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Poison in a Monkey's Garden of Eden

by Kenneth E. Glander

For howlers in a Costa Rican forest, feeding is not just a matter of plucking any leaf

All of the howling monkeys, except for one adult female with an infant clutching her stomach, had finished feeding and had left the carne asada (*Andira inermis*) tree. Suddenly this female started turning in tight circles on a branch, but she completed only two revolutions before losing her balance. For about a minute, her tail hold on the limb prevented her from falling and she hung upside down. Then, convulsing spasmodically, she lost muscle control and plummeted thirty-five feet to the ground. All the while, her ten-day-old infant had kept its grasp. Although the infant was not injured, the mother appeared dazed. After recovering, she climbed back into the tree, but remained sitting in the same spot for the rest of the day and did not feed for the next twenty-four hours.

Her fall was one more piece of evidence that toxic substances in some of the leaves consumed by these mantled howling monkeys (*Alouatta palliata*) not only determine a group's feeding patterns and movements, but may also influence its social organization.

This group of howlers, made up of two adult males, six adult females, and five juveniles, inhabited two types of forest on twenty-five acres of a ranch near Cañas in northwestern Costa Rica. One is a broad-leaf evergreen forest, which runs along the banks of the Río Corobici. Here, the steady supply of water permits such trees as espavé (*Anacardium excelsum*) and sotocaballo (*Pithecellobium longifolium*) to thrive. Most of these trees are about fifty-five feet high but several magnificent specimens reach one hundred feet.

At a distance of seventy-five feet from the river banks, the ground is much drier and the gallery forest gives way to a deciduous one. During the dry season from December through April, the difference between the two forests is most dramatic: the dense green canopy of the gallery forest contrasting sharply with the bare limbs of the deciduous one. During the wet season from May to November, however, the canopies of the deciduous forest are as thick as those of the gallery forest.

In many places the canopies touch, allowing the howlers to move directly from one tree to another. But where cut or blown down trees have created gaps in their travel routes, the howlers usually hesitate momentarily before flinging themselves out into space to land safely in the crown of a neighboring tree. All of the animals, except for those younger than four months old, routinely make these jumps. When these young animals come to gaps that their mothers have already crossed, they edge out to the very ends of the branches and squeal until the mothers cross back to get them. As a result, many of the females have to jump the same gap three times. But by the time the juveniles are six months old their mothers no longer pay attention to their squeals and they must jump the gaps themselves or be left behind. During our fourteen-month study of the ecology of mantled howling monkeys, we observed over seven hundred jumps and never saw an animal miss.

My wife and I had completed only three months of our field work when we saw the mother and infant fall from the carne asada tree. There had been other, similar occurrences within a short time span. During the late afternoon of the previous day, the group had traveled from one side of the Río Corobici to the other, using a natural pathway along the limbs of trees that almost touched. They crossed safely on this occasion, just as they had many other times. We did not wade the river to follow them since darkness was already approaching, but we could see them feeding in the same tree from which the female and infant were to fall. Almost half the tree's crown hung over the river, as did the crowns of some of the sleeping trees used by the group that night. The next morning one of the juveniles was missing. We suspect that the missing juvenile fell and drowned in the river because we could not find his body after a thorough search of the area.

More than a month later, the infant of the female that fell from the carne asada tree drowned in the Río Corobici. On that morning, it was riding on its mother's back while she fed in the crown of a tree that leaned out over the river. We were following another female feeding in a nearby tree when we heard a splash. Upon searching the river, I found the dead infant in three feet of water.

In the two weeks prior to the female's fall, six howling monkeys from other groups on or near the ranch were found dead. I recovered the intact bodies of three animals, all females, for examination, but the other three were too decomposed. During the same two-week period we also found two juvenile females from another group twitching and jerking on the ground. The younger animal, about six months old, died within four hours. The older one, some eighteen months old, recovered.

At least three of the six dead ani-

Recent evidence suggests that to avoid poisoning, howling monkeys—previously thought to have a virtually endless food supply—must be highly selective in the kinds and amounts of vegetation they consume.

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mals and both of the sick ones had been feeding on the leaves of either carne asada or madera negra (*Gliricidia sepium*) trees. The mature leaves of madera negra contain rotenone, a fatty acid called archidic, and an unknown alkaloid. Rotenone is one of the ingredients in some insecticides. In Venezuela, Indians crush madera negra leaves and mix them with water and rice or seeds for use as a rat poison. The leaves of carne asada contain the alkaloid andirine. Five grains of andirine will make a human nauseous. Colombian Indians poison fish by putting crushed carne asada leaves in lakes and rivers.

The unexpected and unusual concentration of dead and sick animals, and our knowledge of what some of these animals ate just before they died, provided us with an opportunity few other field researchers have. The combination in tropical forests of rapid decomposition and efficient scavengers, such as insects and vultures, makes the remains of dead animals quickly disappear. When remains are found, it is usually extremely difficult to discover what the animals consumed just before death.

Tests carried out by the Microbiology Department of the University of Costa Rica ruled out the possibility that the monkeys died from herpes virus, rabies, or yellow fever, and extensive autopsies of the animals produced no apparent pathologies. We were left then with strong circumstantial evidence of natural poisoning by ingestion of toxic leaves.

In order to verify or negate this hypothesis, we began to analyze all plant materials in our study site. The present emphasis is on testing for alkaloids. Although the procedure is accurate, it shows only the presence of alkaloids, not the type. The results are promising, but chemical analyses are just beginning.

We have a much more substantial amount of information on the feeding behavior of the howlers. My wife and I have now spent more than 5,000 hours in the field, either observing the animals in their daily activity or studying their habitat. We have systematically documented the distribution of their food resources by marking, measuring, mapping, and identifying the 1,699 trees in the study area. While in the field, we also kept weekly records on the leafing, flowering, and fruiting of the trees.

The annual rainfall in the howlers' habitat area is about 70 inches, but when we did our study in 1972 and 1973 only 56 inches fell during a twelve-month period, most of it from May through September. No rain fell in January, February, or March. In the wet season, the dense leaves provided shade for us and the animals.

During the wet season, the howlers begin feeding at about 6:30 in the morning and intersperse feeding bouts with periods of moving from one feeding area to another. Toward the hotter middle hours of the day, when temperatures reach about 85°F, they usually move to the lower canopy to seek a shady place for resting. Here, an animal stretches out with its legs straddling a branch and its tail wrapped around it. Infants and juveniles often explore the immediate area around their mothers or play in the tops of the trees during these periods. In a resting position a howler is often difficult to spot from the ground because its coat color blends with the shifting patterns of sunlight and shadows filtered through the tree branches. A second peak of feeding usually begins about mid-afternoon and continues until the group settles into sleeping places at about six o'clock in the evening.

The pattern of daily activity is similar during the dry season, except that the first feeding occurs at about five o'clock in the morning; by seven all the animals are resting again. Temperatures during the dry season are hotter, often reaching 100° F. By feeding earlier, the animals can rest in the shade through the hottest part of the day and feed again in the cooler late afternoon.

When we observed the animals during daylight hours in the wet season, they spent an average of 7.9 hours resting, 2.5 hours feeding, and 1.4 hours moving, as compared to an average of 8.6 hours, 3.0 hours, and 1.3 hours, respectively, during the dry season.

The tree parts that the howlers eat, and the time they spend doing so, vary from day to day and from season to season. During an average wet-season day, the animals might spend 38 minutes eating mature leaves; 47 minutes, new leaves; 23 minutes, fruit; 32 minutes, flowers; and 12 minutes, leaf stems.

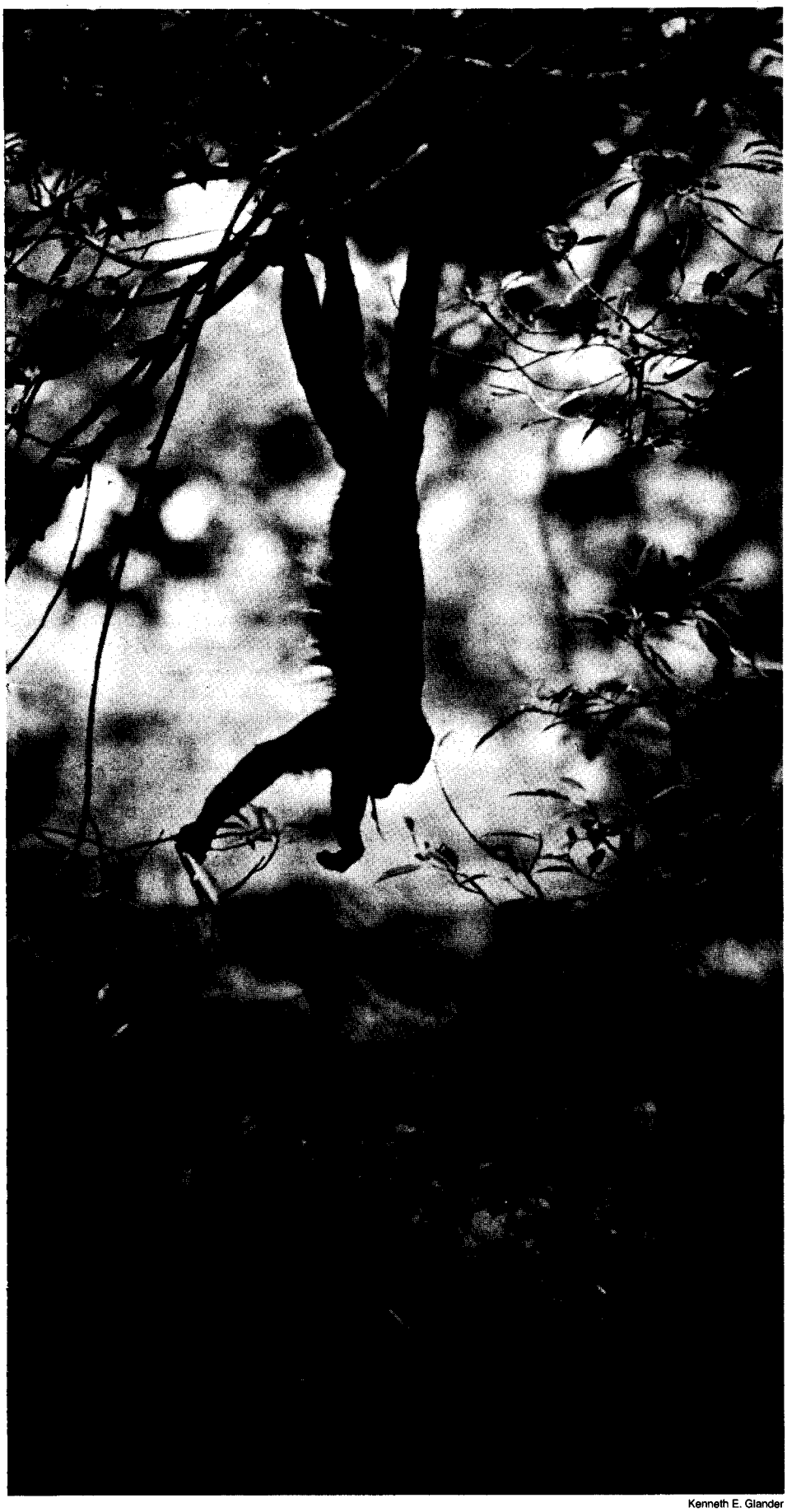
During the average dry-season day, they spend 21 minutes eating mature leaves; 104 minutes, new leaves; 8 minutes, fruit; 33 minutes, flowers; and 18 minutes, leaf stems. The linear distance covered in search of this food may be as much as 1,500 feet.

Although the time spent consuming each vegetational component varies according to season, leaves are unquestionably of great importance all the time. Since leaves are always available in a tropical forest, researchers have traditionally thought that these leaf-eating monkeys have an unlimited supply of food.

The results of our study appear at first glance to support this, since the howlers that we observed obtained all of their food from only 331, or less than 20 percent, of the 1,699 trees in their habitat. Even more surprising was that the animals spent 75 percent of their total feeding time in only 88 trees. This might suggest some discernible pattern in the animals' feeding. Do they select certain trees or tree species over others? Is there anything unique about the trees they use or those they do not use?

Indeed, the animals are very selective, showing preference not only for specific tree species but also for certain trees within a species. Furthermore, they do not divide their time equally among species or individual trees. In many instances howlers feed in only a few trees of a particular species, totally ignoring other individuals of the same species that appear to have identical food resources.

The howlers demonstrated their selectivity in a most dramatic way. There are 149 madera negra trees in their home range. A common tree in almost every part of Costa Rica, it is often used for fence posts. Once a limb is placed in the ground as a post it frequently sprouts roots and begins to grow, resulting in living fencerows. The tree seldom grows taller than forty feet and has a spindly, gnarled trunk. The bright pink flowers, often fried and eaten in Costa Rica and Venezuela, grow in dense masses at the ends of the branches. The fruit resembles an enlarged pea pod, and the leaves grow in pinnate clusters of seven to fifteen leaflets each.



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Although mature leaves are toxic to dogs, rats, mice, and horses, howling monkeys eat them, but not indiscriminately. The howlers of the group we studied, for example, ate the mature leaves of only 3 of the 149 madera negra trees available to them, always returning to the same 3 trees. Members of another howler group, which occasionally visited part of the study area, also fed on the mature leaves of the same 3 madera negra trees.

Two of these trees grew next to each other on one side of the Río Corobici, while the third was more than 900 feet away on the opposite side of the river. Although the howlers moved through many of the other 146 madera negra trees scattered throughout their range, they did not feed on the mature leaves of any of these, although they passed through some of them when traveling among the 3 trees. This suggests that there was something different about these trees, something the monkeys could detect. Our laboratory tests revealed that the leaves of these 3 madera negra trees did not contain alkaloids, while the leaves of adjacent individuals of the same species contained fairly large amounts of alkaloids.

If this difference exists for alkaloids, it could also be true for other compounds. The leaves of one of the madera negra trees, for example, did not have cardiac glycosides while its neighbors had large amounts. Like the production of leaves, flowers, fruits, and nectar, the production of secondary compounds is a variable factor. Whatever the results of tests for these other substances show, the presence or absence of alkaloids appears to be critical to whether howlers in this area eat the mature leaves of madera negra trees.

It would seem advantageous then for the howlers to avoid all potentially toxic foods. The problem is that all

Howlers sometimes feed by hanging from their tails and back legs, although this behavior is rare in other New World monkey species. This adult female is eating leaves from a species of Ficus *tree.*

plants contain substances, known as secondary compounds, that vary in their toxicity. Some tree species in the study area contain more than ninety different secondary compounds. Even such common human foods as celery and spinach contain oxalic acid, 30 and 658 milligrams per 100 grams, respectively. The primary cause of animal deaths from oxalic acid poisoning is kidney failure, resulting from the precipitation of crystals in the kidney tubules. Oxalic acid and many other secondary compounds—tannins, glycosides, organic acids, saponins, essential oils, resins, sulfur oils, toxalbumins—pose a problem for any animal that ingests plant parts containing these compounds.

These secondary compounds protect the plants against insect damage and do not have to kill to be effective. They may serve as repellents by being unpalatable or toxic; they may affect viability of insect offspring or disturb normal reproductive cycles. They also interfere with nutrition by binding certain nutrients, effectively making them unavailable to predators. Tannins, for example, bind proteins. Obviously, not all plants contain the same substances nor is any particular substance effective against all predators.

Among these defensive substances are the irritating oils present in the poison ivy family; hemagglutinins in legumes, which act to disrupt red blood cell functions; peyote alkaloids in the cactus family; cardiac glycosides, which interfere with muscle contraction in the heart; cyanogenic glycosides, which on contact with water yield cyanide; and stimulants, such as caffeine (in coffee and tea) and nicotine (in tobacco).

Any organism that feeds extensively on plant parts must have some means of detoxifying the ubiquitous secondary compounds in order to survive. Detoxification mechanisms vary. One means is through the addition of a molecule of glucose to the toxin, which facilitates its excretion through the urine. This kind of detoxification, as well as other, similar methods, takes place mainly in the liver and kidneys. Another kind of detoxification occurs when bacteria in the intestines break down the chemical structure of the toxins.

As leaf eaters, howlers must acquire food in spite of the toxins present in that food. The role played by the tree's defensive secondary compounds in determining what resources are really available to the howlers must be seen as part of a dynamic relationship between the tree, as prey, and the animal, as predator. A food rich in nutrients is useless unless an animal can handle the toxin that may also be present in it. A dead monkey has little use for nutrients. Howlers certainly have a detoxification system, but they also counter the plant's defenses by preferentially selecting those parts of the tree with the lowest level of toxins. These are the ripe fruits, flowers, and new leaves. When these tree parts are not available or do not provide the proper nutrients for the howlers, they must ingest mature leaves—that part of a tree highest in alkaloids and secondary compounds.

However, the howlers rarely eat the mature leaves of most tree species or, if they do, they consume a limited amount. Instead, they prefer only the petioles (leafstalks). By doing so, they demonstrate their ability to choose plant parts with the least amount of alkaloids.

The selective feeding on particular parts of certain tree species accounts for the animals' dropping large numbers of leaves, a behavior thought by other observers to be wasteful feeding. On the contrary, the animals are selecting that part of the leaf with little or no toxin while disposing of the poisonous part.

The amount of secondary compounds in the leaves and the amount of toxins the detoxification system of the animal can process determine the total number of mature leaves ingested from any one tree species. Depending on these variables, the howlers control the consumption of any one toxin by feeding on a variety of tree species rather than by concentrating on one or two. This strategy may explain why howlers and other leaf-eating animals usually leave a tree before stripping it bare. By eating only small amounts of each kind of leaf, they give their systems time to detoxify the toxin contained in those leaves. Such diversification of food types reduces the amount of any one toxin but requires a broader-based detoxification system to handle the different secondary compounds. The howlers must thus balance the amount and type of toxins ingested with the kinds of foods that are available.

Animals are occasionally forced—by seasonality, overpopulation, or habitat destruction—to feed on unfamiliar trees or to ingest more leaves from a particular tree than they normally would. Thus overburdened, their detoxification systems fail and some animals die. The death of the seven howlers from other groups, the female's fall, and the juveniles' convulsions were probably due to similar sets of circumstances.

Group members, particularly older individuals, may provide a reservoir of knowledge about the habitat. On an evolutionary scale, knowledge of safe foods and the location and timing of seasonal foods could select for sociable animals living in groups since single animals or even a male-female pair would not have enough information to survive as leaf eaters.

Another selection factor for group living may be the group's possession of a pool of sufficiently diverse fringe detoxification systems such that any sudden change in toxins or the destruction of large amounts of preferred food would not be disastrous for the entire population. The sampling of new trees by a single adult animal may be a behavioral expression of this hedge against catastrophe. While we observed all of the adult animals sample unfamiliar tree species, we never saw more than one animal at a time attempt this.

The presence of toxins in plant foods has meaning for human as well as nonhuman primates. Researchers have cited the use of fire for cooking as a major evolutionary step for early man. The heat of cooking destroys toxic substances. But how did early man cope with toxins before the use

This howler on Barro Colorado Island in Panama is in a typical eating posture. Researchers are not certain whether the larger size of these animals is due to the island's dense vegetation.

George Silk

of fire? Extrapolations from studies of extant primates indicate that man depended upon a wide variety of plant parts for food. He must have thus possessed a detoxification system, a system that we still retain, as witnessed by our ability to ingest such toxins as caffeine, chocolate, and hallucinogens. Because man now cooks much of his food, however, he may not rely on detoxification to the same extent as did his ancestors. Just as the destruction of toxins through cooking may have liberated our ancestors from limited food resources and reduced the selection pressure for a nonhuman primate type of social organization, the presence of toxins in some of the food resources of howlers may limit the population size and restrict their social organization to its present form. □

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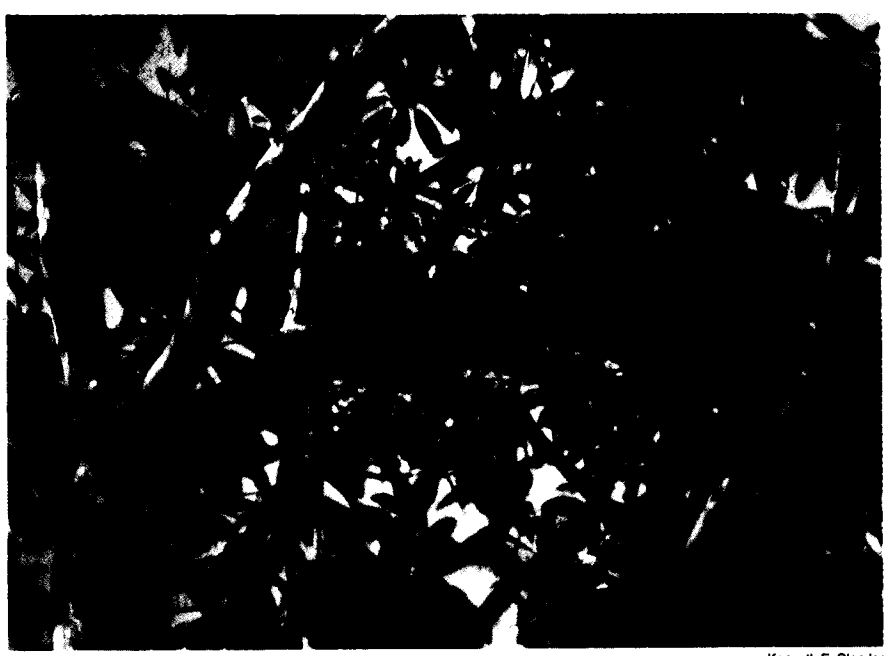

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Adult howlers are capable of a horizontal jump of 20 feet or a vertical fall of up to 60 feet. They usually aim for a specific branch before they leap and rarely miss. Young howlers, such as the one at left, remain in constant proximity to their mothers for six months and may nurse for up to a year. Variations in the duration of nursing may affect a group's reproductive rate. During daytime rest periods, howlers frequently straddle branches, far left, remaining in the same position for up to an hour.