to our camper in the Northwest and in the Yukon Territory by waving a smoking brand around the doorway before entering.

FIG. 3. "Spittle-bug" froth on fresh burn, Georgia. (photo by E. V. Komarek, Jr.)

On June 30, 1968, shortly after I burned a broomsedge area. I noticed an agitated colony of ants (*Camponotus abdominalis floridana*) that had been in the path of the flames. Their nest was in the ground among some logging debris which had been charred by the fire. Some ants were killed by the fire, however, the survivors organized a trail into unburnt vegetation within 1 hour after the flames had passed and were moving eggs and larvae into the unburnt vegetation. By noon of the next day they had completely moved their colony out of the burn.

A similar observation was made by S. Fluker, in Hawaii in November, 1967, (pers. comm.):

> The observation I made in Hawaii concerning ants and their behavior in sugarcane fields before, during, and after the burn involved the ant *Iridomyrmex humilis* (Mayr) the Argentine ant. Because the Argentine ant develops very large almost contiguous colonies in certain sugarcane fields in Hawaii they are fairly easy to observe . . . On three or four occasions I noticed that the Argentine ants would move out of their nest ahead of the fire. Although there was some movement ahead of the fire, by far, the largest movement occurred after the fire had swept through the field and the ashes had cooled. Then, there was an extremely large and seemingly orderly movement of the Argentine ants out of the burned field. Apparently, the fire did not generate heat sufficient to raise the soil temperature enough to kill the colonies. About three hours after the fire, Argentine ants were observed to be moving out of the field in big columns. This would include workers (some carrying brood) and reproductives (both alate and apterous forms.) The emigrating ants would eventually settle and establish nests in adjacent unburned areas. . . . No attempt was made to determine how far in the field the ants immigrated from. Although, my observation was with the Argentine ant, I am sure the other ant species that commonly are found in sugarcane (E.g. *Pheidole megacephala* Fabricius), *Paratrechina longicornis* (Latreille), *P. bourbonica* (Forel), and *Anoplolepis longipes* (Jerdon)) fields act in somewhat the same manner . . . I never noticed any birds feeding on the ants during my observations . . .

Jansen (1967) records interesting relationships of the obligate acacia-ant (*Pseudo myrmex* sp.) to its fire environment. In essence this ant cleans the vegetation around its acacia colony plant to keep the acacia stem and branches from being killed by fire; essentially a

firebreak. It is interesting to note that this same principle has been used by man. Many African native tribes that live in fire environments keep a wide area free of all vegetation and debris so that fires are kept away from their buildings and possessions. In the piney woods of the Deep South it was common custom, before the advent of forest fire protection policies, for the inhabitants to keep a wide area free of vegetation, leaves, etc., by constant hoeing and sweeping. These dooryards around every woodland home were a very obvious adaptation to the forest that has been called "The Forest that fire made." This was a practical solution for while eliminating fires, it likewise kept the immediate area free of rattlesnakes, ticks, and other obnoxious animals. Apparently it was copied from the Indians who also kept the ground bare of vegetation around their homestead and villages.

ANIMALS ATTRACTED TO FIRE AND SMOKE

Birds:—That the fire and smoke of grass or forest fires has an attraction for many species of winged predators such as hawks, eagles, kites, vultures, etc., appears to be common knowledge among rural people or those that live in the "bush" in many parts of North America, Africa and Australia. However, little of this behavior has ever been recorded; the following are the only references I have found.

William Bartram (1791) who traveled through the lower southeastern states from April 1773 to January 1778, writes in regard to the King Vulture (*Sarcoramphus papa*) (Harper, 1936);

> . . . These birds seldom appear but when the deserts [pine barrens] are set on fire (which happens almost every day throughout the year, in some part or other, by the Indians, for the purpose of raising game, as also by lightning): when they are seen at a distance soaring on the wing, gathering from every quarter, and gradually approaching the burnt plains, where they alight upon the ground yet smoking with hot embers; they gather up the roasted serpents, frogs, and lizards; filling their sacks with them; at this time a person may shoot them at pleasure, they not being willing to quit the feast, and indeed seeming to brave all danger. (Bartram, 1791; Harper, 1936)

Allen (1871) in discussing Bartram's observations said that it was well known that the Caracara (*Caracara cheriway*) also had this habit of being attracted and congregating on burns. Goldman (1920) noted that hawks in Panama were attracted by such fires. Paintin (1965) and Komarek (1967) mention that Drongoes (*Picurus asimilis*), a few Grey Hornbills (*Lophoceros nasutus*) and Lilac-breasted Rollers (*Coracias caudata*) came to fires and that:

> "As I had travelled through this area frequently and had never before noticed this dense populations of Drongoes I assume that they had been attracted by the smoke column from far afield.
>
> "I had noticed this dense behavior on several occasions in the past but never to such a great degree."

Oakley (1961) wrote:

> ". . . just as rooks and some other birds exhibiting "anting behavior" seek fire and smoke (Burton, 1959, pp. 99–109).

In the Proceedings of the London Entomological Society is this interesting note:

> *BIRDS AND INSECTS AT THE EDGE OF FIRE.*—Dr. G. B. Longstaff states that large areas of the reeds and papyrus on the White Nile which constitute "the Sudd" are annually burned. Many birds are attracted to these fires, amongst others Mr. A. L. Butler of Khartum had especially noticed various species of swallow. Dr. Longstaff had, on more than one occasion, seen a number of kestrels in the smoke to the leeward of a fire, and had once watched for some time a pair of bee-eaters (*Merops nubicus*) perch within a few feet of a fire on the windward side. He saw them fight for a large Orthopterous insect which was driven out. This Merops, a beautiful copper-red bird with peacock-blue head and rump, was locally called the "fire-bird." The picture postcards exhibited showed four kites (*Milvus aegyptius*) hawking in the smoke.
>
> Commander Walker observed that he had seen the same thing occur in Australia, birds waiting for insects at the edge of a bush-fire and seizing them as they came out. (Proc. Ent. Soc. London, 1912, p. xlii and xliii)

Williams (1963) writes in regard to the above Bee-eater which

FIG. 4. Cattle egrets flying and feeding ahead of sugarcane fire in Puerto Rico. Photo by Dr. Herminio L. Lugo.

he calls the Carmine Bee-eater: "Numbers are frequently attracted to grass fires."

Machlan, (1966) mentions that the Lilac-breasted Roller ". . . is quickly attracted by grass fires," and that the Fork-tailed Drongo (*Dicrurus adsimilis*) ". . . may be seen when numbers are attracted . . . when grass is being burnt."

The African cattle egret (*Bubulcus ibis*) is frequently attracted to grass fires. My family and I have watched them many times while they stood motionless a short distance *ahead* of the moving line of flames; suddenly they will strike and catch an insect as it jumps ahead of the fire. We witnessed this same behavior at a fire in Natal, South Africa. At this fire several unidentified hawks, black-headed herons, and other birds flew into the burn. Dr. Herminio Lugo has photographed cattle egrets flying in the dense smoke of a burning sugar-cane field in Puerto Rico.

In southern Kenya on September 16, 1968, my wife and I watched

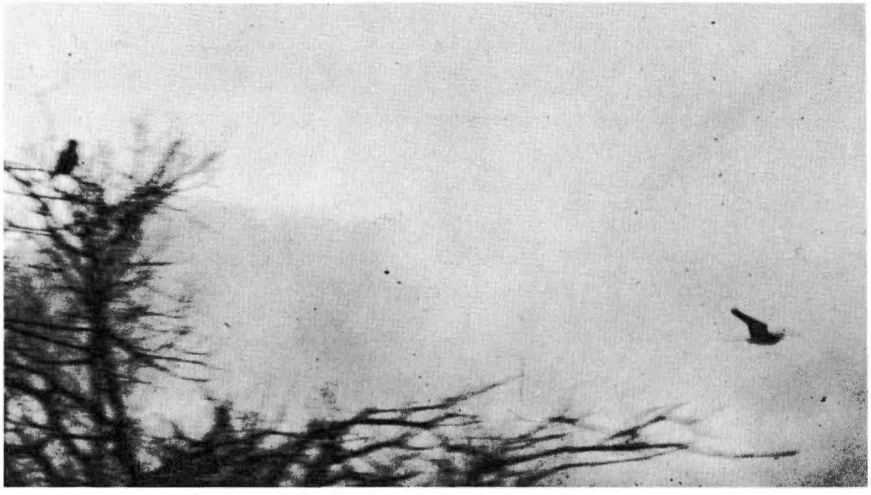

FIG. 5. Lilac-breasted rollers hovering over fire, Masai country, Tanzania.

a dazzling display of eight Lilac-breasted Rollers course through the dense smoke of a Masai fire. These birds would perch in small trees, usually ahead of the advancing fire, and swoop into the dense smoke apparently after flying grasshoppers or locusts. At times the rollers would hover upright within 2 or 3 feet of the flames with their brilliantly colored feathers of irridescent blues, lilac and tawny brown flashing in the sunlight. Words cannot describe the bewildering effect made by these vividly colored birds (about 16 inches long) dashing through billowy dense smoke seemingly courting the dangerous flames. Two drongos, several fork-tailed swifts, two hornbills, one sacred ibis (*Threskiornis aethiopicus*), and small flocks of crowned plovers were also attracted to this fire. Kites and drongos were also noted at an experimental fire on Gwaai Forest Reserve, Rhodesia. These birds perched in trees or bushes ahead and behind the fire and preyed on insects as they flew out from the smoke and on those killed by the fire.

Hawks of all our resident and migratory species regularly come to fires in southeastern United States. They quickly appear after we

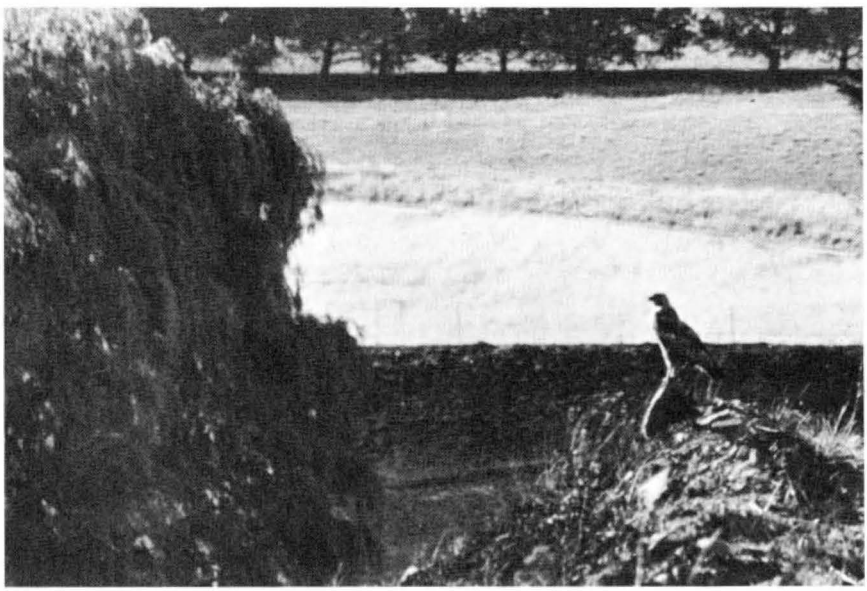

FIG. 6. Hawk watching fire travelling across a fley (wet grassland) Stabamhlope Experiment Station, Natal, South Africa.

start our control burning operations. My associates and I are surprised when a fire and its smoke column does not attract at least one hawk. Other smaller winged predators are also drawn to fire and smoke.

Loggerhead shrikes (*Lanius ludovicianus*) have been seen hovering in the smoke over the fire, and catching prey such as a house mouse (*Mus m. musculus*), a young cotton rat (*Sigmodon h. komareki*), and a variety of insects there. Several species of fly-catchers, phoebe (*Sayornis phoebe*), wood pewee (*Cantopus virens*), and kingbird (*Tyrannus tyrannus*) have been seen catching food on the wing right in the smoke. The wood or grass smoke does not seem to appreciably annoy these birds. I have seen them frequently returning to perch on dead trees in spite of thick smoke. Swallows, both tree (*Irdoprocne bicolor*) and rough-winged (*Stelgidopteryx ruficollis*) have been repeatedly observed skimming over the smoking burn.

After watching purple martins (*Progne subis*) come to my experi-

mental fires for several days, I decided to time their arrival. Within 6 minutes after setting my fire I observed them swooping through the smoke apparently feeding on insects that were present. The smoke was so dense that I could not tolerate to stand in the area; at times the birds could not even be seen because of the intensity of this smoke.

Dragon-flies:—Certain insects also are attracted to fire and smoke of grass and forest fires. Early in our investigations we had noted at least one species of dragon-fly around our experimental fires as well as some small flying insects. Further study showed that the common blue dragon-fly (*Pantala flavescens*) hunted in the cooling burn as well as in the smoke. A typical observation follows:

> July 28, 1968 (fire KB-17) Fire backed slowly through the grass and produced considerable amount of dense white smoke characteristic of fires in which there is a large amount of green vegetation mixed with the dead grasses of the previous years. The line of flames which were about 2 to 3 feet high was about 75 yards long shortly after it was lit at 5:30 p.m. About 10 minutes after the fire had started to burn well, one common blue dragon-fly flew in and began to "course" above the line of fire right in among the smoke, flying the full length of the fire-line and then back. Shortly afterwards two more came and repeated the same behavior. They were certainly "hawking" for small insects in the smoke, and kept this up until the fire had burned itself out about an hour and a half later. One giant dragon-fly (*Ajax junius*) came over the fire and smoke, passed through the smoke one time, and went on. Several feet ahead of the advancing flames, four brown dragon-flies (*Erythemis simplicicollis*) perched on stems above the main grasses and would fly over the fire and then come back to their perch.

All three of the above species were commonly seen around fires throughout June, July, and August but not at all fires. Apparently they come only to certain types of fires at certain times of day and of the year, as is true with birds. In addition to these observations, a small dragon-fly (*Lespes vigilax*) is also seen flying in the grass a yard or two in front of the advancing flame.

Smoke flies:—Flies of the genus *Microsania* have been called smoke-flies because they are attracted to grass or wood smoke in large numbers and at times come very quickly.

> It is one of the oddities of nature that these flies, so seldom caught by the methods of ordinary collecting, can be conjured up, as it were, by the demoniacal process of lighting a fire. (Oldroyd, 1964)

> Until 1921 specimens of *Microsania* were considered great rarities; but in that year Mons. G. Severin discovered that in various parts of Belgium males could be obtained in hundreds in the immediate vicinity of heath fires, the insects flying in the smoke and settling on the still hot ground and burnt herbage in one case they were said to be so numerous as to hinder the work of those engaged in trying to extinguish the conflagration. (Collin, 1934).

> Flies of the genus *Microsania* were not captured in England in quantity until Edwards (1934) found *M. pectinipennis* swarming in the smoke of a smouldering bonfire on July 21 of that year. He collected some 300 specimens and they all proved to be *M pectinipennis.* Returning to the exact spot three days later he was unable to find a single one of the flies until he had made a new smudge. Within a few minutes they were swarming once again in the smoke. (Kessel, 1947.).

Smoke flies have been captured in New Zealand where they were found "dancing in the smoke of a smouldering fire;" in the Belgian Congo "on ashes . . . at the time of a forest fire in 1935;" and in New South Wales, Australia "in the smoke of a camp fire." (Kessel, 1947).

Kessel (1947) remarked on the occurrence of smoke flies (*Microsania occidentialis*) in California as follows:

> A year's intensive collecting trip by the writer in Marin County had accumulated representatives of all the American genera of Clythiidae except *Microsania* . . .

> Finally, on August 19, shortly before dusk, the first smoke flies were taken, flying over the chimney of the writer's barbecue . . .

> About 9 o'clock the next morning a new fire was made in the barbecue and green grass and fresh weeds were added in quantity to insure a large volume of dense smoke . . . In fifteen minutes about a dozen more of the tiny black dipterans had been taken . . . Hour by hour the flies became more numerous . . . By early

> afternoon they were dancing in great numbers in the thick of the smoke above the chimney, some strokes of the net yielding as many as thirty specimens . . .

Kessel continued his experiments and collected smoke flies by using smoke in many areas of western United States as far north as Alaska and Great Slave Lake in northern Canada. He also discovered that these smoke flies did not require hot or even visible smoke as an attractant:

> . . . but responded to the odor of smoke as it lingers on smoke-saturated clothes. As long as I wore my smoked-up clothes I found that again and again smoke flies followed me about even though no fires were burning in the vicinity. The effect lasted not just for hours, but for days. (Kessel 1960a)

He then conducted experiments in Glacier National Park with cold smoke (the aersol bee hive bomb) and a camp fire;

> . . . with net in hand, I sat down at the table to see if any of the microsanias would be enticed upwind from the hot smoke to the cold smoke source. I did not have long to wait. During the next half-hour I alternately caught flies and resprayed the cloth. When the hive bomb had been emptied, I had captured some sixty-five microsanias.
>
> . . . We still do not know the significance of the positive fumatropism which is exhibited by *Microsania* . . .(and) what element or elements of smoke serve as the attractant stimulus. Kessel, 1960b)

For a year Snoddy and Tippins (1968) recorded their monthly observations of this species behavior in smoke from a paper-mill's burning waste. They concluded that this species has a positive response to smoke, furthermore, "Smoke appears to affect mating behavior, serving as a mating swarm marker." Some of their interesting observations follow:

> In October of 1966, *M. imperfecta* were observed in large swarms in the smoke above smoldering debris and burning logs. They were also crawling on and in the burned and unburned debris *quite near the flames.* (italics mine)

> On March 8, 1967, swarms of *M. imperfecta* were observed almost continuously throughout the day . . . the smoke stream from the burning logs was about 6 ft. in diam. at the source and quite dense. It fanned out to about 30 ft. wide and 20 ft. high at 50 yd. downwind . . . The flies were most abundant from 6 ft. beyond the flames to 50 ft downwind. They followed the smoke stream as it shifted both horizontally and vertically. Both sexes were present and seemed to be generally distributed throughout the smoke stream during most of the day. However, at about 3 p.m. many distinct swarms of males began to form in the smoke. These small streams were spherical, 1–2 ft. in diam., and were estimated to contain several hundred male flies:
>
> As a female entered the male swarm, there was a flurry of excitement, as she was quickly grasped by a male, and mating occurred in flight . . .
>
> The mating activity was continuous until observations were terminated at 7 p.m. During the period of several hours that mating was observed, several hundred mating pairs were always visible in and near the smoke stream . . .

The positive reaction of *M. imperfecta* to smoke is related to mating behavior and the smoke stream serves as a marker for mating swarms.

Positive attraction to smoke has been reported for the following species:

Microsania australis	Australia
M. brevicornis	United States
M. imperfecta	United States
M. occidentalis	United States and Canada
M. pallipes	Europe
M. pectinpennis	Europe
M. quhesquierei	Belgian Congo
M. stigmaticalis	Europe
M. tonnoiri	New Zealand

> "Doubtless all the species of *Microsania* will ultimately be found to exhibit this astonishing response to the stimulus of smoke." Kessel (1947)

This genus, formerly considered rare, is apparently common

throughout the world for it has been found in Central and South America as well as the above mentioned localities. It should make an ideal insect for behaviorists interested in fire and animal behavior as well as to fire ecologists to study.

Predaceous flies and smoke:—Another genus of Diptera, *Hermopeza* are also called smoke flies and are attracted to smoke. Collins (1934) mentioned that with exception of the Microsanias "the only other case in the Diptera known to me is that of a rare Empid *Hormopeza obliterata*, Zett . . ."

Kessel (1965) had suspected that "the attraction to smoke had something to do with mating" in *Hormopeza* and that they were preying on the *Microsania* as well. He had the opportunity to experiment on August 23, 1965 north of Juneau, Alaska:

> . . . almost an entire day was devoted to this study; this time the fire was regulated carefully to produce only a moderate amount of smoke so as to enhance visibility. On previous occasions I had tried to produce all the smoke possible so as to attract more flies . . .
>
> Both *Microsania occidentalis* Malloch and *Hormopeza copulifera* Melander were attracted in considerable numbers. The flies of both species merely danced in the thin smoke without regard to their fellows. But in the afternoon the hormopezas formed a number of small swarms in which the flies danced in a manner characteristic of emphidids (such as balloon flies) and of platypezids (Kessel, 1955, 1962). Sampling these swarms with my net I found, as expected, that the dancing flies were all males, and I was not surprised when, a little later, a mating pair of hormopezas settled out of one of the swarms onto the sleeve of my jacket. It is evident that these were mating swarms of males waiting for females to join them.
>
> Because hormopezas are empidids like the balloon flies referred to above, and in which the males carry gifts to prospective mates as they dance in swarms, I examined each male that I took to see if he carried such a gift. Not one was found.

Later a male *Hormopeza* was captured carrying a *Microsania* in its grasp.

The African horse fly (*Chrysops silacea*) a canopy-dwelling horse fly in the tropics also will assemble,

> . . . in the smoke of fires. It is thought that the movement of the swirling smoke may attract attention. In the case of biting flies it suggests nearness of a potential victim; in the case of hovering flies it may imply convection currents . . (this fly) is brought down in the compounds of houses by the smoke of woodfires. In this case the objective is not mating, but feeding . . . (Oldroyd, 1964).

Coleoptera—"Fire-beetles":—Certain species of coleoptera are also called "fire beetles," "fire bugs" or "cigarette beetles" because they are stimulated or attracted by fire or smoke. In The Habits of the Australian Buprestid "Fire-Beetle," *Merimna atrata*, Lap. et Gory (Poulton, 1915) the following remarks are made:

> Prof. Poulton exhibited specimens of the above named beetle and read the following note, which was sent to him by Mr. H. M. Giles, F.E.S., of the Zoological Gardens, South Perth: "This beetle is known locally as the 'Fire-beetle' from its extraordinary habit, which is I think quite unique. It is only seen when a bush-fire is raging—in fact, the best way to take it is by starting one. The beetles seem to come from all quarters and fly straight into the fire, alighting and running about the hot steaming branches, and sometimes even over the parts that are glowing red, yet without injury to the tarsi. It is one of the most agile species known to me, and as alert and active as an eagle . . ." Prof. Poulton said that the instinct of the beetle, like the wonderful fire-resisting powers of many Australian trees, had probably been developed in ancient times as a response to bush fires . . . Mr. C. F. M. Swynnerton had suggested in conversation the probable hypothesis that the beetle is stimulated by the scent of the fire to seek a spot where its larvae can feed upon wood from which volatile protective substances have been driven by heat . . . Mr. G. C. Champion had recently drawn attention (E.M.M., 1913, pp. 109–110) to Mr. A. H. Manee's observation in N. Carolina that the Buprestid *Melanophila notata*, Lap. et Gory, known locally as the "firebug" was attracted in numbers to a blazing pine-stump and settled nearby. Mr. Champion also pointed out that the allied *M. acuminata*, de G. had been taken on charred pines near Woking.

Reference is also made to the attraction of the Buprestid *Melanohila notata* known in North Carolina as the "fire-bug," to a "blazing pine-stump," (Manee, 1913), to *M. acuminata* having been taken on charred pines, that the "fire-beetle" was captured by campfires in

New South Wales, and that another Buprestid was known as the "fire-beetle" in Canada because of similar habits.

Evans in a remarkable series of experiments beginning with a paper entitled "Infra-red Receptors in *Melanophila acuminata* DeGeer" (1964) discovered that these fire beetles were locating and coming to fires by infra-red radiation detecting devices. Sloop (1937) had separated the subgenus *Melanophila* from the other subgenera on the basis of certain sensory pits and noted that only these species had the habit of flying to fires. Evans, after having failed to demonstrate "any reaction other than avoidance to smoke . . . in laboratory tests" discovered that these sensory pits, which contain from about 70 to over 100 spine or hair-like sense organs, were in fact sensitive to infra-red radiations and that they required only a very minute amount of energy to respond. He concluded:

> It is suspected that *M. acuminata* orients to fires by detecting infra-red radiation at considerable distances from the source. During flight the pit organs are completely exposed and could function tropotactically to guide the insect to the heat source. The antennal temperature-receptive sense organs probably function for long-range orientation.

Linsley (1943) had noted that the beetles of this subgenus could apparently locate forest fires at great distances (60-100 miles). In continuing studies Evans (1966a) described the morphology of these sensory pits and then (1966b) explained the mechanisms involved in such long range location of fire by *Melanophila*, as well as the ecological implications of such habits to forest succession. Boag and Evans (1967) write:

> Fire beetles have the unique habit of flying to forest fires, where they buzz around burning snags and crawl over the very hot surfaces of logs . . . When they reach the site of a fire they become quite active and apparently excited. Mating takes place on log surfaces quite close to the glowing embers and hot ashes. The female then deposits her eggs under the undamaged bark of scorched coniferous trees . . . The ability of these insects to detect infra-red radiation means that they are able to arrive at the site of fire-killed trees before other wood-boring competitors, and so initiate the breakdown of wood, often before the fire is out.

The studies of Callahan (1964–1969), although not directly concerned with fire, may have wide ranging implications in fire and animal behavior. He has propounded several "theories of electromagnetic communication by insects" (1969) which imply that these animals have many undiscovered sense organs sensitive to infra-red radiations and possibly other undetected electrical radiations or wavelengths. He has shown that certain insects can detect infra-red radiations and communicate among themselves with such electrical impulses. He has also demonstrated that certain insects also use such impulses as a locating device in their environment, and that they have developed very miniaturized circuitry for this and other purposes. Such sensing devices, most of which remain undiscovered, certainly could play a large part in the response of animals to fire and smoke.

There are scattered generalized references to other insects being attracted to fire but for lack of space cannot be considered here. However, the cigarette-beetles (*Lasioderma serricorne*) apparently are quite common in the lower southeast. Roy Komarek has called my attention to the fact that he has seen this beetle quite commonly on the Seminole Indian Reservation, Big Cypress Swamp, Florida and that it is attracted to burning cigarettes very quickly. He has lit a cigarette and quietly watched these beetles come to it a arms length. The larvae of this beetle are known to live in tobacco and apparently the fumes of the burning tobacco are more attractive than just the odor of the tobacco itself.

Mammals:—Compared to birds and insects there appear to be few records of mammals attracted to fire. This, however, may simply be a lack of observation or recording. Mammals of many species are attracted to the fresh burns but these will be discussed later. I have seen both cows and horses use the dense smoke of fires for protection from biting insects and for warmth on cool evenings. Our dog, Prince, a golden Labrador retriever has for 14 years been a companion on many management and experimental burns. Much of his time is spent hunting for rodents in the unburnt grass just ahead of the fire with what seems to be utter disregard for the flames, only moving away when they get entirely too close. He hunts there

FIG. 7. Labrador retriever hunting cotton rats ahead of and next to fire.

although there is sufficient unburnt grassland available. Apparently carnivores would do likewise in nature.

Mr. Bruce Austin, Warden, Wankie National Park, Rhodesia, informed us that just a few days before our visit three lions (*Panthera leo*) had been observed walking adjacent to a fire in the unburnt grass. The *Animals of East Africa* (Nat'l Geo. Soc. 1968) has a two page color plate with a male lion resting on the edge of an unburned strip with the fire coming towards him. Phillips (1965) mentions that the lion, leopard (*Panthera pardus*), and the cheetah (*Acinonyx jubatus*) hunt near fire.

I have previously quoted references regarding Tarsiers (*Tarsius carbonarius*) sitting near unattended campfires, baboons in close proximity to fires, and Pongidae also converging on unattended campfires (Komarek, 1967). Dr. L. S. B. Leakey (pers. comm. 1968) informed me that he has seen this same behavior by the black and white colobus monkeys (*Colobus polykomos*) in Central Africa

several times. Curiously enough in the excellent studies on animal behavior of the gorilla and the chimpanzee by Schaller (1964) and Goodall (1963, 1968) respectively, no references are made to fire in spite of the fact that both studies were made where fires are of frequent occurrence. In both instances they discuss the habitat in connection with seral or successional vegetation some of which were certainly induced by fire.

That the hippopotamus (*Hippopotamus amphibius*) will come out of the water at night and rush and scatter a campfire was told us several times in Africa but we did not obtain a direct visual report. However, this behavior appeared to be common knowledge to most "bush" people with whom it was discussed.

ANIMAL RELATIONSHIPS TO BLACKENED AREAS CAUSED BY FIRES

When an area is burned, the behavior patterns of the many species of animals living in such an environment are changed. The area attracts predators which pressure the local inhabitants exemplifying the operation of effective natural selection. This is accomplished by adaptive coloration and behavioral changes. Poulton (1926), in "Protective resemblance born by certain African insects to the blackened areas caused by Grass Fires," discusses the possible changes necessary for the survival of many insect species, stating that:

> . . . grass-fire sweeps rapidly through the dry growth and leaves the stronger stalks scorched and charred, but standing. Many species are adapted to this environment not by developing a melanic form, but one in which the black and darkened straw-colour are combined. And similarly with the mixture of the darker tints of a burnt area with the bright green grass of the young grass which springs up at, or even just before, the beginning of the wet season. Examples of these characteristic patterns and colours will be found on the later pages.

Hocking (1964) in "Fire melanism in some African Grasshoppers" studied 27 species on burnt and unburnt grasslands. He noticed that:

> It was at once clear that the easiest places to collect grasshoppers were the margins of burnt-off areas; in working from a burnt

> into an unburnt area, dark forms were disturbed and moved into the unburnt areas of light background where they were conspicuous. Conversely, working into burnt areas from unburnt areas, the light forms were conspicuous against the dark background and their collection was favored . . ."

He concludes by saying:

> Further studies of this question, especially where the history of grass burning is known, should yield interesting data on rates of evolutionary change.

Burt (1951) in "The Ability of adult Grasshoppers to Change Color on Burnt Ground" discusses a series of experiments in Africa that led him to conclude:

> It has been shown that the *adult, non- teneral Acridids*, whether recently emerged or several months in age, can change in appearance and become melanized when kept on burnt ground. This change occurs rapidly, being sometimes noticeable after as little as two days. The change can take place on freshly burnt ground, or on ground burnt some months previously. The area of burnt ground need only be very small if the insect is confined to it. . . "The principle which has thus been demonstrated to apply to two very dissimilar species seems likely to apply to melanized ACRIDIDAE generally.

Cott (1957) also has a thorough discussion on this subject in his *Adaptive Coloration of Animals* which should be studied by anyone interested in this subject.

On July 15 and 16, 1968 I had a splendid opportunity to study the behavior of several species of grasshoppers and katydids on a wood pulp company's slash burn near Nahunta, Georgia. A few days before, the slash from a clear cut pulp operation was burned under very dry conditions. Due to the tremendous amount of fuel the burn blackened the area except for small patches of vegetation. A loggerhead shrike darting over one of these unburned spots to flush a green katydid attracted me. Here were several bright green colored katydids and other grasshoppers which panicked as I approached. Their bright color was quite noticeable against the blackened terrain. Most species of rodents and birds that live in grassland fire environments have color patterns that harmonize with burnt, or partially

burnt, vegetations. Coloration is an adaptive advantage to them as well as to grasshoppers.

On the burn itself, I was attracted by the behavior of several species of grasshoppers. The black ones would remain motionless, allowing me to catch them by hand. The lighter colored had to be approached with caution and netted, still others could not be approached. One large species, brownish in color, would fly while I was still quite a distance from them. Occasionally, lighter colored grasshoppers would be seen on the bare ground. These too would fly long before they were within netting distance, although I had an 8 foot handle on the net.

I noted that a small black species of grasshopper was mating on the blackened burn. The behavior of several species to fire and the resulting burn is a continuing study and will be discussed more fully at a later time. Rodents, ground nesting birds, and insects on burned and unburned areas should be of considerable interest to students of animal behavior and predation. Relatively few studies have been made in this field.

Animals come to burns for other reasons than predation. Grange (1965) observed the varying hare (*Lepus americanus*) eating ash; Komarek (1966) also noted this behavior at a campfire. Cotton rats have also been observed eating charcoal on a smoking burn site. In July 1966 an experimental burn to study the effects of burning on bryophytes was made in a field of broomsedge (*Andropogan virginicus*) on Tall Timbers Research Station. A clean burn was made and the resulting ashes were left totally undisturbed by humans. The burn was made late in the afternoon and resulted in a heavy, evenly distributed covering of ash. The next morning I noticed that the ash covering had been ruined for our purposes. Upon investigation it was found that the area of less than an acre had been trampled completely by Virginia or white-tailed deer—not a square yard was without disturbance. The deer had congregated on the burn at night presumably to nibble on the ash. This was the only summer burned area within about 4 miles.

It is common knowledge throughout elephant country in central and South Africa that the elephants (*Loxodonta africana*) will return to burned savanna and mopane bush (*Colophospermum mopane*) and

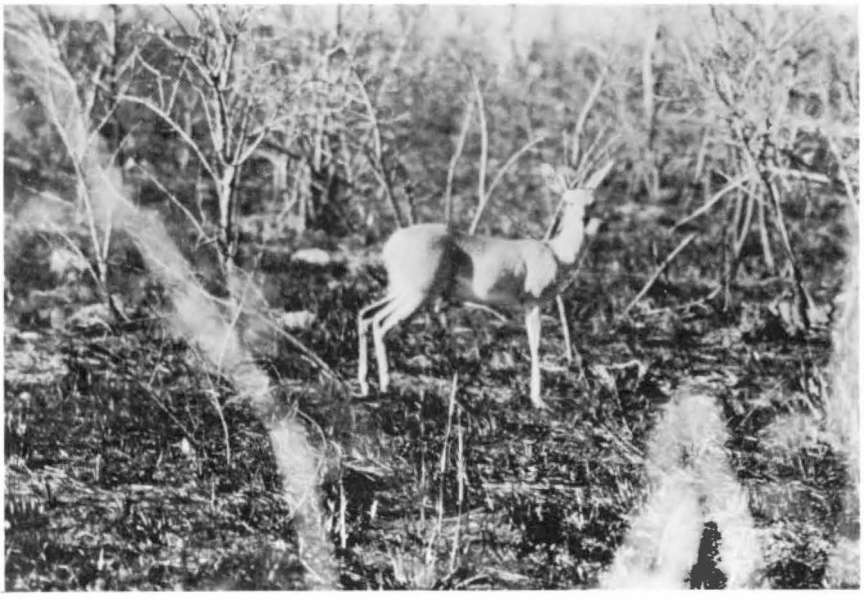

FIG. 8. Steinbock on fresh burn, Kruger National Park, South Africa.

eagerly eat the charred twigs of this bush. Many animals come back to a burn while it is smoking although there is sufficient unburned region in the area. On the evening of September 16, 1968 we noticed a wildfire on the southeastern corner of the Nairobi National Park, Kenya. The next morning we had an opportunity to visit the burn which had been stopped along one of the main roads. To our surprise the area was covered with a large number of animals such as the Masai giraffe (*Giraffa c. tippelskirchi*) Coke's hartebeest (*Acelaphus b. cokii*), Burchell's zebra (*Equus burchelli*), impala (*Aepyceros emlampus*), wildebeest (*Connochaetes taurinus*) Masai ostrich (*Struthio camelus*), and the secretary bird (*Sagittarius serpentarius*), many nibbling on the burn. Time did not permit more observation but apparently these animals had converged on the burned area for a particular purpose for there was plenty of unburned area across the road.

We watched a small flock of redleg or scaly francolin (*Francolinus*

FIG. 9. Black rhino on green burn, Hluhluwe Game Reserve, Natal, Africa.

squamatus) feeding on a fresh burn in southern Kenya. Their actions reminded us of our local bobwhite quail (*Colinus virginianus*) which will land oblivious of the still smoking burn to scratch and feed.

Since grass and forest fire ash is high in calcium, potash, phosphate, and trace minerals, animals will seek burns. Also it may be that the charred twigs of some plants have a nutritional value. The field personnel on the game reserves and national parks we visited in North America, Australia, and Africa all agree that animals regularly congregate on fresh burns.

That some animals utilize recent burns for calving of their young was noted in Africa; the Lichtenstein's hartebeest (*Alcelaphus lichtensteinii*) was reputed to do this.

ANIMALS ATTRACTED TO "GREENING" BURNS

One of "early man's first attempts to draw conclusions and make predictions" certainly must have concerned the attraction of herbiv-

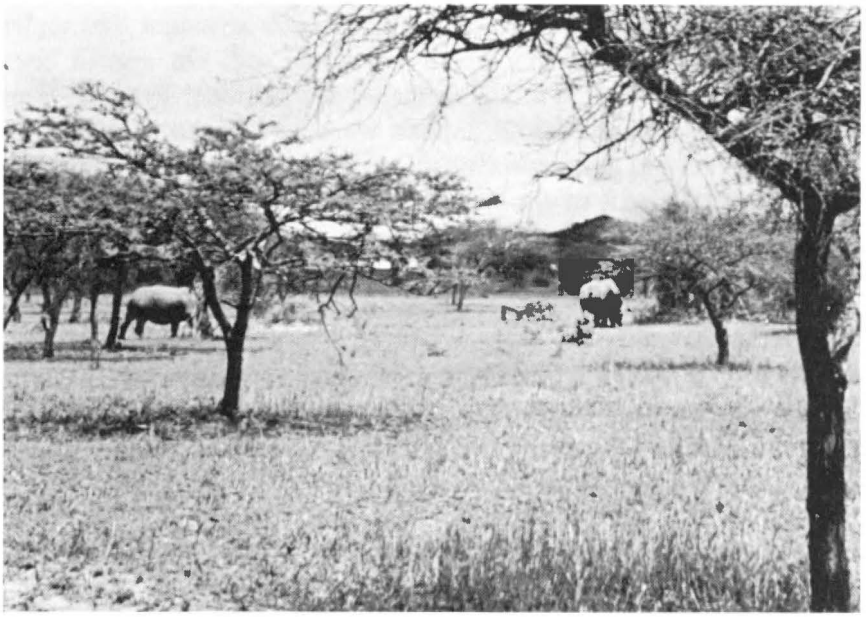

FIG. 10. White or square-lipped rhino on green burn, Umfolozi Game Reserve, Natal, South Africa.

orous animals to the fresh nutritious vegetation that follows fire. This kind of animal behavior directed man's early use of fire in connection with the domestication of certain animals. It was obvious to early man that wild animals as well as his livestock grew fat and sleek on burnt grasslands. These men quickly learned that with the proper use and distribution of fire he could manage his animals to a certain extent. This kind of fire-knowledge appears to have been common information to all races of mankind although in the last few decades such information has been discounted. Today we know, and with outstanding uniformity, from studies made in various parts of the world that the plant growth following fire is *always* higher in protein, calcium, phosphate, potash and other necessary nutrients for animal growth. The past nine proceedings of the annual Tall Timbers Fire Ecology Conferences are replete with such information.

Animals will seek this type of grazing to such an extent that under certain conditions they will literally mine the soil. On a small burn near the Victoria Falls Hotel, Victoria Falls National Park, on September 22, 1968, herbivorous animals were actually eating the roots of grass plants and grazing sprouted bushes down to 1 inch, although there were hundreds of square miles of adjacent unburnt grasslands. The burn had occurred long after the dry spell had started and apparently this burn contained the only available high protein food. Although no rain had fallen for months, the grass and shrubs, stimulated in some unknown manner by the fire itself, had sprouted. It was noted in several places in both Africa and Australia that fire stimulated grass and shrubs to grow without any precipitation for several months. Apparently, this growth is highly desired by animals during the drought period in particular.

FIG. 11. Kangaroo on green burn, Victoria, Australia.

SUMMARY

I have discussed the reaction and behavior of animals to fire, smoke and the resulting burnt ground along four general lines; 1. Avoidance response to fire and smoke; 2. Animals attracted to fire and smoke; 3. Animals relationships to blackened areas caused by fire, and 4. Animals attracted to the"greening" burns. Space has not permitted a discussion of other aspects of fire and animal behavior. However, it is evident that many animals are adapted to a fire environment and that natural selection has been a major factor in such adaptation. Animals have certain mechanisms, such as infra-red detection, olfactory detection, sight, and possibly other unknown receptors or sensing organs that allow them to live safely in a fire environment; they are attracted to fire and smoke for food, warmth, protection, and mating (fire beetles and smoke-flies). The aspects of fire and animal behavior is a much neglected scientific endeavor, and it can be studied by experimental methods as well as by observational techniques. A knowledge of the radiations emitting from fire and smoke and their relation to the animal and plant life in fire environments is practically unknown. The reactions of animals, including man, to fire is a field of animal behavior that has been neglected. It is hoped that this discussion will stimulate such research.

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APPENDIX

Animals Observed in relation to Fire and Smoke in North America

	Attracted to fire and smoke	On black burn	On green burn
Canada goose (*Branta canadensis*)			X
Turkey vulture (*Cathartes aura*)		X	
Black vulture (*Caragypus atratus*)		X	
Marsh hawk (*Circus cyaneus*)	X	X	X
Red-tailed hawk (*Buteo jamaicensis*)	X	X	X
Red-shouldered hawk (*Buteo lineatus*)	X	X	X
Cooper's hawk (*Accipiter cooperii*)	X	X	X
Sparrow hawk (*Falco sparverius*)	X	X	X
Wild turkey (*Meleagris gallopavo*)		X	X
Gambel's quail (*Lophortyx gambeli*)			X
Scaled quail (*Callipepla squamata*)			X
Bobwhite quail (*Colinus virginianus*)		X	X
Snowy egret (*Leucophoyx thula*)			X
Cattle egret (*Bubulcus ibis*)	X	X	X

	Attracted to fire and smoke	On black burn	On green burn
Great blue heron (*Ardea herodias*)		X	X
Killdeer (*Charadrius vociferus*)	X	X	X
Woodcock (*Philiohela minor*)			X
Common snipe (*Capella gallinago*)		X	X
Mourning dove (*Zenaidura macroura*)		X	X
Ground dove (*Columbigallina passerina*)			X
Great horned owl (*Bubo virginianus*)	X	X	
Chimney swift (*Chaetura pelagica*)	X		
Yellow-shafted flicker (*Colaptes auratus*)		X	X
Eastern kingbird (*Tryannus tryannus*)	X		
Eastern phoebe (*Sayornis phoebe*)	X	X	
Eastern wood pewee (*Contopus virens*)	X	X	
Horned lark (*Eremophila aplestris*)			X
Tree swallow (*Irodprocne bicolor*)	X	X	
Rough winged swallow (*Stelgidoptera ruficollis*)	X	X	
Purple martin (*Progne subis*)	X	X	
Blue jay (*Cyanocitta cristata*)		X	X
Steller's jay (*Cyanocitta stelleri*)		X	X
Black-billed magpie (*Pica pica*)		X	X
Common crow (*Corvus brachyrhynchos*)	X	X	X
Fish crow (*Corvus ossifragus*)		X	X
Black-capped chickadee (*Parus atricapillus*)	(feeding in trees in smoke)		

	Attracted to fire and smoke	On black burn	On green burn
Tufted titmouse (*Parus bicolor*)		X	X
White-breasted nuthatch (*Sitta carolinensis*)	(feeding in trees in smoke)		
Brown-headed nuthatch (*Sitta pusilla*)	(feeding in trees in smoke)		
House wren (*Troglodytes aedon*)		X	
Carolina wren (*Thryothorus ludovicianus*)		X	X
Mockingbird (*Mimus polyglottos*)	X	X	X
Brown thrasher (*Toxostoma rufum*)		X	X
Robin (*Turdus migratorius*)	X	X	X
Wood thrush (*Hylocichla mustelina*)		X	
Eastern bluebird (*Siala sialis*)		X	X
Cedar waxwing (*Bombycilla cedrorum*)			X
Loggerhead shrike (*Lanius ludovicianus*)	X	X	X
Starling (*Sturnus vulgaris*)		X	
Eastern meadowlark (*Sturnella magna*)		X	X
Western meadowlark (*Sturnella neglecta*)		X	X
Red-winged blackbird (*Agelaius phoeniceus*)		X	X
Tricolored blackbird (*Agelaius tricolor*)		X	X
Rusty blackbird (*Euphagus carolinensis*)		X	X
Boat-tailed grackle (*Cassidix mexicanus*)		X	X
Common grackle (*Quiscalus quiscala*)		X	X
Brown-headed cowbird (*Molothrus ater*)		X	X
Orchard oriole (*Icterus spurius*)		X	X

	Attracted to fire and smoke	On black burn	On green burn
Summer tanager (*Piranga rubra*)			X
Cardinal (*Richmondena cardinalis*)		X	X
Evening grosbeak (*Hesperiphona vespertina*)			X
Blue grosbeak (*Guiraca caerulea*)		X	X
Indigo bunting (*Passerina cyanea*)		X	X
American goldfinch (*Spinus tristis*)		X	X
Rufous-sided towhee (*Pipilo erythrophthalmus*)		X	X
Savannah sparrow (*Passerculus sandwichensis*)		X	X
Lark bunting (*Calamospiza melonocorys*)		X	X
Vesper sparrow (*Pooecetes gramineus*)		X	X
Slate-colored junco (*Junco hyemalis*)		X	X
Bachman's sparrow (*Aimophila aestivalis*)		X	X
Tree sparrow (*Spizella arborea*)		X	X
Chipping sparrow (*Spizella passerina*)		X	X
Field sparrow (*Spizella pusilla*)		X	X
White-throated sparrow (*Zonotrichia albicollis*)		X	X
Fox sparrow (*Psserella iliaca*)		X	X
Swamp sparrow (*Melospiza georgiana*)		X	X
Song sparrow (*Melospiza melodia*)		X	X
Cotton rat (*Sigmodon h. komareki*)		X	X
Cottontail rabbit (*Sylvilagus f. floridanus*)		X	X
Marsh rabbit (*Syvilagus p. palustris*)		X	X

	Attracted to fire and smoke	On black burn	On green burn
Varying hare (*Lepus a. americanus*)	X	X	X
Virginia deer (*Odocoileus v. virginianus*)	X	X	X
Dragonflies (*Pantala flavescens* and	X	X	X
(*Erytehmis simplicicollis*)	X	X	X
Damselfly (*Lespes virgilax*)	X	X	X
ANIMALS OBSERVED IN AFRICA			
Ostrich (*Struthio camelus*)		X	X
Black-headed heron (*Ardea melanocephala*)		X	
Cattle egret (*Bubulcus ibis*)	X	X	X
Sacred ibis (*Threskiornis aethiopicus*)			X
Hadeda (*Hagedashia hagedash*)			X
Secretary bird (*Sagittarius serpentarius*)	X	X	X
Many unidentified species of hawks, eagles, vultures	X	X	X
Crested francolin (*Francolinus sephaena*)		X	X
Other unidentified francolins		X	X
Helmeted guinea fowl (*Numida mitrata*)		X	X
Crested guinea fowl (*Guttera edouardi*)			X
Unidentified bustard species			X
Crowned plover (*Stephanibyx coronatus*)	?	X	X
Red-billed hornbill (*Lophoceros erythroynchus*)	X	X	X
Yellow-billed hornbill (*Lophoceros flavirostris*)	X	X	X
Ground hornbill (*Bucorvus leadbeateri*)			X
Lilac-breasted roller (*Coracias caudata*)	X	X	X
Superb starling (*Spreo superbus*)			X

	Attracted to fire and smoke	On black burn	On green burn
Yellow baboon (*Papio cynocephalus*)			X
Baboon (*Papio ursinus*)			X
African elephant (*Loxodonta africana*)			X
Black rhinoceros (*Diceros bicornis*)			X
White rhinoceros (*Diceros simus*)			X
Common zebra (*Equus burchelli*)		X	X
Warthog (*Phacochoerus aethiopicus*)			X
Common giraffe (*Giraffa camelopardalis*)		X	X
Wildebeest (*Connochaetes taurinus*)		X	X
Hartebeest (*Alcelaphus buselaphus*)		X	X
Duiker (*Cephalophus* species)		X	X
Impala (*Aepyceros melampus*)		X	X
Steinbock (*Raphicerus c. capricornis*)		X	X
Gazelle (*Gazella* species)		X	X
Roan antelope (*Hippotragus equinus*)		X	X
Sable antelope (*Hippotragus niger*)		X	X
Eland (*Taurotragus oryx*)		X	X
Greater kudu (*Tragelaphus strepsiceros*)		X	X
African buffalo (*Syncerus caffer*)		X	X
ANIMALS OBSERVED ON BURNS IN AUSTRALIA			
Kangaroos and wallabies (species unknown)			X

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Black butcher bird (*Cracticus spaldingi*)
Grey butcher bird (*Cracticus torquatus*)
Silverback butcher bird (*Cracticus argenteus*)
Pied butcher bird (*Cracticus nigrogularis*)
"Pheasant coucal" (*Centropus macrourus*)
Red-backed sea eagle (*Haliastur indus*)
Little eagle (*Aquila morphnoides*)
Whistling eagle (*Haliastur sphenurus*)
Little falcon (*Falco longipennis*)
Peregrine falcon (*Falco macropus*)
*Grey falcon (*Falco hypoleucos*)
*Black falcon (*Falco subniger*)
Australian goshawk (*Acipiter fasciatus*)
Spotted harrier (*Circus assimilis*)
Swamp harrier (*Circus approximans*)
Brown hawk (*Falco berigora*)
Black or fork-tailed kite (*Milvus affinis*)
Black-shouldered kite (*Elanus notatus*)
Letter-wing kite (*Elanus scriptus*)
Blue winged kookaburra or kingfisher (*Dacelo leachii*)
Australian crow (*Corvus cecilae*)
Little crow (*Corvus bennetti*)

*Doubtful if a regular visitor to fires.

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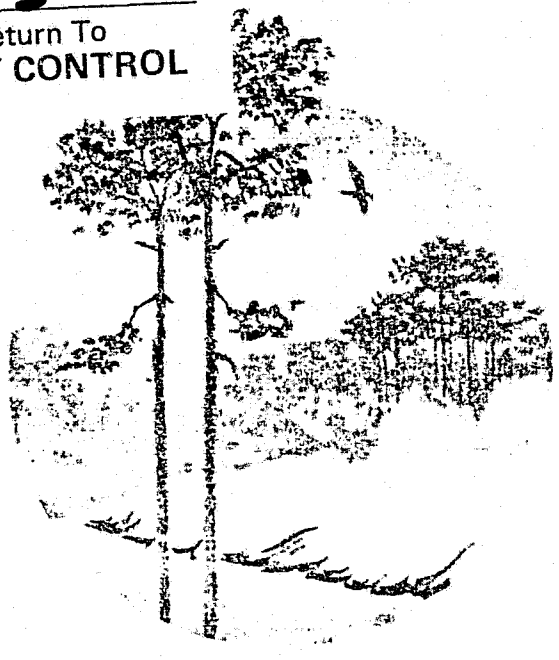

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