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Colobus monkeys and coconuts: a study of perceived human–wildlife conflicts

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Summary

1. Approximately half of the remaining Zanzibar red colobus *Procolobus kirkii*, one of Africa's most endangered primates, reside permanently outside protected areas, many within agricultural areas. Consequently, conservation of this endangered species is strongly dependent on the development of effective management plans that address the potential human–wildlife conflicts in these agricultural areas.

2. There are a growing number of complaints about red colobus consumption of coconuts in the agricultural areas and requests by local farmers for compensation and/or removal of the colobus. Prior to taking actions that would hinder the conservation of this highly endangered species, it is necessary to quantify and compare the actual impact of the colobus on coconut harvest with that perceived by the farmers.

3. In this study we monitored five experimental and two control plots to quantify the potential impact of red colobus on coconut crops and to assess the ecological variables that may influence this impact.

4. We found that red colobus consumption of coconuts was highest in areas of high red colobus density and low availability of alternative red colobus food resources. Despite these correlations, red colobus feeding on immature coconuts did not appear to limit coconut harvest. On the contrary, red colobus consumption of coconuts was found to be positively correlated with harvest. This correlation is probably due to a pruning effect.

5. Based upon our findings that red colobus are having no significant negative impact on coconut harvest and are actually a source of tourist revenue to the region, we recommend no action be taken to remove colobus from the agricultural areas.

6. This study illustrates the importance of scientific documentation of perceived human–wildlife conflicts.

Key-words: Cocos nucifera, crop raiding, *Procolobus kirkii*, pruning by monkeys.

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Introduction

The extremely high rate of human population growth in Africa leads to ever-increasing encroachment on wildlife habitats and an increase in human–wildlife conflicts. Species that are unable to adapt to altered habitats are being forced into small, marginal habitat patches. Those species that, because of their behavioural flexibility, are able to adapt to a changing ecology and survive in agricultural systems often come into direct competition with humans and are persecuted as pests. The adaptability, intelligence and opportunistic nature of some primate species has led to them being considered a serious menace to agriculture in many tropical countries (Strum 1986; Mittermeier & Cheney 1987; Else 1991).

In Zanzibar, most medium- to large-size mammals are considered by agriculturists to be pests (Bensted-Smith 1990; Mturi 1991; Krain *et al.* 1993). The Sykes monkey *Cercopithecus mitis albogularis* (Sykes 1831) and the Zanzibar red colobus *Procolobus*

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kirkii Gray 1868 are ranked as the second and third most serious vertebrate pests based on farmers' complaints about crop raiding (Krain *et al.* 1993).

Since 1991 we have been studying the population ecology of the Zanzibar red colobus monkey, one of Africa's most endangered primates that is found only on the island of Unguja (Zanzibar). Approximately half of the remaining Zanzibar red colobus reside permanently outside protected areas, many within agricultural areas. Consequently, long-term conservation of this endangered species is strongly dependent on the development of effective management plans in these agricultural areas (Struhsaker 1992, 1993; Struhsaker & Siex 1994, 1996; Siex 1995).

Of particular interest in this regard is the potential conflict over coconuts *Cocos nucifera* L. Coconuts are important as food for the red colobus (Mturi 1991; K.S. Siex, personal observation), and as part of the economy and nutrition of the Zanzibaris. The coconut tree is the third most important food species of red colobus living in agricultural areas (Mturi 1991), while coconut exports accounted for more than 90% of the foreign exchange earnings during the late 1980s and early 1990s, and coconut products are an important component of the local human diet. It is speculated that the elimination of coconut from the local human diet would lead to nutritional deficiency (Wirth *et al.* 1988; Hettige 1990; NCDP 1991; FAO 1992).

Between 1991 and 1996 we met frequently with the chief and residents of the village of Pete and agricultural plots within and near our study area in Jozani Forest Reserve. Informal discussions with these residents led us to believe that there was genuine concern over losses in harvest yields due to the consumption of young coconuts by red colobus. These discussions cannot be taken as a formal study. They were neither quantitative nor systematic and all that we can report here are our impressions. We talked with at least 20 farmers and two village chiefs (Muungoni and Pete villages). They expressed a range of attitudes toward the colobus. Overall, our impression was that less than half of the farmers we met had any complaints about the red colobus raiding crops, although these stated attitudes may have changed over the years (see the Discussion). In contrast, virtually all complained about the crop raiding of the much more numerous Sykes monkeys and, we were told, farmers frequently shot at Sykes monkeys. This pattern is consistent with the T.T. Struhsaker's 37 years of experience throughout tropical Africa, namely that Sykes or their close relatives are considered to be agricultural pests by local farmers, whereas colobus are not.

It was already evident to us in 1991 that red colobus ate small, young coconuts. Given these observations, combined with the endangered status of red colobus and the complaints by some farmers about crop raiding by red colobus, we felt it was important to determine through objective and systematic study the extent to which the colobus affected the coconut harvest yields for humans on Zanzibar.

There have been a number of studies on the effect of wildlife on plant and tree crops (reviewed by Gill 1992c and Huntly 1991; Oppenheimer & Lang 1969; Oppenheimer 1978; Struhsaker 1978; Maganga & Wright 1991; Horrocks & Baulu 1994; Boulton, Horrocks & Baulu 1996 address the effects of primates). However, all too often these studies are strictly qualitative and rely on farmers' perceptions to estimate the extent of damage. Furthermore, very few studies have attempted to distinguish the variables that affect the level of wildlife impact. The majority of research on this issue deals with small mammals and deer in temperate forests (reviewed by Gill 1992a,b). These studies illustrate the difficulty in separating the effect of single independent variables thought to be important in predicting rates of browsing. Furthermore, studies that have found significant correlations between predicting variables and the level of impact are often contradictory (Gill 1992a,b). These contradictions are probably the result of the complex interaction between biotic variables (e.g. species density, basal area, diversity, dispersion); abiotic variables; and the density, demography and behaviour of the species competing with humans. Furthermore, although some general trends have appeared, the factors found to be important in predicting the incidence and level of impact in one location are site and species specific, and thus not applicable to other situations (Gill 1992a,b).

Our goal in Zanzibar was to quantify the impact of red colobus on coconut crops, to assess the ecological variables that may influence this impact, and to propose management recommendations that would minimize potential conflicts. We hypothesized that the level of coconut consumption by the red colobus would be positively correlated with the number of red colobus using a plot and, more specifically, the number of red colobus per coconut tree in a plot. Furthermore, if the red colobus were having a negative impact on coconut harvest, we predicted a decreased yield to the farmer as a result of increased consumption. We also hypothesized that in habitats with higher density, diversity and basal area of red colobus food trees other than coconuts, the red colobus use of coconut trees would be lower and thus coconut tree yields would be higher.

Study sites

The Zanzibar red colobus occurs naturally only on the island of Unguja (also called Zanzibar). Unguja is located in the southern Indian Ocean (4°50′–6°30′ S, 39°10′–39°90′ E) and is separated from mainland

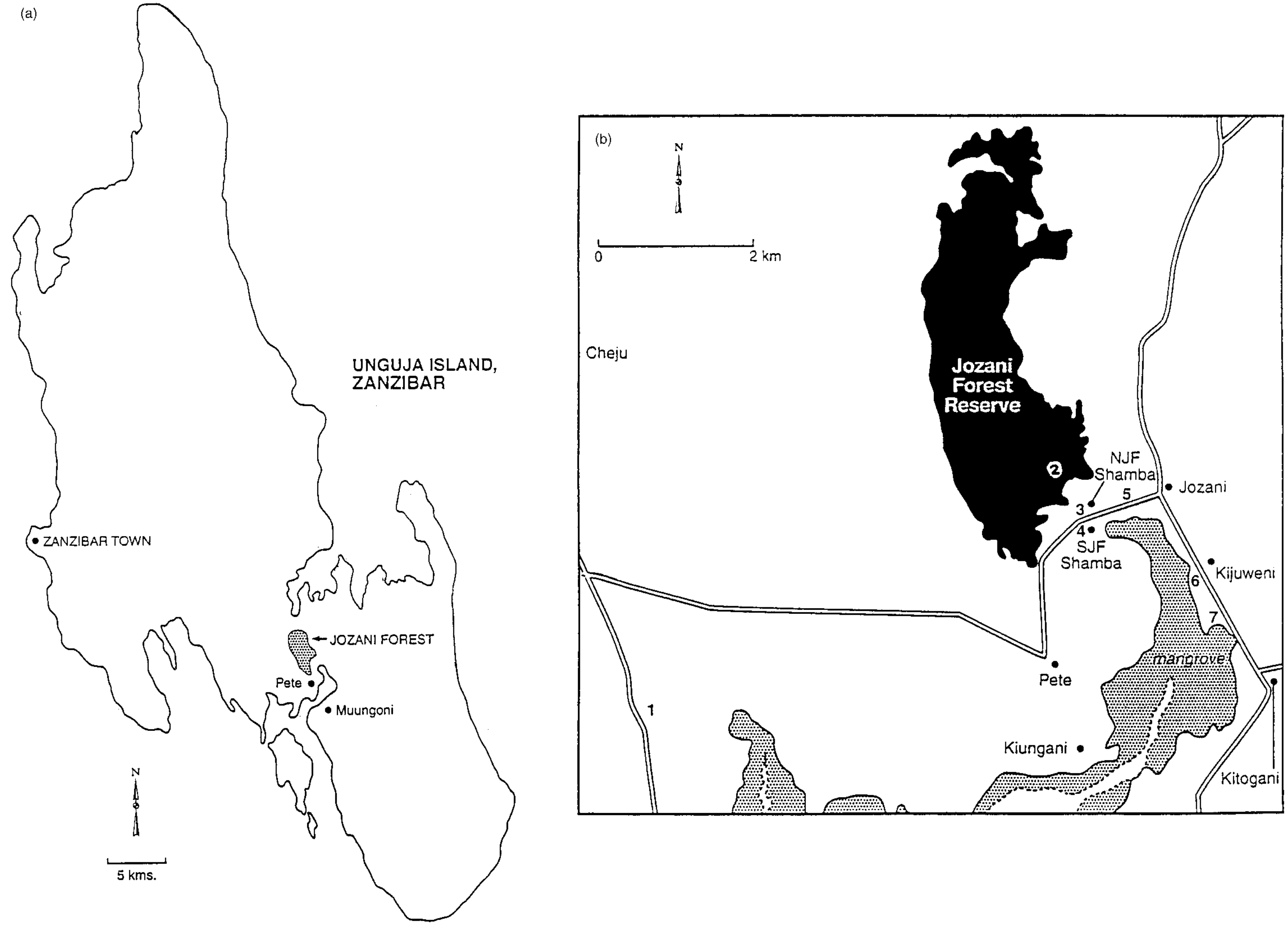

Fig. 1. (a) Unguja Island, Zanzibar, Tanzania, East Africa. (b) Study sites. Control plots: 1 = UU, 6 = KIJ. Experimental plots: 2 = FOR, 3 = NJF, 4 = SJF, 5 = JO V, 7 = KIT.

Tanzania by approximately 40 km. Our research focused on two subpopulations of red colobus utilizing the Jozani Forest Reserve and the agricultural areas adjacent to the southern border of the reserve (Fig. 1). The majority of the estimated 1500–2000 remaining Zanzibar red colobus live in this area (Struhsaker & Siex 1996).

JOZANI FOREST RESERVE

Jozani Forest is a small forest reserve (approximately 22 km^2, only 2–5·5 km^2 of which is ground-water forest) located 35 km south-east of Zanzibar town (Fig. 1). It has been described as a *Calophyllum inophyllum* ground-water forest with low species diversity (Robins 1976; Beentje 1990). Although protected by law, Jozani is still threatened today by agriculture encroachment, illegal cutting of poles, and hunting of pigs and duikers (Siex & Struhsaker 1999).

AGRICULTURAL AREAS

The agricultural areas (or shambas) south of Jozani Forest Reserve comprise annual and tree crops (mainly *Cocos nucifera*, *Mangifera indica* L. and *Terminalia catappa* L.). The average area of a shamba, including fallow areas, is approximately 3 ha and they are mainly used for producing crops for local consumption. These agricultural areas are very dynamic; there is great vegetative variation between areas and within areas over time. They range from those being heavily utilized by humans to those that have been fallow for several years and have a very dense shrub and herbaceous understorey.

Methods

COCONUT PLOTS

Seven plots were established to quantify the impact of red colobus on coconut crops and to assess the ecological variables that influenced this impact. Five ‘experimental’ plots were established in the home ranges of red colobus study groups (one in Jozani Forest and four in agricultural areas). Two control plots were established in agricultural areas not used by red colobus. All plots were approximately 2 ha in size and were established within a small geographical range, in order to minimize site-specific variables such as rainfall and soil type (Fig. 1).

In each plot 30 coconut trees (a total of 210 trees) were randomly selected and marked for evaluation each month, i.e. a study of repeated measures. Each month (September 1992–March 1993, inclusive) the area beneath each marked tree was cleared and the coconuts fed upon and dropped by the red colobus were collected. Nuts eaten by red colobus are very distinctive; red colobus eat only the basal one-third of an immature coconut and the remainder is discarded. Red colobus do not carry coconuts away from the source tree.

Full size, harvestable coconuts in each tree were counted each month. Because red colobus were observed only to consume immature coconuts, mature coconuts left in the tree were used as an estimate of potential harvest for the farmers.

Values for coconuts consumed and harvestable nuts for each tree were averaged over all months to determine the mean number of coconuts consumed and harvestable nuts per tree over the entire study. We used an ANOVA followed by a Tukey’s studentized range test to determine if there were differences between plots for each of the two variables (coconuts consumed by the red colobus and potential harvest for the farmer). These data (counts of coconuts) were square-root transformed before analysis to ensure that variances were independent of the means.

ECOLOGICAL VARIABLES

Red colobus consumption of coconuts and potential harvest to the farmer were also compared with the following ecological variables for each experimental plot using Spearman correlation coefficients (see Siex & Struhsaker 1999 for demographic and vegetation details). A Spearman correlation coefficient was also calculated to determine if there was a correlation between red colobus coconut consumption and potential harvest.

Red colobus use

For each of the five experimental plots, the density of red colobus in each plot was determined from group size and home range data (Table 1).

Vegetative analysis

In each of the seven plots, vegetation was sampled in contiguous plots (5 × 50 m) along line transects. Sampling was terminated when a cumulative species–area curve for the 5 × 50-m trail segments reached an asymptote. Using this criterion, between 13% and 25% of each of the seven coconut plots was sampled.

We calculated density, diversity and basal area for all red colobus food species and then for the top 10, top three and single most important food species (Table 1). Ranking of food species was based on Mturi’s (1991) study of the feeding ecology of the Zanzibar red colobus.

Table 1. Calculated values for ecological variables that may influence the effect of red colobus feeding on coconut crops

	Experimental plots					Control plots	
	NJF	SJF	FOR	KIT	JO V	UU	KIJ
Red colobus density (no. ha^{-1})	52·16	33·82	29·63	5·50	16·50	0·00	0·00
Red colobus coconut tree-1	0·47	0·41	1·04	0·06	0·09	0·00	0·00
Food species							
Density (no. ha^{-1})	318·00	425·89	445·69	502·83	183·14	1064·00	194·69
Diversity (H$'$)*	1·12	1·38	1·45	2·36	2·27	2·09	1·48
Basal area (m^2 ha-1)	7·66	7·85	13·69	11·08	6·95	3·76	2·06
Top 10 food species							
Density (no. ha^{-1})	52·00	244·71	202·85	156·51	61·05	220·00	5·34
Diversity (H$'$)*	0·77	0·42	0·68	1·48	1·45	1·11	0·69
Basal area (m^2 ha^{-1})	4·19	5·38	13·19	9·94	1·30	2·94	0·97
Top 3 food species							
Density (no. ha^{-1})	44·00	225·89	202·85	69·93	35·78	56·00	2·67
Diversity (H$'$)*	0·31	0·10	0·69	0·50	0·61	0·60	0·00
Basal area (m^2 ha^{-1})	4·17	4·91	13·19	8·45	1·10	2·67	0·97
Top food species							
Density (no. ha^{-1})	40·00	221·18	114·28	59·94	25·26	40·00	0·00
Basal area (m^2 ha^{-1})	1·73	2·08	1·22	0·19	0·09	0·05	0·00

* H$'$ = Shannon–Wiener information index.

Results

DIFFERENCES IN COCONUT CONSUMPTION AND POTENTIAL HARVEST BETWEEN PLOTS

Consumption of coconuts by the red colobus was not uniform between plots (Fig. 2). Significantly higher levels of coconuts were consumed by red colobus in one of the five experimental plots, NJF, than in the other four experimental plots (Tukey's W, $P < 0·05$).

There were also significant differences in potential harvest between plots (Fig. 3). One experimental plot, FOR (Jozani Forest), yielded a significantly lower potential harvest than all other plots (Tukey's W, $P < 0·05$). One of the two control plots, KIJ, yielded a significantly higher potential harvest than all experimental plots except JO V (Tukey's W, $P < 0·05$). However, it also yielded a significantly higher potential harvest than the other control plot, UU (Tukey's W, $P < 0·05$). The potential harvest of control plot UU was not significantly higher than any of the experimental plots except for FOR (all other plots were also significantly higher than FOR).

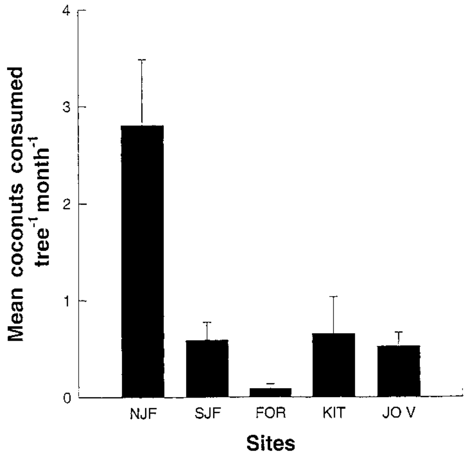

Fig. 2. Mean number of coconuts consumed by red colobus per tree per month for the five experimental plots.

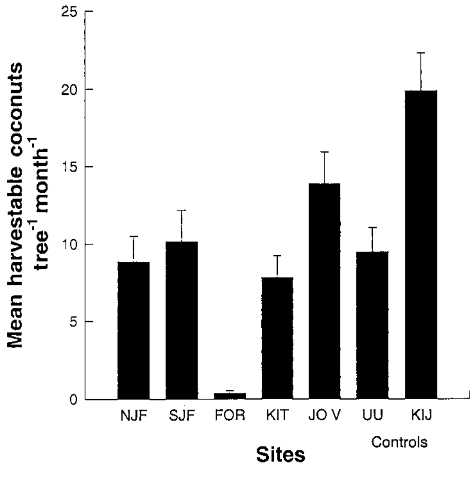

Fig. 3. Mean number of harvestable coconuts per tree per month for all seven plots.

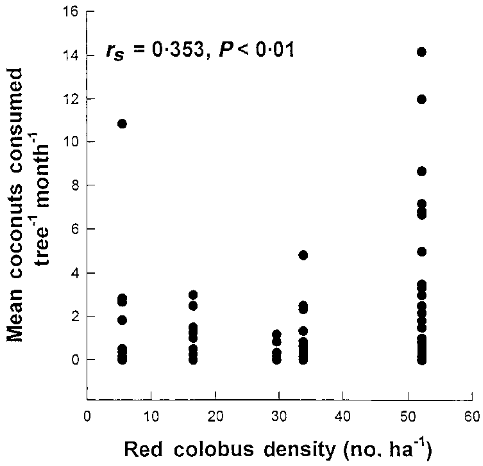

Fig. 4. Correlation between red colobus density and the mean number of coconuts consumed by red colobus per tree per month for the five experimental plots. The correlation is significant (Spearman correlation coefficient, $r_s = 0{\cdot}353$, $n = 150$, $P < 0{\cdot}01$) (linear regression, $r^2 = 0{\cdot}12$, m = 0·04, b = –0·22).

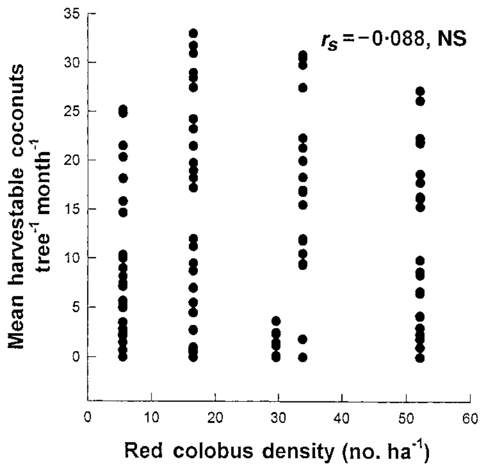

Fig. 5. Correlation between red colobus density and the mean number of harvestable coconuts per tree per month for the five experimental plots. The correlation is not significant (Spearman correlation coefficient, $r_s = -0{\cdot}088$, $n = 150$, $P > 0{\cdot}05$) (linear regression, $r^2 = 0{\cdot}008$, m = –0·03, b = 9·15).

CORRELATIONS BETWEEN DENSITY OF RED COLOBUS, COCONUT CONSUMPTION AND POTENTIAL HARVEST

As predicted, consumption of coconuts by red colobus was positively correlated with the density of red colobus in a plot (Spearman correlation coefficient, $r_s = 0{\cdot}353$, $n = 150$, $P < 0{\cdot}01$; Fig. 4). However, there was no significant correlation between potential harvest and red colobus density (Spearman correlation coefficient, $r_s = -0{\cdot}088$, $n = 150$, $P > 0{\cdot}05$; Fig. 5). There was great variation in the levels of coconut consumption and harvest between trees within a single plot (Figs 4 and 5). Although there was a significant positive correlation between red colobus density and consumption of coconuts, red colobus density was not a very strong predictor of the level of consumption. Red colobus density accounted for only 12% of the observed variation in consumption of coconuts ($r^2 = 0{\cdot}12$).

CORRELATIONS BETWEEN RED COLOBUS PER COCONUT TREE, COCONUT CONSUMPTION AND POTENTIAL HARVEST

Consumption of coconuts by red colobus was not significantly correlated with the number of colobus per coconut tree (Spearman correlation coefficient, $r_s = 0{\cdot}023$, $n = 150$, $P > 0{\cdot}05$; Fig. 6). However, potential coconut harvest was negatively correlated with the number of colobus per coconut tree (Spearman correlation coefficient, $r_s = -0{\cdot}390$, $n = 150$, $P < 0{\cdot}01$; Fig. 7). Once again, there was very high variation in the levels of consumption and harvest between trees within each plot. Because of this variation, the number of colobus per coconut tree, although significantly correlated with harvest, only accounted for 15% of the observed variation in harvest between plots ($r^2 = 0{\cdot}15$; Fig. 7).

CORRELATIONS BETWEEN ALTERNATIVE FOOD, COCONUT CONSUMPTION AND POTENTIAL HARVEST

Consumption of coconuts by red colobus was significantly negatively correlated with all measures of the

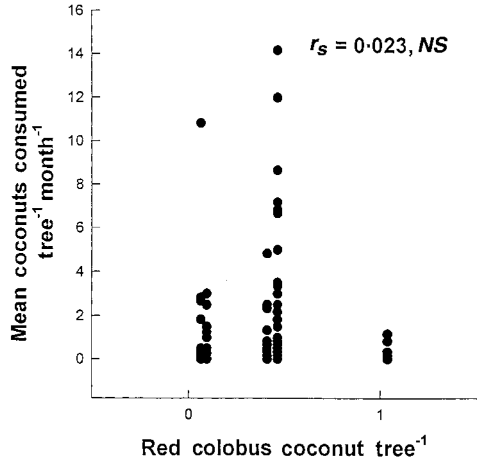

Fig. 6. Correlation between the number of red colobus coconut per tree and the mean number of coconuts consumed by red colobus per tree per month for the five experimental plots. The correlation is not significant (Spearman correlation coefficient, $r_s = 0{\cdot}023$, $n = 150$, $P > 0{\cdot}05$) (linear regression, $r^2 = 0{\cdot}001$, m = –0·33, b = 1·07).

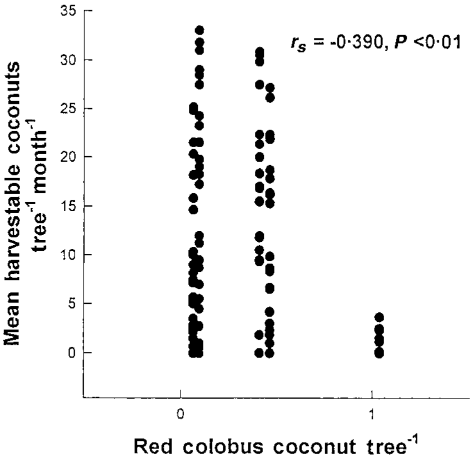

Fig. 7. Correlation between the number of red colobus per coconut tree and the mean number of harvestable coconuts per tree per month for the five experimental plots. The correlation is significant (Spearman correlation coefficient, $r_s = -0{\cdot}390$, $n = 150$, $P < 0{\cdot}01$) (linear regression, $r^2 = 0{\cdot}15$, m = –10·60, b = 12·61).

density and basal area of alternative red colobus food, and most measures of the diversity of alternative red colobus foods (Table 2). Thus, as predicted, red colobus consumed more coconuts when there was less alternative food available. However, contrary to predictions, this increased consumption did not lead to a decreased potential harvest. Potential coconut harvest was also negatively correlated with all measures of the density and basal area of alternative red colobus food, and one of three measures of the diversity of alternative red colobus foods (Table 2). In other words, both levels of consumption and production of harvestable nuts were negatively correlated with density, basal area and diversity of other red colobus plant foods, suggesting competition between these other plants and the coconut trees.

CORRELATION BETWEEN COCONUT CONSUMPTION AND POTENTIAL HARVEST

We found a significant positive correlation between consumption of coconuts by red colobus and potential harvest of coconuts (Spearman correlation coefficient, $r_s = 0{\cdot}167$, $n = 150$, $P < 0{\cdot}05$; Fig. 8). In other words, the more young coconuts that were eaten by colobus from a given tree, the higher the yield of large coconuts that were suitable for harvest from that tree. Although this correlation was significant, consumption of coconuts by the red colobus accounted for only 2·8% of the observed variation in potential harvest ($r^2 = 0{\cdot}028$).

CORRELATION BETWEEN COCONUT AVAILABILITY AND CONSUMPTION PER TREE

There was a significant correlation between the mean number of young and potentially edible coconuts available on a given tree and the mean number of young coconuts consumed from the same tree by red colobus (Spearman correlation coefficient, $r_s = 0{\cdot}262$, $n = 150$, $P < 0{\cdot}01$; Fig. 9). The availability of young coconuts was, however, a poor predictor of the number of coconuts eaten by red colobus from a particular tree, accounting for only 6·9% of the variance ($r^2 = 0{\cdot}069$).

Table 2. Spearman correlation coefficients between ecological variables and coconuts consumed by the red colobus and potential harvest for farmers

Ecological variable	Coconuts consumed by red colobus	Potential harvest for farmers
Food species		
Density (no. ha^{-1})	–0·325**	–0·271**
Diversity (H′)†	–0·353**	0·088
Basal area (m^2 ha^{-1})	–0·370**	–0·433**
Top 10 food species		
Density (no. ha^{-1})	–0·299**	–0·237**
Diversity (H′)†	–0·039	0·252**
Basal area (m^2 ha^{-1})	–0·370**	–0·433**
Top 3 food species		
Density (no. ha^{-1})	–0·185*	–0·303**
Diversity (H′)†	–0·345**	–0·227**
Basal area (m^2 ha^{-1})	–0·370**	–0·433**
Top food species		
Density (no. ha^{-1})	–0·185*	–0·303**
Basal area (m^2 ha^{-1})	–0·199*	–0·155*

*$P < 0{\cdot}05$; ** $P < 0{\cdot}01$; †H′ = Shannon–Wiener information index.

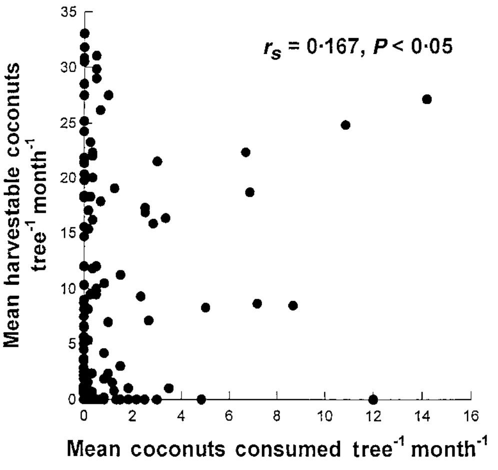

Fig. 8. Correlation between the mean number of coconuts consumed by red colobus per tree per month and the mean number of harvestable coconuts per tree per month for the five experimental plots. The correlation is significant (Spearman correlation coefficient, $r_S = 0{\cdot}167$, $n = 150$, $P < 0{\cdot}05$) (linear regression, $r^2 = 0{\cdot}028$, m = 0·71, b = 7·56).

Discussion

DIFFERENCES IN COCONUT CONSUMPTION AND POTENTIAL HARVEST BETWEEN PLOTS

Red colobus consume immature coconuts and apparently contribute in a positive way to the variance observed in potential harvest levels between plots. They do not appear to be the limiting factor in coconut harvest. We recorded large and significant differences in potential harvest between plots even in the absence of red colobus.

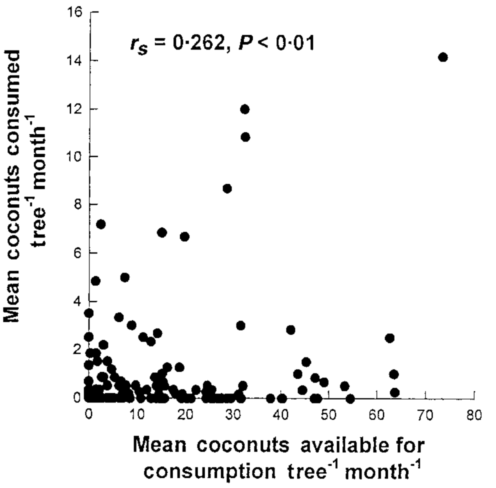

Fig. 9. Correlation between the mean number of coconuts available for consumption per tree per month and the mean number of coconuts consumed by red colobus per tree per month· The correlation is significant (Spearman correlation coefficient, $r_S = 0{\cdot}262$, $n = 150$, $P < 0{\cdot}01$) (linear regression, $r^2 = 0{\cdot}069$, m = 0.035, b = 0·45).

Studies of *C. nucifera* cultivation in Zanzibar, in the absence of red colobus, have also shown very high levels of variance in productivity between sites (Herz-Schweizer 1986; NCDP 1991). Even in research sites that were selected for their high nut yields, differences in harvest of 27·3% were found between sites (Herz-Schweizer 1986). Much of the variance in yield between sites has been attributed to husbandry practices, site-specific ecological differences, and damage done by the insect pest *Pseudotheraptus wayi* (NCDP 1991). *Pseudotheraptus wayi* infestation is one of the major problems in coconut cultivation and causes reduction in tree yield in many locations throughout Zanzibar (NCDP 1991).

During this study, only one experimental plot (FOR) had a significantly lower mean potential harvest than any of the control or other experimental plots. This plot was located in Jozani Forest Reserve; all other plots were in agricultural areas. The lower potential harvest recorded for this plot was possibly due to seasonal flooding. During the long rains, this plot was inundated for approximately 3 months (April–June, inclusive). Waterlogged soils are unsuitable for the cultivation of *C. nucifera* because coconut trees require well-drained soils (Corner 1966). The majority of coconut trees in this plot exhibited stem tapering (a narrowing of the stem), a common symptom of inadequate drainage (Ohler 1984). In contrast, none of the other plots flooded during this study. Removal of this unusual plot (FOR) from the analysis only strengthens our conclusions.

The very large harvestable crop of coconuts in one of the controls (KIJ) may be accounted for by differences in husbandry practices. This was the only plot where coconut trees were intercropped with beans. Beans are nitrogen fixers and when intercropped with coconut trees increase coconut yield (Thampan 1981; Ohler 1984).

CORRELATIONS BETWEEN RED COLOBUS DENSITY, RED COLOBUS PER COCONUT TREE, COCONUT CONSUMPTION AND POTENTIAL HARVEST

Although the consumption of young coconuts by red colobus was greatest in habitats with high densities of red colobus, this did not have a significant impact on harvestable yields (Table 3). Our conclusion that red colobus are not having a significant negative impact on yields of mature coconuts is also supported by the fact that there was no correlation between the number of red colobus per coconut tree and the number of nuts consumed. The significant negative correlation between the number of red

Table 3. Predicted correlations (if the Zanzibar red colobus are having a negative impact on coconut production) and observed correlations

	Predicted		Observed	
	Coconuts consumed (per tree)	Harvest (per tree)	Coconuts consumed (per tree)	Harvest (per tree)
Red colobus density	+	–	+	NS
Red colobus per coconut tree	+	–	NS	–
Alternative red colobus food	–	+	–	–
Coconuts consumed per tree		–		+

colobus per coconut tree and the final yield of mature nuts appears to be spurious because higher densities of colobus per tree did not result in higher levels of nut consumption per tree (Table 3). Thus, we conclude that although red colobus are consuming coconuts, their consumption does not have a significant negative impact on harvest.

CORRELATIONS BETWEEN ALTERNATIVE FOOD, COCONUT CONSUMPTION AND POTENTIAL HARVEST

In habitats where there are higher densities and basal area of alternative food resources for the red colobus, red colobus consume fewer coconuts and there is a lower yield of coconuts for the farmers (Table 3). This decrease in harvest accompanying a decrease in consumption is contrary to what would be predicted if the red colobus have a negative impact on coconut harvest.

This unpredicted correlation could be due to increased competition between trees. Higher densities and basal areas of other red colobus food species are related to higher overall tree density within a plot. With most plants, high densities lead to competition between individuals for resources and could have a negative impact on productivity. Experimental trials have found coconut tree productivity to be negatively affected by high tree densities (Thampan 1981; Ohler 1984; NCDP 1991), just as we found in all of our plots (Table 2).

CORRELATION BETWEEN COCONUT CONSUMPTION AND POTENTIAL HARVEST

We found red colobus feeding to be positively correlated with coconut tree potential harvest. We propose that this positive correlation between colobus consumption of young nuts and the yield of mature nuts is due to a pruning effect. Although we cannot reject the alternative explanation that red colobus are preferentially foraging on trees that are unusually productive, differences in productivity between trees account for less than 7% of the variance in red colobus feeding intensity. Furthermore, the existence of a pruning effect is supported by experimental data from the National Coconut Development Project (NCDP) on Zanzibar. Pruning of young coconuts is recommended by NCDP as a means of increasing the size and number of harvested nuts (J. Issa, personal communication). Contrary to farmers' perceptions, red colobus do not appear to be the limiting factor in coconut harvest. In fact, it appears that red colobus consumption of coconuts, which is restricted to small and immature nuts, actually contributes to a slight increase in the final yield to farmers.

In this study we were unable to account for nuts that were harvested by people. However, because nuts were being harvested from all plots, we believe this to be a constant. If anything this unknown harvest would bias our results by underestimating the number of harvestable coconuts. Thus, the impact of the red colobus may even be less negative than we have estimated.

Conclusions

Successful conservation of red colobus utilizing agricultural areas requires management plans that address the red colobus' use of plant species important to both the red colobus and the local human population. The first step in developing these plans is to determine if the red colobus significantly impact the yield of agricultural crops, and then to ascertain which ecological variables influence the degree of impact.

We found that red colobus consumption of coconuts was highest in habitats with higher densities of red colobus and lower availability of alternative red colobus food species. However, although red colobus were consuming immature coconuts, they did not appear to be the limiting factor in the yield of mature and harvestable nuts. There was great variation in potential harvest, not only between plots (even in the absence of red colobus) but also between trees within plots. There are obviously many factors other than red colobus use that determine the number of harvestable coconuts that each tree produces. These factors probably include, but are not limited to, soil quality, water availability, insect pests, competition between trees, and husbandry practices.

Contrary to farmers' perceptions, it appears that red colobus consumption of coconuts, which is restricted to the small and immature nuts, contributes to a slight increase in the final harvest for farmers. This is probably due to a pruning effect. These data illustrate the importance of quantifying perceived conflicts. Observed consumption of a plant part by a wildlife species does not necessarily mean that there will be a conflict with harvest for humans.

It is our impression that the number and intensity of complaints against red colobus increased after 1995 and was coincident with the arrival of foreign aid from CARE Austria. At this time CARE Austria initiated a community-based conservation project in the Jozani area. As a result of the numerous complaints, meetings were held in 1996 and 1997 at the village of Pete between CARE representatives, government officials and local residents to discuss crop raiding by the red colobus. This is perplexing because our data show that red colobus have no significant negative impact on coconut harvests and, in fact, may actually be beneficial to crop yield. Given these results, what are some of the possible explanations for the farmers' negative perceptions, attitudes and complaints about red colobus as crop raiders and our impression that these complaints have increased in recent years?

1. Although some of the complaints came from farmers who had coconut trees within our study plots and were therefore not supported by our studies, complaints from others may have had a factual basis. In other words, the impact of red colobus on coconut yields may have been greater in shambas located outside of our study plots. We think this is an unlikely explanation because there was no obvious difference between our study plots and these other areas.

2. The escalating habitat destruction by humans may have caused even greater compression of the few remaining red colobus populations into the older shambas with established tree crops. If true, this would mean that pressure on tree crops by the colobus may have actually increased since our study was completed.

3. Crops other than coconuts may be impacted significantly by red colobus, such as mangoes and breadfruit, whose leaf and floral buds are eaten by red colobus. Negative attitudes resulting from this may have been generalized to all red colobus, including those feeding on coconuts.

4. Damage caused by Sykes monkeys, such as on bananas, may have been blamed incorrectly on red colobus. This is possible because the more secretive and inconspicuous Sykes monkeys often intermingle and move together with the large and noisy groups of red colobus. From a distance, the colobus are readily seen and the Sykes readily overlooked. Any crop damage discovered following the passage of an association of these two species might be attributed incorrectly to the red colobus.

5. Farmers may have increased their complaints about red colobus because of the foreign aid for conservation in the Jozani area that began in 1995, and which has used the red colobus as one of its most important flagship species. These complaints may have been an attempt by the farmers to acquire some of this aid for their own personal benefit.

6. Similarly, farmers may also have complained as a means of receiving a greater percentage of the gate receipts from tourists who come to see the red colobus at Jozani. Most of the tourism at Jozani occurs on land leased to private individuals, but with the majority of gate receipts reverting to the central government. This has been a contentious issue that we first raised with government officials in 1992. As a result of several years of lobbying, some of these revenues are now being shared with the local community.

In the absence of a detailed and much needed sociological study, we can only speculate as to the motives underlying farmers' attitudes. Our data show, however, that any resentment by them towards red colobus because of perceived losses in coconut harvests is unwarranted unless there have been major ecological changes since our study was completed.

Finally, in making decisions about land-use management and resolving human–wildlife conflicts from a national perspective, compromises must be made between different interest groups and different levels of society, e.g. national, village and individual. In most democratic states, national interests usually prevail, at least in principle, reasoning that the interests of the majority should rule. In the case described here, several points must be considered. First, less than 2% of Zanzibar island is set aside for the conservation of the majority of species, i.e. the indigenous flora and fauna, while humans have priority of access to more than 98%. This issue illustrates the dichotomy of a biocentric vs. an anthropocentric value system. Secondly, the great majority of coconut production occurs on parts of Zanzibar where there are no red colobus. Consequently, whatever damage red colobus cause to coconuts is insignificant to the broader national interests and, apparently, of little, if any, consequence to the individual farmers either. Thirdly, the red colobus play a very important role in tourism, which is rapidly becoming Zanzibar's single most important source of foreign exchange. The red colobus attracted between 17 360 (Basha & Kitwana 1998) and 20 000 (Commission for Natural Resources 1997) tourists in 1997. Gate receipts at Jozani Forest Reserve from tourists viewing the colobus more than tripled from about $12 000 to $40 000 (Commission for Natural Resources 1997) or $63 612 (Basha & Kitwana 1998) between 1995 and 1997. This income is of national, local and individual interest in a country where annual per capita income is well below $400. Tourists, of course, spend much more throughout the island on transport, food and lodging.

With increased employment opportunities and revenue sharing, the local communities and individual farmers benefit directly from the red colobus while being able to continue with at least some, if not all, forms of agriculture.

We recommend that ongoing efforts to educate the local community about conservation in general and the red colobus in particular be expanded. Without a fundamental ethical commitment, conservation movements based largely, if not solely, on financial rewards are problematic at best. This is especially true for tourism, which is extremely sensitive to civil unrest and economic vagaries. Equally important to education is the issue of revenue sharing. This should be done in such a way as to benefit as many members of the local community as possible without attracting or facilitating immigration, which only exacerbates conservation efforts. We do not endorse plans calling for compensation for crop losses because of the problems of verification. Given the highly endangered status of the red colobus, we recommend against removal of them from areas of complaint except in the most extreme cases, and only after detailed study and only if suitable alternative habitat can be found elsewhere that has no existing populations of red colobus. Ever effort should be made to conserve them throughout their range.

Finally, the most important long-term goal for the conservation of red colobus and other wildlife and for improving human welfare on Zanzibar is the curtailment of the very rapid human population growth. This problem is due to both high intrinsic annual growth rates (3–4%) and immigration.

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