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# Fly switching by Asian elephants: tool use to control parasites

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**Abstract.** A type of tool use by Asian elephants alluded to over a century ago by Darwin is their use of branches as a switch, allegedly to repel flies. In a study of Asian elephants used to take tourists for rides into a national park in Nepal the elephants were observed to grab branches spontaneously and switch with them during the rides and to switch frequently with branches presented to them at the stable. A study of 15 adult working female elephants was conducted to determine whether the use of swtiches was related to intensity of fly harassment, and if the behaviour functioned to reduce fly intensity around the elephants. Elephants were presented with switches resembling those they spontaneously picked up during rides. At daybreak (0600 hours), when no flies were present, the median switching rate was about 30 per 10 min. At four other observation times during the day (approximately 0800, 1100, 1500 and 1800 hours), when fly counts ranged from a median of 1·5 to 4·0 flies on and around the elephants, the median switching rate ranged from 150 to 186 per 10 min. A comparison of switching rate with daytime temperature changes and feeding schedules indicated that switching is not a manifestation of confinement stereotypy or a behaviour related to cooling the body. In an experiment on eight elephants conducted during the time of day when fly activity was most intense (approximately 1100 hours), fly counts were conducted for 10 min when no branch was available and immediately thereafter for 10 min when the elephants were presented with branches. The median fly count was significantly reduced by 43%. Elephants of the study sometimes modified the branches by removing side stems or shortening the branch. The frequency of fly switching by wild Asian elephants is not currently known. However, among the captive elephants of this study, fly switching would appear to be one of the most frequently employed instances of tool use.

Mammals have a number of behavioural means of controlling parasitic flies. Fly repelling actions of small rodents, such as tail flipping, ear flipping, face rubbing, and foot stamping, markedly reduce mosquito bites (Edman et al. 1974). The rates of ear twitching, head tossing, tail switching, foot stamping, and muscle twitching in cattle are correlated with fly intensity in cattle (Harris et al. 1987) and red deer (Woollard & Bullock 1987). Observations on sets of twin dairy heifers in New Zealand indicate that those heifers with docked tails (a common husbandry practice in New Zealand) not only increase the frequency of tail switches and leg stamps, but have two to three times as many flies landing on them as heifers with intact tails (Ladewig & Matthews 1992).

A particularly interesting behaviour of Asian elephants, *Elephus maximus*, which would appear to be related to control of flying parasites, is their use of branches from shrubs or trees as switches, apparently to dislodge biting flies or prevent flies from landing on them. In his discussion of animal tool use in the *The Descent of Man*, Darwin (1871) mentions that tamed India elephants are well known to break off branches of trees and use them to drive away flies. A writer in an 1871 field newsletter (Zoophilus 1871) describes his encounter in India with a wild bull elephant which he observed whisking off flies with a leafy branch. The same author also mentions that everybody who has been in India must have seen tame

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elephants engaging in the same behaviour. In 1879 Peal recounted his observation of a tamed Asian elephant (upon which he was riding), that was being harassed by flies, fashioning a fly switch from a branch obtained from a bush along the side of the trail. Rensch & Altevogt (1954) mention seeing many captive Asian elephants of both sexes using branches to repel flies. Chevalier-Skolnikoff & Liska (1993) recorded fly switching behaviour with some type of vegetation as one of the most frequent acts of tool use by captive Asian and African elephants, *Loxodonta africana*, and as an occasional behaviour in wild African elephants. If the behaviour of using switches by elephants is correlated with the presence of flies, and actually functions to reduce fly intensity, the behaviour would appear to represent a classical example of animal tool use (Beck 1980) as well as a behavioural adaptation to control parasitic flies.

This study represents an experimental approach to understanding the occurrence of switch use behaviour by Asian elephants as a possible adaptation for the control of fly harassment. Alternative explanations such as waving branches for cooling, or as a form of confinement stereotypy were also considered. A second purpose was to examine switching from the standpoint of animal tool behaviour, by conducting observations on the variety of objects or materials used, and the modification of branches to presumably increase their efficiency as a switch.

To show that a behavioural pattern is an adaptation for the control of parasites first requires that attacks by the parasite result in some cost in fitness to the animal and second that the behaviour in question be effective in helping the animal avoid or remove the parasites (Hart 1990). The second requirement is the focus of this study; the first requirement needs some additional explanation. Biting flies may cause pain and remove substantial amounts of blood, thereby directly reducing an individual's personal fitness, and flies may indirectly impact fitness by acting as vectors of disease. However, wild animals indigenous to an area are usually immune to vector-borne diseases so it is difficult to assess this indirect cost. There are no data available regarding blood loss to Asian elephants from biting flies. However, biting flies are clearly aversive to elephants, and they act to remove or repel them with their ears, tail and trunk. In the course of this study we noticed that flies swatted on elephants and removed by their caretakers often contained blood. Although the dermis is reported to be 2 cm thick, there are apparently papilla-like, outward projections in the dermis (Altevogt 1990). Such papillae would presumably allow flies access to a blood meal. Thus, contrary to the concept engendered by the term 'pachyderm', Asian elephants are quite vulnerable to biting flies. One indication of the costs of biting flies in removing blood is a study on tabanid flies that attack horses in upstate New York. Investigators estimated that on a typical summer day a horse could be bitten by as many as 4000 flies, producing a blood loss of 0·5 litre per day (Tashiro & Schwardt 1953). It has been argued elsewhere that the most important measure of the cost to fitness that ectoparasites, such as biting flies, inflict is not outright illness or death, but the decrement in body resources (blood proteins and haemoglobin) which could be critical when conspecifics compete with each other, such as in competition between males for breeding access to females or reproductive competition between lactating females (Hart 1990). For example, a drop in milk production and slower growth rate of suckling young, resulting from loss of blood to biting flies in times of nutritional stress, may reflect a comparative disadvantage in reproductive fitness of lactating females that sustain the most fly bites.

The specific aims of the study were: (1) to relate the frequency of switch use in captive Asian elephants with signs of fly intensity and (2) to conduct a field experiment whereby the effectiveness of using a switch in reducing flies was determined. The subjects were female working adult Asian elephants of Nepal that are used to transport tourists from lodges into the Royal Chitwan National Park. Elephants from two different lodges were observed. In addition to collecting data bearing on the two specific goals, observations were made on the types of plant material used for switching, modification of presented switch material, use of the vegetation for scratching (another cited example of elephant tool use) and types of biting flies found on and around the elephants.

## METHODS

### Study Sites and Subjects

We used privately owned adult female Asian elephants, ranging in estimated age from 16 to 49 years. Eight elephants belonged to one tourist

lodge, and seven to another lodge. Elephants in Nepal are generally bought at auctions in India and life histories are not available. According to interviews with the elephant drivers and lodge managers, most of the elephants had been obtained from India and were probably wild caught (India currently restricts capture of wild elephants). The lodge settings differed in the surrounding vegetation; site 1 was in the saal forest and site 2 was beside a riverine habitat. The density of flies attracted to the elephants was higher at site 1 than site 2. Data from subjects from the two sites were not pooled.

Each day most of the elephants were used once in the early morning (0630–0800 hours) and once in the late afternoon (1600–1800 hours) to take tourists on rides into the Royal Chitwan National Park to view wildlife, including the Asian rhinoceros, several species of deer, wild boar, sloth bear, gaur, and many species of birds and butterflies. The study was conducted from mid-March through mid-April 1992 when the ambient temperature was becoming hot just before the monsoon season.

A handler usually takes the elephants out for 5–6 h in the middle of the day for free-ranging grazing and to gather forage which is brought back to the stable for feeding during the night. Thus, the elephants have frequent exposure to native vegetation and ample access to native plants for switch use. At the stables the elephants were fed a rice-molasses supplement with varying types of plant material, some of which could easily be used for switching (leafy branches, banana leaves, elephant grass) and some of which was ineffective for switching (short segments of vines, grasses). At the stables the elephants were each tethered to a post with a foot chain. The tether posts were 9–20 m apart.

### Behavioural Observations

We recorded switching behaviour during 10-min focal observations. Switch use was defined as the elephant grasping a branch, or other vegetation, in its trunk and swinging the free end against some part of its body. With a leafy branch the elephant invariably grasped the woody stem and swished the free leafy end against the body. With long vines or banana leaves, the elephant grasped one end and switched the free end. Switching generally occurred in bouts of individual switches at intervals of 1–2 s. A bout was considered terminated when no switching occurred for 10 s or when the elephant engaged in some other activity such as eating, scratching, or throwing dirt or vegetation on its body.

To begin the 10-min focal observation, we dropped a freshly picked, leafy branch (1–2 m in length, with at least 20 leaves) within 1 m of the focal elephant's front legs. The size of the branch was modelled after the range in sizes of branches obtained by elephants spontaneously during rides into the jungle. The branches were from bushes common in the area surrounding the stable. At site 1 the presented branch was of the shrub *Clerodendrum viscosum*, and at site 2 the branch was of the scrub *Colebrookea oppositifolia*. These shrubs were reported by handlers not to be particularly palatable to elephants, and branches of these scrubs had been observed to be used by elephants as switches during rides. If a branch deteriorated from repetitive use as a switch during an observation, an additional branch was provided.

Switching behaviour, and the part of the body hit with the switch (frontal surface of head, side of head, shoulder, legs, and underside of sternum and belly) were observed by teams of two investigators in which one person counted the bouts, number of switches and body areas hit, and the second person recorded the data on a standard form. As suggested by Martin & Bateson (1986) inter-observer reliability between teams of observers was determined by Spearman rank correlation from scores on practice trials, and found to be 0·96 ($N=14$).

A general note was also made as to whether switching movements were active or lethargic. These data were recorded for the presented branch, as well as other available vegetation. Any modification of the branch was noted. Elephants may modify branches by holding the branch in the mouth or with a front foot and pulling off side branches, or by breaking off part of the stem, with the tip of the trunk. This behaviour was counted as switch modification (tool fabrication) if the elephant did not eat the parts removed. If scratching occurred, using either the presented branch or an available stick, this was also noted.

### Fly Counts and Sampling

Starting just before the focal observation (time 0) and at times 2·5, 5·0, 7·5 and 10·0 min, fly

counts were made by the observer noting switching behaviour. The counts included flies that could be seen on one side of the head and body plus those in the air within 0·3 m surrounding the elephant during a 5-s viewing of the body and surrounding air space. When possible, the side of the body viewed was alternated between counts. Starting fly counts were those recorded at time zero. The measure of fly counts used during the observation was the mean of the counts taken at 2·5, 5·0, 7·5 and 10·0 min. A Spearman rank correlation measure of inter-observer reliability of fly-count means between teams of observers in practice trials was 0·76 ($N=14$).

We obtained a sample of flies for later identification by asking the elephant handlers to catch flies that landed on the elephants (after attempting unsuccessfully to capture flies in an insect net). Samples were taken during early morning when flies were first emerging and late morning when fly intensity was high. Other than attempting to obtain a sample of fly species representative of those on the elephants, no systematic effort was made to randomize the fly species captured.

### Observation Schedule

#### *Comparison of switching rate with ambient temperature, fly intensity and feeding schedule*

The observation schedule at each study site was structured around the requirements for the elephants to graze and to carry tourists on rides. Because daily maximum temperatures were increasing during the project, the study was constrained by the necessity to restrict observations to a course of 6–10 days at each study site so that each elephant was observed under similar daytime temperature ranges. At site 1, observations were scheduled to include the following times over a 5-day period: (1) daybreak, approximately 0600 (0545–0615) hours, the coolest time of day, when no flies were expected and elephants had been eating all night (if flies were detected no observations were conducted); (2) early morning, approximately 0800 (0730–0815) hours, when it was still cool, but fly intensity was increasing; (3) late morning, approximately 1100 (1030–1200) hours, when the temperature was hot and fly intensity high; (4) mid-afternoon, approximately 1500 (1430–1530) hours, when the temperature was highest but fly intensity low, and (5) late afternoon, approximately 1800 (1730–1830) hours, when the ambient temperature was cooling, but still warm, fly intensity was high, and elephants were hungry and being fed their grain supplement plus forage. The late afternoon observations were conducted just before it became too dark to count flies.

At site 1, we made one 10-min focal observation per elephant at both daybreak and early morning, three to four observations per elephant at late morning, and one to two observations per elephant at mid and late afternoon. These observations all included branch presentations. We made no more than one observation during each time period per elephant per day. Except for the late afternoon observations, when elephants were being fed, the tether areas were clear of food and other switch material. When forage was used for switching rather than the presented branch (i.e. in late afternoon), the switches were counted the same as if a branch had been used. At site 2, we made from two to five daybreak observations and three to five mid-afternoon observations per elephant; these all included branch presentations. Observations from daybreak until late afternoon were designed to compare starting fly count and switching rate for the subsequent 10 min. Ambient temperature was recorded throughout the daylight hours. When more than one observation was made per elephant for a particular time period, we obtained individual medians of switch use and starting fly counts. The purpose of this study was to possibly differentiate between the effects of fly intensity, ambient temperature, hunger and food availability on switch use. The use of a branch for scratching was also noted. We used the Wilcoxon matched-pairs signed-ranks test (two-tailed) to test for differences between time periods with regard to switching rate and fly counts ($P<0·05$ or 0·01).

#### *Effects of switching in reducing fly counts*

At site 1, in the late morning, when fly intensity was high, an experiment was conducted to test the effect of switching on fly counts. This experiment consisted of an initial 10-min focal observation during which no branch was presented, but flies were counted at 2·5, 5, 7·5 and 10 min. The tether area had been cleaned of uneaten vegetation so that there was no switch material available. Immediately following this first

observation a second 10-min observation of switching and fly counts was made following the presentation of a branch by the same team of observers. Three to four replications of no-branch versus branch tests were conducted on each elephant, and the median fly counts for all replications were calculated for each elephant. Wilcoxon matched-pairs signed-ranks (two-tailed) tests were conducted on the median fly counts in no-branch and branch observations. Observer expectation that the fly count would be reduced by switching was a concern. The likelihood of such bias was reduced, however, because in each test the observer had counted flies several times and would have difficulty remembering earlier counts. The recorder did not show the observer the previously recorded data and the observer was busy counting switches between fly counts.

### Spontaneous Use of Switches by Elephants

During rides into the jungle instances of elephants grabbing or picking and using a branch for switching were noted. The species of plant picked, the branch length, and the approximate duration of time that the switch was used were also noted. The visibility of the elephant's trunk and its manipulation of the switch were somewhat restricted in these observations during the elephant rides.

## RESULTS

### General Description of Switching

Switching with a leafy branch or other object, such as bark from a vine or banana leaves, was a frequent activity during all observation periods except those at daybreak. All elephants at both study sites engaged in switching. A total of 132 10-min observations with switch presentation were made on the 15 elephants. In every observation elephants switched at least once. At sites 1 and 2 at daybreak, the time of lowest switch activity, the median switching rate was 29 (range=3–90) and 5·5 (range=2–38) per 10 min, respectively. At site 1, during the late morning, the time of greatest fly intensity, the median number of switches per 10-min observation was 186 (range=55–245).

Switching usually occurred as bouts of rhythmic switches delivered to the body at the rate of about one per 1–2 s. The number of switches per bout was much less when the switching rate was less. For example, at daybreak at sites 1 and 2, median switches per bout were 3 and 2·8, respectively, while at all other time periods switches per bout were significantly higher ($P<0·01$), ranging from a median of 12·7 to 26·5 across time periods. Switching intensity was almost always noted as active except at daybreak when switching was usually noted as lethargic. Body parts that were hit by switches were the shoulder and adjacent rib cage, ventral surface of the thorax and abdomen, top of head, sides of the head and front legs (Fig. 1). As a rule, switching was delivered to the area where the most flies were seen, which was the ventral surface of the thorax and abdomen. There were some marked individual differences in switching rate. For example, during the replicate observations conducted during the late morning at site 1, there was no overlap in range of switching rate per 10 min for three elephants, which had median switching rates of 55, 106, and 245 when a branch was presented. Although the median switching rate for elephants at site 1 was higher than that at site 2, even with no flies, the difference was not significant.

Although not systematically recorded, the elephants often seemed to designate the presented branch as a switch and either continued to hold it in their trunk between bouts of switching or dropped it on the ground and later picked it up for a subsequent bout of a switching (Fig. 2). When vegetation was available for feeding (late afternoon), a particularly suitable branch (not necessarily the presented branch) would often be 'saved' in this fashion while other vegetative matter was eaten. We never noticed such saving of branches beyond 30 min. The deteriorization of the branches with use and/or eating them would preclude prolonged saving. At other times, elephants would use a branch for a bout of switches and then eat it; this occurred especially if there was plenty of switch material available, such as when the animals were fed parts of *Ficus* sp. plants that served as appropriate switch material. The variety of switch material used is illustrated in Fig. 3, including the use of a vine and a burlap bag. On 13 occasions (seven different animals) elephants were observed to modify a presented branch by removing small side branches or shortening the stem without eating the removed part (Fig. 4). In a few instances a long piece of bark

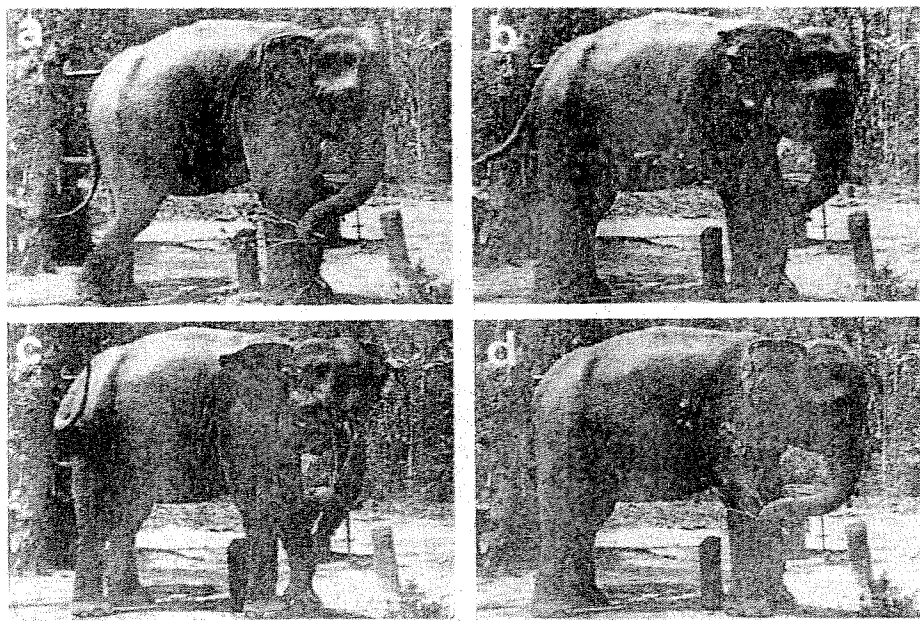

**Figure 1.** Examples of different body parts hit by a leafy branch used as a switch. The sequence shown in (a)–(d) comprised one bout. Switching tended to be directed to areas where flies were most attracted, namely legs (a), central abdomen (b), head (c) and lower rib cage (d). The branch is a *Ficus* sp. fed to the elephant.

was stripped off a vine and used as a switch. Scratching the skin with either the stem-end of the presented branch or a short stick from the ground (Fig. 5) was observed in 14 of the 15 elephants on 54 occasions.

During rides into the forested jungle four elephants were observed to grab a branch and carry it along, using it as a switch. This happened a total of nine times. Such branches were not carried for longer than 30 min. As mentioned, the size of these branches (1–2 m) was used as a guide for the size of branches presented to elephants during the 10-min observations. The following plant species were obtained and used by elephants for switching on rides: *Colebrookea oppositifolia, Murray koenigiu, Clerodendrum viscosum, Adena cordifolia, Litsea monopetala.*

We collected and identified 28 flies belonging to the genera *Tabanus* ($N=11$ species; $N=20$ flies) and *Haematopota* ($N=3$ species; $N=8$ flies); both genera comprise species commonly known as horse flies or tabanids.

### Relation of Switching to Fly Intensity

At site 1 we made a comparison of the switching rates and fly counts at daybreak (0600 hours), early morning (0800 hours), late morning (1100 hours), mid-afternoon (1500 hours), and late afternoon (1800 hours), for observations in which a branch was presented. We determined an individual median of the switching rate and starting fly count (time 0) for each elephant for each observation period (when more than one observation was made per time period). The group medians of these measures are presented in Fig. 6 which shows that at daybreak, when ambient temperature was coolest and there were virtually no biting flies evident, switching rate was lowest. By early morning, when the ambient temperatures had warmed by about 5°C, and a small number of flies were around the elephants, the switching rate increased close to the maximum reached later in the day. There was a significant difference between the daybreak switching rate and that of all other observational periods ($P<0{\cdot}01$). There was also a significant difference in switching rate between late morning and mid-afternoon ($P<0{\cdot}05$). There was no difference in switching rate between the other observational periods.

The fly count at daybreak observations, which were intentionally conducted to occur when no flies were out, was, of course, significantly less

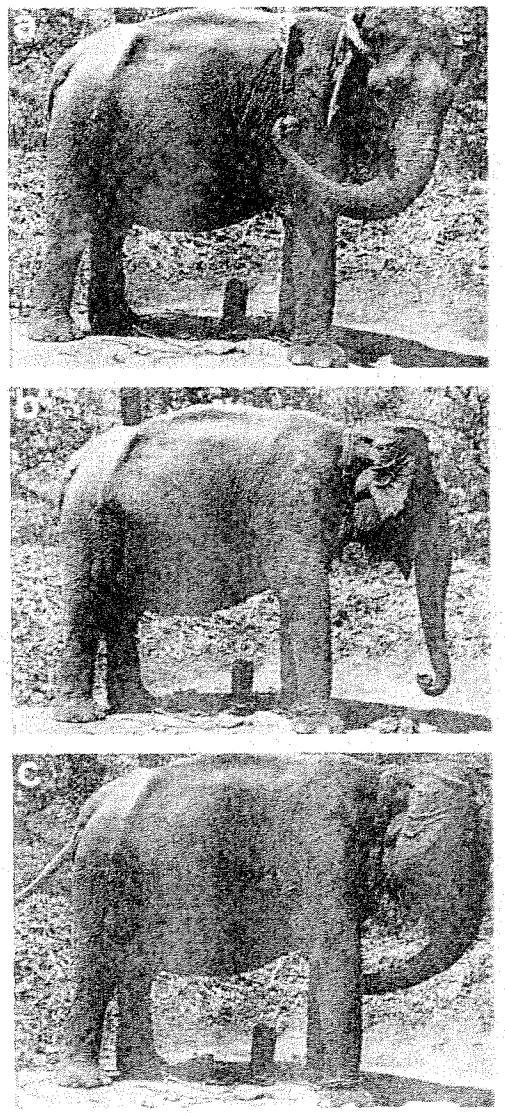

**Figure 2.** Use of a leafy branch (*C. viscosum*) as a switch. Often elephants held the switch in the trunk (b) between switching bouts (a) and (c).

than all subsequent counts ($P<0{\cdot}01$). The fly count was highest at late morning. The observations at mid-afternoon were made during the hottest part of the day and the fly count was low at this time, significantly lower than late morning and late afternoon ($P<0{\cdot}01$). By late afternoon, when flies were out again, switching was maintained even though the elephants were hungry and were eating as well as switching. At this time the elephants typically alternated using the trunk for switching and for feeding.

At site 2 a comparison between the switching rate and fly count at daybreak and mid-afternoon also revealed a significant increase in the median switching rate from 5·5 (range=2–38) to 95 (range=25–211) and an increase in the median starting fly count from 0 to 4·0 ($P<0{\cdot}01$). These data from site 2 thus corroborate the change in the switching rate at site 1 from daybreak to later in the day.

### Effectiveness of Switching in Reducing Flies

The effectiveness of switching to reduce flies was explored during late morning observations at site 1 by conducting a 10-min fly count when no branch was available for switching and immediately thereafter conducting a 10-min fly count when the elephants were given a branch. The number of replications of this experiment was four for six elephants and three for two elephants. We calculated an individual median fly count for each elephant for replicates with and without switching. All elephants experienced a reduction in the number of median flies counted from no-branch to branch tests. Figure 7 shows the group median fly counts along with the median number of switches and illustrates that switching resulted in a 43% drop in number of flies counted; this was a significant change ($P<0{\cdot}01$). The elephant with the lowest switching rate during late morning (55 per 10 min) had a 30% reduction in flies counted and the elephant with the highest switching rate had a 57% reduction in flies counted. However, due to overlap in the range of switching rates, a Spearman rank correlation of the median switching rates and fly counts during switching did not reveal a significant correlation between switching rate and per cent fly reductions.

## DISCUSSION

Despite the belief that the thick skin of elephants should provide protection from external parasites, Asian elephants are subject to the pain and blood loss inflicted by biting flies. A sample of two genera (14 species) of biting flies (horse flies or tabanids) were collected from the surface of elephants in this study. When flies were killed on the elephants, it was obvious that they contained

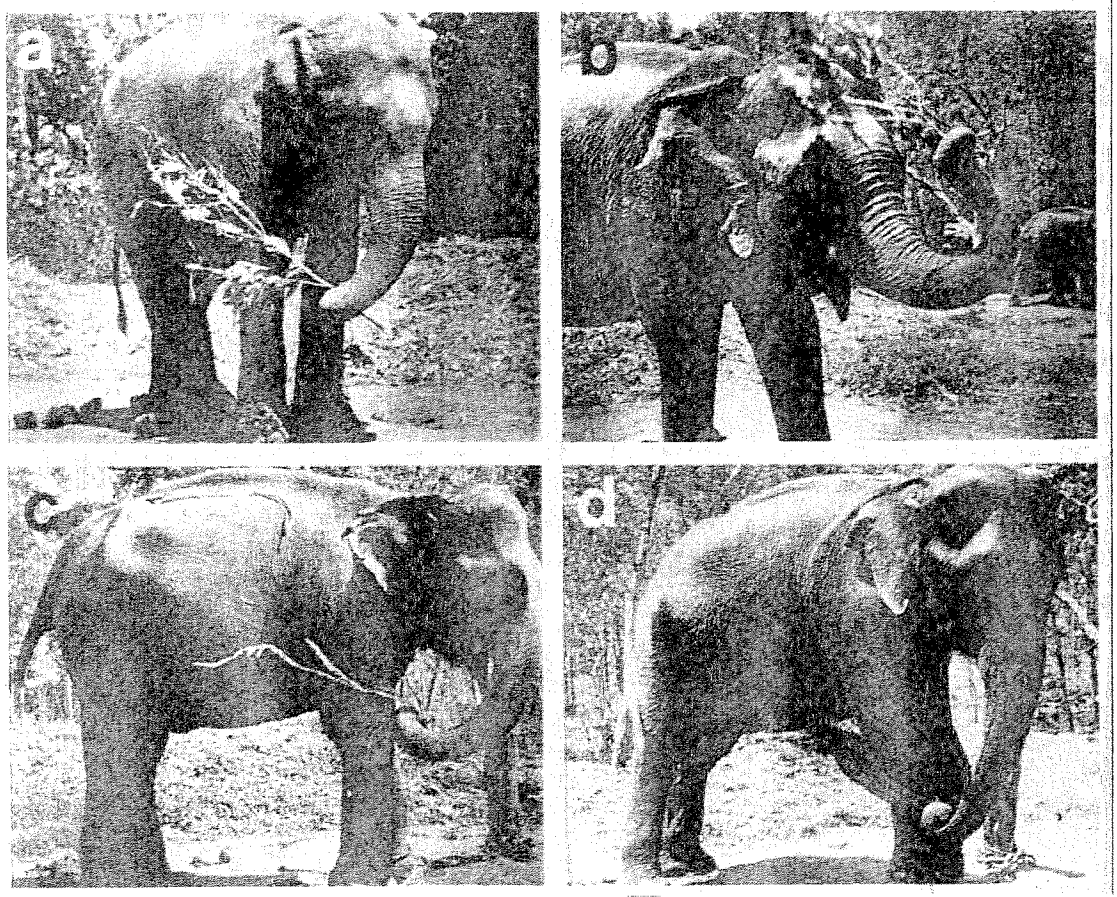


**Figure 3.** Illustration of types of material used as a switch. (a–b) A leafy branch (*C. viscosum*), (c) a long vine, and (d) a burlap bag.

blood. The pain and blood loss from fly bites would appear to provide for the natural selection and/or learning of a fly repelling behaviour such as switching with a branch if such switching is effective in reducing fly attacks. Clearly, in other species, especially ungulates which are frequently afflicted by biting flies, a variety of behavioural patterns have been observed that appear to reduce fly attacks (Hart 1990). These behaviour patterns include grouping (Mooring & Hart 1992), as well as lying down, taking evasive actions, microhabitat seeking and fly repelling behaviour such as ear twitching, head tossing and tail swishing (Hart 1990).

The elephant's trunk is extremely versatile as a prehensile organ and many parts of the body that are not accessible to the tail can be reached with the tip of the trunk. Despite its dexterity, the tip is not as well adapted to repelling flies as the hairy tails of equids or cattle, for example. The use of a leafy branch, 1–2 m in length, could increase the efficiency of the trunk, not only in dislodging flies from much of the elephant's body, but in reducing flies in the air. Switching with a branch was a common behaviour displayed by all 15 elephants studied. Elephants used leafy branches, banana stalks, bark from vines, grass and burlap cloth for switches. Consistent individual differences in switching rates existed among some elephants, as exemplified by the most active elephant consistently switching at four times the rate of the least active elephant.

A comparison of switching rate with presence of flies provided some evidence that switching with a branch is a behavioural adaptation to the presence of biting flies. Switch use occurred at a

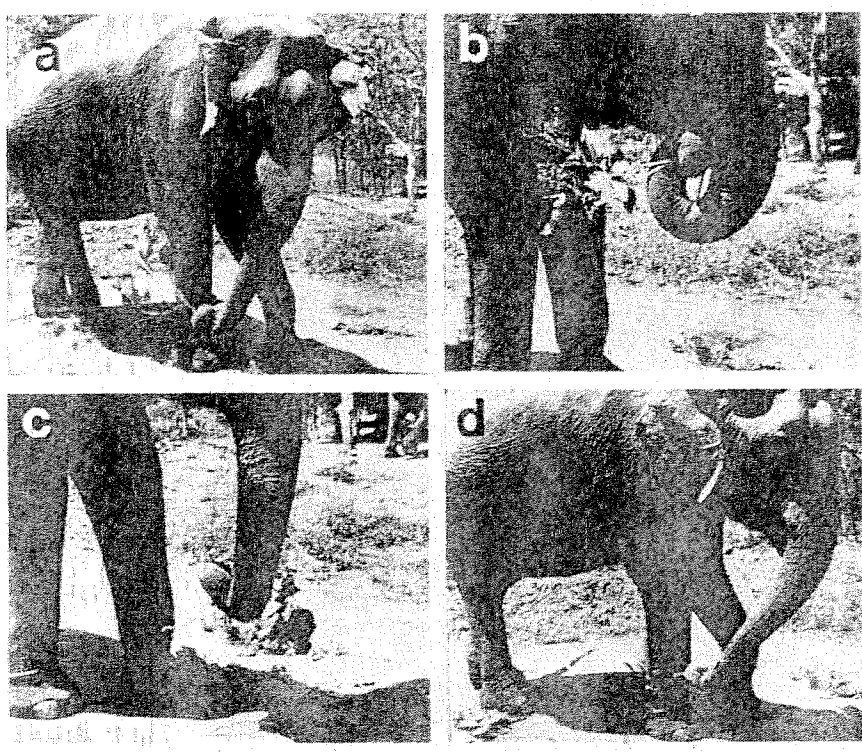


**Figure 4.** Modification of a branch used in switching. The branch (*C. viscosum*), as presented to the elephant and initially used unmodified in a bout of switching (a), then shortened using the trunk and mouth (b) to the resultant switch seen in (c) and (d). Note leaves on ground after the branch was shortened.

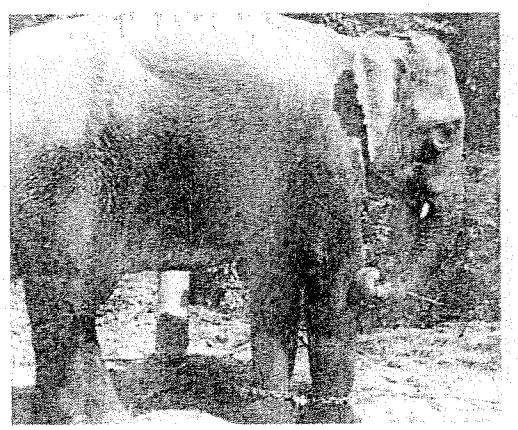

**Figure 5.** Use of a stick for scratching was a frequent occurrence.

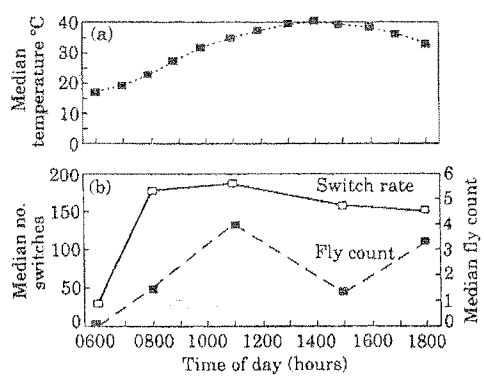


**Figure 6.** (a) The median ambient temperature during the observation periods. (b) Relationship between number of switches delivered per 10-min observation (□) and fly counts at the beginning of each observation (▩). The data represent medians of observations on eight elephants at site 1.

low frequency and much less energetically (median = 29 switches) at daybreak at site 1, when flies were virtually non-existent. By late morning (1100 hours), when a median of four flies were counted on and around the elephants, switching escalated to a median of 186 switches per 10 min.

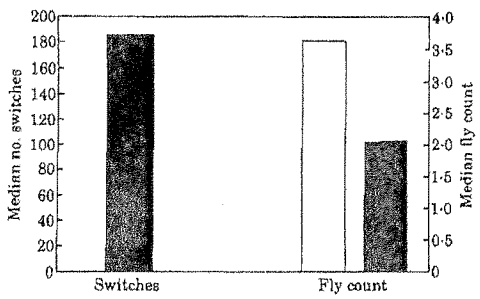


**Figure 7.** Effects of switching on median fly counts. The recordings of switch use were made during 10-min observations in late morning (1100 hours), initially when no branch was available (□), and then when a branch was presented for switching (▩). The data are based upon medians of three to four replications on eight elephants at site 1. The 43% reduction in flies counted when a branch was available was significant ($P<0{\cdot}01$).

In both types of observations, equivalent branches were made available to the elephants. The data could be interpreted to suggest that switching reached a near maximum rate with only a few active flies and was not closely graded according to the number of flies. The changes in fly switching behaviour as a function of time of day are similar to the changes in ear flicking behaviour in cattle (Harris et al. 1987) and red deer (Woollard & Bullock 1987) over the course of a day. However, the appearance of flies did not occur until there was a moderate increase in ambient temperature. Thus, switch use was also related to ambient temperature changes. The fact that elephants used vine stems or leafless branches for switching argues against the value of switching as a cooling mechanism.

The second type of observation, performed as an experiment, provided the best evidence of switch use as an adaptation to biting flies. The tests, conducted at site 1 in the late morning when fly intensity was highest, consisted of pairs of 10-min fly counts, first when no switch material was available and then when leafy branches were presented. The median number of switches delivered in the second 10 min was 186 and the number of flies per count was reduced (significantly) by 43%. Interestingly, the decrease in the number of flies per 10-min count in tests when elephants could switch with a branch versus no branch was similar to differences in fly density noted on dairy heifers with intact tails compared with those with docked tails (Ladewig & Matthews 1992).

Three types of observations indicate that branch switching is not a manifestation of confinement or boredom stereotypy. One is the relation of switching to the presence of flies rather than with periods of minimal environmental stimulation, such as at daybreak after the elephants had been eating all night and their tethers had been cleaned. During late afternoon when the elephants were fed highly palatable grain and molasses supplements along with forage and were actively eating, the fly intensity was high. The use of the trunk for switching with a branch, which was alternated with the use of the trunk for feeding, was still 150 times per 10 min. If the forage was of the type that could be used for switching (banana leaves), this forage was often used for switching and then eaten. Finally, elephants were observed to pick branches and use them as switches when they were taken into the jungle on rides.

In using a fly switch, the elephants would often use a presented branch for switching, lay it down and then take it up again, perhaps after engaging in some other behaviour such as eating or throwing dust on their backs. This behaviour was suggestive of 'saving' a branch that was particularly suitable for switching. The regularity with which this saving behaviour occurred and individual differences were not noted.

On nine occasions, while taking people on jungle rides, the elephants were observed to grasp a branch, carry it for some distance and use it as a switch before dropping it (i.e. not eating it). On 13 occasions (out of 132 branch-presentation observations) the elephants were observed to remove side stems from a presented branch without eating the removed parts. This behaviour was interpreted as modifying the branch and possibly increasing its efficiency as a switch.

Assuming that the use of switches by elephants functions to repel and dislodge flies, the behaviour satisfies one generally accepted definition of animal tool use: 'the external employment of an unattached environmental object to alter more effectively the form, position, or condition of another object, another organism or the user itself when the user holds or carries the tool during or just prior to use and is responsible for the proper and effective orientation of the tool' (Beck 1980, page 10). Our observations of modification of the branch and the report by Peal (1879) of a captive elephant stripping down a branch before breaking

it off and using it as a switch, reveal that elephants also fashion this particular tool. A study of wild Asian elephants with emphasis on the age and development of fly switch use by young elephants, and the frequency with which adults fashion and save switches, would prove most interesting. More than any other non-primate species, elephants are known for tool use (Chevalier-Skolnikoff & Liska 1993). A comparison of tool use frequency by captive and wild African elephants revealed that tool use acts by wild animals occurred at only about one-tenth the rate as in captive animals (Chevalier-Skolnikoff & Liska 1993). However, swatting the body with vegetation was the most frequently recorded tool-use behaviour other than throwing or blowing dirt or water onto the body. Thus fly switch use may be frequent enough in wild elephants, including Asian elephants, to provide quantitative information for more in-depth exploration of tool use by elephants.

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