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BRIEF REPORTS

Seasonal and Social Correlates of Changes in Hair, Skin, and Scrotal Condition in Vervet Monkeys (*Cercopithecus aethiops*) of Amboseli National Park, Kenya

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In a 20-month study of six groups of vervet monkeys (*Cercopithecus aethiops*) in Amboseli National Park, Kenya, I documented changes in hair loss in all individuals, and scrotal color and hyperpigmentation in all adult males. Hair loss occurred seasonally and was most pronounced in low-ranking individuals, especially males. The mean shade of scrotal color for all males and the percentage of males with scrotal hyperpigmentation both covaried with hair loss over time. Scrotal color was strongly negatively correlated with scrotal hyperpigmentation. The underlying causes are not yet known. I present three scenarios based on nutrition, stress from competition, or a combination of the two, that might explain these patterns. Awareness of these easily observable changes may provide fieldworkers with a quickly assessed visual measure of physical or emotional stress in free-ranging vervets.

Key words: nutrition, stress, dominance, hair loss, hyperpigmentation, scrotum

INTRODUCTION

The well-being of both captive and wild primates is an increasingly important concern of primatologists. Physical health and emotional health have been less extensively monitored for wild primates than for captive primates. This is based partly on ease of manipulation of captive animals. However, it may also be based on the belief that primates in captivity face greater stress than primates in the wild or that we have an ethical responsibility to maintain captive, but not wild, animals in good health.

Physical and emotional health in wild primates have been monitored by examining parasites [e.g., Freeland, 1976; McGrew et al., 1989], measuring endocrine levels [Sapolsky, 1982; Alberts et al., 1992], and measuring body weight [Goldizen et al., 1988]. Although these are legitimate measures of an animal's condition, they require intensive effort to document. In studies where health is not

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the main focus of the study but is of interest nonetheless, it would be useful to have a measure for assessing general health that requires less effort. Here, I present data on changes in physical condition of wild vervet monkeys (*Cercopithecus aethiops*) that are easily assessable and appear to reflect natural stresses faced by the monkeys.

METHODS

Study Site and Subjects

This study is based on data collected from June 1986 until January 1988 on six groups of habituated and individually identified vervet monkeys in Amboseli National Park (2° 41′ S, 37° 10′ E), Kenya.

The study area included two habitat types: one dominated in the past by *Acacia xanthophloea* (fever trees) and the other, *A. tortilis*. A die-off of fever trees began in Amboseli in the mid-1950s [Western, 1983] and ended in the study area in 1992 (personal observation) after the last fever tree died. The decline of the fever tree population has been attributed to a combination of short-term climatic change, elephant browsing, and stand senescence [Western & van Praet, 1973; Young & Lindsay, 1988]. The vervet population declined along with the fever tree population [Struhsaker, 1973, 1976; Cheney et al., 1988; Isbell et al., 1990]. Vervet groups whose home ranges did not include fever trees had lower reproductive rates than groups whose home ranges had fever trees, suggesting that the vervet population ultimately declined as a result of reduced food resources [Cheney et al., 1988].

The decline of the vervet population was exacerbated during this study by an increase in predation. The increase in predation was most likely a consequence of the vervets' movement away from the dying fever tree woodlands and into unfamiliar areas, and also a consequence of greater leopard (*Panthera pardus*) activity than in previous years [Isbell, 1990; Isbell et al., 1990; Isbell & Young, 1993a; Isbell et al., 1993].

Vervets live in multi-male, multi-female groups. Within groups, both adult males and adult females can be placed in linear dominance hierarchies based on fights and approach-avoidance interactions [Seyfarth, 1980; Whitten, 1983]. In Amboseli, both males and females are aggressively involved in defense of their group's home range against incursions by neighboring groups [Cheney, 1981; Cheney & Seyfarth, 1987]. Over a 10-year period, intergroup encounters declined in rate from one every 1.8 days [Cheney & Seyfarth, 1987], to one every 6.7 days [Isbell et al., 1990], coincident with the decline in population size.

Adult and subadult male vervets are immediately identifiable by a blue scrotum into which the testes have descended.

Data Collection

I conducted censuses or systematic sampling on each of the six main study groups over an average of eight days each month from June 1986 until January 1988, excluding September 1987 [range: 4–22; see Isbell et al., 1990; Isbell & Young, 1993b; Isbell et al., 1993 for more details]. As part of the long-term demographic record, I noted during censuses and systematic sampling when any individual exhibited physical changes, including loss of hair or blackening of exposed skin (see results). Additionally, for males, I recorded from October 1986 until November 1987, the color of the scrotum and the presence of scrotal hyperpigmentation, seen as black, pea-sized spots on the scrotum or just above the penis. Monthly sample sizes for each male ranged from one to six (median = 4). Scrotal color varied over a large range, and was scored into one of four broad categories of very different shades. These shades were gray (assigned a score of 0), light blue (1), azure blue (2), and purple-blue (3). Use of these shades was based on four months of preliminary investigation which showed that males could be readily assigned one of these shades on any given day. Scores were averaged monthly for each male. Averaging minimizes potential variation in perception of color caused by extrinsic factors, such as changes in natural lighting, e.g., cloudy vs. sunny days, or mornings vs. afternoons.

I constructed linear dominance hierarchies within groups separately for males and females on the basis of physical fights and approach-avoidance interactions [Seyfarth, 1980; Whitten, 1983] during 1,187 hours of systematic observations. For analysis, individuals were placed into one of two categories, high rank or low rank. Individuals in the exact middle of the dominance hierarchy were placed in the category of low rank. Relative ranks of females did not change during the study. In comparisons of hair loss in individuals of different rank and scrotal changes in males of different rank, I assigned to each animal the rank it held during the first month in which any animal in its group exhibited these changes.

Feeding behavior ($n = 6{,}289$) was recorded during systematic scan sampling of activities [see Isbell & Young, 1993b for details]. Whenever an animal was observed feeding during systematic sampling, the food species and item were recorded.

Statistical tests are taken from Zar [1984]. Tests were two-tailed when directional alternatives were not made a priori, e.g., all tests of sex and age differences. Tests of rank differences were one-tailed because directional alternatives were made a priori. Tests had one degree of freedom unless noted otherwise. Seasonal variation in hair loss and hyperpigmentation was tested with a χ^2 goodness-of-fit test, which is a conservative test for seasonal data [Reijneveld, 1990].

RESULTS

Seasonal Changes in Hair Loss

Sixteen of 51 (31.4%) adult and subadult males and females, vs. four of 22 (18.2%) juvenile males and females, lost hair on various parts of their bodies during the study (Cochran-corrected $\chi^2 = 1.31$; $P > 0.20$). Most commonly, hair loss occurred more or less symmetrically on both sides of the abdomen, knees, elbows, and on inner thighs. This was invariably accompanied by an obvious blackening of the skin in the areas that were newly exposed.

Hair loss with hyperpigmentation (hereafter called hair loss) lasted one month to five consecutive months (median = 2.0 mos.). Hair loss was seasonal ($\chi^2 = 66.18$, d.f. = 18, $P < 0.001$; two-tailed), peaking in November 1986 through January 1987 ($x = 15.4\% \pm 2.2$ S.E.), and again in November, 1987 through January, 1988 ($x = 14.1\% \pm 1.3$). In contrast, the percentage of vervets showing hair loss was smaller in the other 13 months ($x = 2.0\%$, ± 0.70) (Fig. 1). Hair loss was positively correlated with the overall proportion of *A. tortilis* flowers in the diet of the vervet population with a lag of one month ($r_s = 0.64$; $p < 0.02$, 2-tailed; Fig. 1).

Hair Loss in Relation to Rank and Sex of Adults

Low-ranking individuals were significantly more likely to show hair loss than high-ranking individuals (Cochran-corrected $\chi^2 = 2.75$; $P = 0.05$; Fig. 2). Males, more than females, were apparently responsible for this rank effect. Hair loss occurred in three of 11 (27.2%) high-ranking females and in six of 14 (42.8%) low-ranking females (Cochran-corrected $\chi^2 = 0.70$; $P \approx 0.20$). Hair loss occurred in one of six (16.7%) high-ranking adult males (one newly emigrated, high-ranking male with hair loss was excluded because his rank in his previous group was

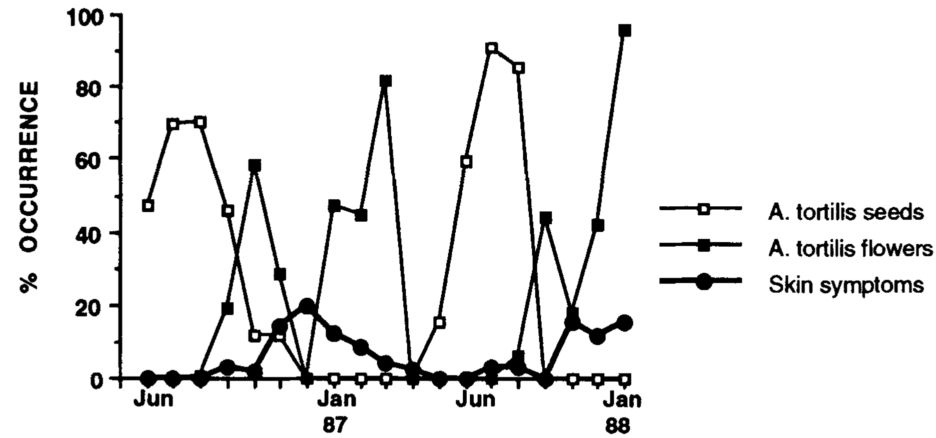

Fig. 1. Seasonal change in percentage of vervets with hair loss, and seasonal consumption of *Acacia tortilis* seeds and flowers by the vervet population.

unknown), and in five of eight (62.5%) low-ranking adult males (Cochran-corrected $\chi^2 = 2.68$; $0.05 < P < 0.10$; Fig. 2). Overall, however, females did not differ significantly from males in frequency of hair loss. 36% of the females and 43% of the males showed these symptoms (Cochran-corrected $\chi^2 = 0.007$; $P > 0.90$).

Because groups of vervets living in adjacent home ranges can vary substantially in feeding behavior [Wrangham & Waterman, 1981], rates of predation [Cheney et al., 1988; Isbell et al., 1990], and activity budgets [Isbell & Young, 1993b], I also examined among groups for variation in frequency of hair loss. Three groups had relatively few cases of hair loss (Group A: 20%; Group C: 28%; Group 3: 28%). The other three groups had more cases (Group 2: 57%; Group B: 62%; Group 4: 75%). The reason for this is unknown; the variation was not obviously related to habitat type, distance to water, or rate of group decline [see Isbell & Young, 1993a, Table I for more details].

Scrotal Hyperpigmentation

Seven of 16 (44%) adult and subadult males exhibited, at one time or another during the study, circular patches of hyperpigmented scrotal skin. Scrotal hyperpigmentation lasted one month to seven consecutive months (median = 1.5 mos.). Low-ranking adult males (3/8) were not more likely than high-ranking adult males (4/7) to have scrotal hyperpigmentation (Cochran-corrected $\chi^2 = 0.27$; $P > 0.50$).

Scrotal Color

Males varied in overall mean shade of blue coloration. One (low-ranking) male, in particular, had a consistently far deeper blue scrotum than any other male (GY; Fig. 3). There was a non-significant tendency for high-ranking adult males to have deeper scrotal color (x = 1.25 ± 0.07) than low-ranking males (x = 1.10 ± 0.04) when GY was excluded from the analysis (Mann-Whitney U = 12, $n_1 = 7$; $n_2 = 7$; $P = 0.06$).

Covariance of Hair Loss, Scrotal Hyperpigmentation, and Scrotal Color

All three changes in the physical condition of vervets covaried through time. The percentage of males with scrotal hyperpigmentation was positively correlated

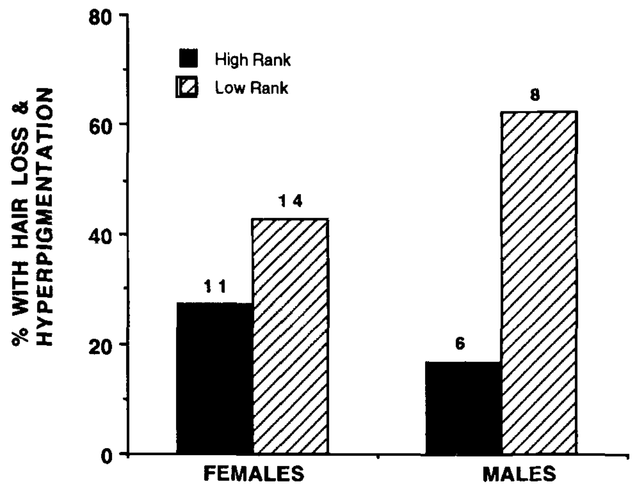

Fig. 2. Percentage of males and females of high and low rank with hair loss and hyperpigmentation. Numbers above bars are total numbers of individuals of high and low rank.

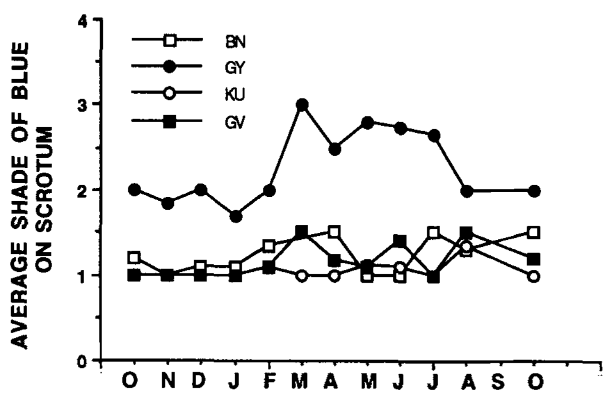

Fig. 3. Individual variation in scrotal shade over time. All males who were in the population throughout the period for which scrotal shade was estimated are shown. GY had a consistently deeper blue scrotum than any other male.

with the percentage of individuals (both males and females) with hair loss. The correlation was strongest when the percentage of males with scrotal hyperpigmentation was compared with hair loss in the following month ($r_S = 0.67$; $P < 0.02$; n = 11). The average shade of scrotal color for all males combined was negatively correlated with the percentage of individuals with hair loss in the following month ($r_S = -0.71$; $P < 0.02$). The average shade of scrotal color for all males combined was strongly negatively correlated with scrotal hyperpigmentation in the same month ($r_S = -0.90$; $P < 0.01$; Fig. 4). The strong negative correlation over time between scrotal hyperpigmentation and scrotal color suggests that 1) males with scrotal hyperpigmentation also had lighter scrotal coloration, 2) only the blue

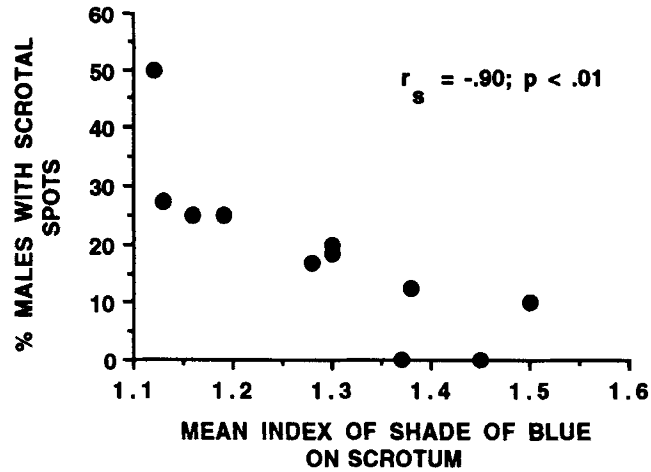

Fig. 4. Correlation between scrotal shade, averaged across all males, and percentage of males with scrotal hyperpigmentation. Each point represents one month.

coloration appeared lighter in contrast with the dark spots of hyperpigmented skin [color contrast: Burnham et al., 1963], or 3) these changes occurred at the same time but independently in different males. The former two alternatives are not supported by the data. Males with scrotal hyperpigmentation did not have significantly lighter scrotal color (x = 1.13 ± 0.07) than males without scrotal hyperpigmentation (x = 1.22 ± 0.06) (Mann-Whitney U = 15.5; n_1 = 7, n_2 = 7; $P > 0.10$).

DISCUSSION

Captive vervets not exposed to sunlight have lighter faces than vervets that are exposed to sunlight (J.E. Fincham, personal communication), and it is likely that the (non-scrotal) hyperpigmentation was a direct consequence of exposure to sun after loss of hair. Scrotal hyperpigmentation and color also covaried with these changes in the physical condition of vervets through time. Their covariance may have occurred because they were caused by the same underlying factor. It is also possible, however, that their covariance was spurious and caused independently by different factors. The underlying cause(s) of hair loss and changes in scrotal condition is (are) not yet known. Seasonal molting, which occurs after the mating season in rhesus macaques *Macaca mulatta* (F. Bercovitch, personal communication), does not appear to explain the hair loss. Hair loss has been observed recently in population of vervets in Laikipia, Kenya (J. Pruetz, personal communication; see below). These two populations of vervets are synchronous in their birth seasons but thus far, the hair loss has been observed in the Laikipia population only in months when it was not observed in Amboseli. Regardless of the cause(s), individuals of different age classes and of both sexes were equally likely to be affected. The seasonality of hair loss and its relationship to social rank, particularly in adult males, suggest several possible causes, all related to either physical or emotional stress. I offer three scenarios below as a guide for future research.

Scenario 1: Nutritional Deficiency

The seasonal increase in hair loss coincided with the birth season. Lactation, especially, is an energetically demanding time for female mammals [Portman, 1970] and it is possible that females who lost hair during this time were particularly stressed nutritionally. If this was the case, then low-ranking females, who generally have poorer access to preferred foods [Wrangham & Waterman, 1981; see also Whitten, 1983] would be expected to be more stressed than high-ranking females, and to show a greater frequency of hair loss, or produce fewer offspring, than high-ranking females. Although rank had no apparent effect on hair loss among females, low-ranking females did produce fewer infants than high-ranking females (6/12 vs. 10/10 of those surviving the birth seasons) during the study period. However, greater energetic needs during lactation cannot completely explain the seasonality of hair loss. Three of the six low-ranking females who did not reproduce, and many adult males, also lost hair.

During the long dry season months of June through October, vervets in Amboseli ate mainly *A. tortilis* seeds (Fig. 1), and low-ranking individuals were more restricted to eating seeds than high-ranking individuals [Isbell & Young, in prep.; see also Wrangham & Waterman, 1981]. *Acacia tortilis* seeds have a trypsin-inhibitor [Altmann et al., 1987] which interferes with protein digestion. This also reduces availability of tryptophan, an essential amino acid [Ramsey, 1982: 272]. Tryptophan is a precursor to niacin [Bogert et al., 1973: 139; Ramsey, 1982] and niacin and protein deficiencies often occur together [Ramsey, 1982]. A number of nutritional deficiencies, including niacin and protein deficiencies, produce symptoms in other primates similar to those observed in Amboseli vervets. In rhesus monkeys, niacin (and perhaps protein) deficiency caused hair loss and hyperpigmentation [Tappen et al., 1952; Belavady et al., 1968]. Niacin or protein deficiency also caused edema in the scrotal area in rhesus macaques [Tappen et al., 1952]. The color of the vervet's scrotum is controlled proximally by the amount of interstitial fluid in the dermis: more fluid causes the color to pale, whereas less fluid causes the color to deepen [Price et al., 1976]. Edema, brought on by a nutritional deficiency, could cause a paling of the blue color on the vervet's scrotum.

There are some problems with this scenario. First, implication of *A. tortilis* seeds as the sole cause of the changes in physical condition of Amboseli vervets requires a lag of about three to five months (Fig. 1). In experimental studies, animals vary in the length of time between deprivation and symptoms of deficiency [e.g., Tappen et al., 1952; Follis, 1957; Belavady et al., 1958]. Lag times are likely to be shorter in captive animals than in free-ranging, unprovisioned animals where access to food is not controlled by the investigator. However, a three- to five-month lag, especially when it includes two months of eating highly preferred *A. tortilis* flowers, may be unreasonably long.

Second, a film of Amboseli vervets made in the 1960s by T. Struhsaker when fever trees were still numerous (T.T. Struhsaker, personal communication) clearly shows vervets with a pattern of hair loss and hyperpigmentation similar to that observed during this study. During Struhsaker's study, vervets fed less on *A. tortilis* and more on fever trees relative to the present study.

On the other hand, seeds of legumes in general, including fever trees, may have trypsin-inhibitors (S.A. Altmann, personal communication) that produce the same deficiencies, especially if the diet is low in diversity as it is in Amboseli. If this is the case, vervets that rely heavily on seeds of legumes in other areas should also show these symptoms. Hair loss with hyperpigmentation in females and scrotal hyperpigmentation have been observed in a population of vervets in Laikipia, Kenya (personal observation; M. Lewis, personal communication; J. Pruetz, personal communication), and preliminary data indicate that *Acacia* seeds represent similar proportions in the annual diets of both Laikipia and Amboseli vervets (Laikipia: 28%; Amboseli: 25% (unpublished data)). These values are somewhat higher than the 19% yearly consumption of *Acacia* seeds at Samburu [calculated from Whitten, 1983] where no symptoms were noted (see below).

Scenario 2: Social Stress Associated with Competition

Another possibility is that the stress of aggressive competition alone caused hair loss and scrotal changes. Captive low-ranking males facing aggression from high-ranking males showed a paling of the scrotum within two weeks [Gartlan & Brain, 1968; but see Henzi, 1985]. The mechanism that would cause the scrotum to become paler under such social stress is unclear.

Hair loss and scrotal hyperpigmentation were not noted (though this is not necessarily synonymous with noting their absence) in vervets at Samburu, Kenya (P. Whitten, personal communication) or at Burman Bush Nature Reserve, South Africa (S.P. Henzi, personal communication). It is possible that competition for food has typically been more severe in Amboseli than in other study sites. This is suggested by the greater rate of intergroup encounters in Amboseli compared with other areas [Cheney, 1987]. Perhaps physical changes in hair and skin are observed only when competition is severe. If this is the case, it would be valuable to have a simple, easily assessed physical indicator of severe competition, particularly as other indirect measures, e.g., changes in population growth rate, can take years to determine.

Scenario 3: Nutritional Deficiencies Together with Competition

There is strong evidence that vervets face food competition both within and between groups [Cheney & Seyfarth, 1987; Isbell et al., 1990]. Competition can take the form of aggressive interactions (contest competition) or of passive reduction of foods merely by the presence of others who eat those foods (scramble competition) [van Schaik, 1989; Isbell, 1991]. Scramble competition alone might prevent low-ranking individuals from getting the nutrients they need. Alternatively, low-ranking animals may require more nutrients than high-ranking animals, especially niacin and other B vitamins, if they are under greater emotional stress than high-ranking animals [Ramsey, 1982:271].

Unfortunately, the available data do not allow rejection of any of these scenarios. Experimental manipulation is needed to elucidate the exact cause(s) of hair loss and scrotal change. Nonetheless, the seasonal and rank-related patterns to these changes in physical condition suggest that they are not random, but instead reflect underlying patterns of physical or emotional stress. The recent documentation of similar changes in skin and hair condition in another population of vervets suggests that this phenomenon could also occur in other populations. Awareness among fieldworkers of the potential significance of these easily observable changes in vervets may allow quick and reliable assessment of the general health of their study populations.

CONCLUSIONS

1. Vervets in Amboseli National Park, Kenya, exhibited seasonal changes in hair loss and hyperpigmentation in areas denuded of hair.
2. Hair loss was associated with social rank, especially in adult males.
3. Changes in scrotal condition (hyperpigmentation and color) covaried with hair loss.
4. The percentage of males with scrotal hyperpigmentation was strongly negatively correlated with average shade of scrotal color over time.

5. Possible explanations for these changes in physical condition include nutrition, stress from competition, or both. Such changes may provide fieldworkers with an easily documented measure of physical or emotional stress.

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