

## Relationship Between Chimpanzee (*Pan troglodytes*) Density and Large, Fleshy-Fruit Tree Density: Conservation Implications

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Conservation efforts to protect chimpanzees in their natural habitat are of the highest priority. Unfortunately, chimpanzee density is notoriously difficult to determine, making it difficult to assess potential chimpanzee conservation areas. The objective of this study was to determine whether chimpanzee density could be predicted from the density of trees that produce large, fleshy fruits. Using chimpanzee nest counts from six sites within Kibale National Park, Uganda, collected during a year-long study, a predictive trend was found between chimpanzee nest density and large, fleshy-fruit tree density. This relationship may offer a quick, reasonably reliable method of estimating potential chimpanzee densities in previously unsurveyed habitats and may be used to evaluate the suitability of possible re-introduction sites. Thus, in conjunction with other survey techniques, such as forest reconnaissance, it may provide an effective and efficient means of determining appropriate chimpanzee habitat in which to allocate conservation efforts. *Am. J. Primatol.* 51:197–203, 2000. © 2000 Wiley-Liss, Inc.

**Key words:** *Pan troglodytes*; chimpanzee nests; marked nest count; census; re-introductions

### INTRODUCTION

It is estimated that 105,000 chimpanzees inhabit equatorial Africa [Oates, 1996a]. Unfortunately these estimates are based on data from only a few surveys. In addition, chimpanzee populations are highly fragmented and overall it is uncertain which of Africa's surviving forests contain viable chimpanzee populations [Teleki, 1989]. Moreover, although chimpanzees are legally protected, they are increasingly threatened by loss of habitat due to conversion of forests into farmlands, degradation of remaining forests by logging operations, and commercial and subsistence hunting [Teleki, 1989; Marchesi et al., 1995; Chapman et al., 1999; Robinson et al., 1999].

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As human populations continue to increase and anthropogenic habitat disturbances increasingly threaten forest-dwelling primates, a variety of strategies for conserving chimpanzees should be evaluated. Habitat loss and hunting pressures are the primary threats to chimpanzee populations today; thus, protecting existing forests inhabited by chimpanzees, combined with legal protection of chimpanzees, is widely recognized as the highest conservation priority [Teleki, 1989; Oates, 1994; 1996b; Kemf & Wilson, 1997]. Another way to improve the survival chances of this endangered species is through the re-introduction of confiscated chimpanzees into their natural environment. Unfortunately, it is difficult to assess which forests represent critical areas for the allocation of scarce conservation resources, or which areas should be targeted for re-introduction programs. Assessing which habitats will best support existing or re-introduced chimpanzee populations requires information regarding the status of current chimpanzee densities and their potential food resources in these areas. However, chimpanzee density is notoriously difficult to determine [Marchesi et al., 1995; Plumptre & Reynolds, 1996]. Direct counts of groups from line transect censuses are known to underestimate chimpanzee density since apes occur at low densities, and unhabituated chimpanzees often flee before they are detected [Ghiglieri, 1984; Tutin & Fernandez, 1984; Skorupa, 1988]. Alternatively, nest counts have been used as a measure of chimpanzee density and it is widely asserted that this is the most practical and reliable method to estimate chimpanzee densities [Skorupa, 1988; Hashimoto, 1995; Plumptre & Reynolds, 1997]. However, nest counts are time consuming, requiring that censuses be conducted over a number of months. For quick surveys into unknown areas, such a time commitment is often not feasible. Moreover, parameters such as nest decay rates gathered from other sites are likely to yield inaccurate estimates due to high inter-site variation [Plumptre & Reynolds, 1996], and surveys of a short duration can be very inaccurate because chimpanzee ranging patterns vary seasonally and nests tend to be clumped in distribution [Ghiglieri, 1984; Tutin & Fernandez, 1984].

While chimpanzee populations may be influenced by factors such as disease or predation, food availability is often assumed to be the critical factor determining primate abundance [Milton, 1996; Chapman et al., 1999]. For example, several primate populations have been documented to decline with a natural reduction in their food resources [e.g., vervets in Amboseli, Kenya: Struhsaker, 1976; baboons in Amboseli, Kenya: Altmann et al., 1977; toque macaques in Sri Lanka: Dittus, 1977]. Thus, despite the fact that some primate populations may be severely impacted by hunting, in the absence of human predation, it is reasonable to assume that food resources may limit chimpanzee densities. If a positive relationship exists between food resources and chimpanzee density in non-hunted areas, this suggests that designating protection of chimpanzees and their habitats in potentially resource-rich forests will help ensure their survival.

The objective of this study was to determine whether chimpanzee nest density could be predicted by the density of tree species that produce large, fleshy fruits, a diet item on which chimpanzees rely heavily. This analysis is applicable to short-term surveys in habitats where chimpanzee diet has not been quantified, but where it is feasible to determine the fruiting characteristics of the flora. If such a relationship exists, this would allow one to predict the potential abundance of chimpanzees in different areas or assess potential chimpanzee habitat for re-introduction programs based on a one- to two-day survey of tree species found in these areas.

## METHODS

Kibale National Park is a moist-evergreen forest located in western Uganda [Struhsaker, 1975], where the mean annual rainfall is approximately 1,780 mm (1990–1998). This study was conducted at six sites distributed throughout the park (Sebatoli, Kanyawara K-30, Kanyawara K-14, Kanyawara K-15, Dura River, and Mainaro [Chapman & Chapman, 1997; Chapman et al., 1997]). The Kibale forest received National Park status in 1993. Prior to 1993, Kibale was a Forest Reserve, gazetted in 1932, with the stated goal of providing a sustained production of hardwood timber [Chapman & Chapman, 1999]. As a result, three of the study sites were selectively logged in the late 1960s. No hunting of chimpanzees has occurred in Kibale since at least the early 1960s [Struhsaker, 1975].

At each of the sites, a census route, approximately 4 km long, was established to estimate chimpanzee density. For each census, new nests were flagged perpendicular to their location along the transects, and the following were recorded: perpendicular distance from the transect to the nest, the height of the nest, the age-class of the nest, and the tree species in which the nest was located. This methodology is equivalent to the marked nest counts in which only new nests are counted [Plumptre & Reynolds, 1996]. From June 1996 to July 1997, these data were collected biweekly at K-30 (N = 26), K-15 (N = 24), K-14 (N = 23), and Dura River (N = 23), and once a month at Sebatoli (N = 14) and Mainaro (N = 10). Rebel activity prevented us from sampling at Mainaro in January, February, and April of 1997.

Chimpanzee nest density was calculated based on the total number of nests seen per km<sup>2</sup> per day. For each site the area sampled was the length times the width of the census route, times the number of days between the first and last walk of the transect. To determine the strip width, the nests were placed in perpendicular distance categories of 5 m, and the sighting distance was selected to a 50% cut-off rule. If  $X_i$  is the number of sightings in distance class  $i$  at a given site, the last distance considered was at the end of the first class such that  $X_{i+1}/X_i$  and  $X_{i+2}/X_i$  were both equal to 0.50 or less [Skorupa, 1988]. To ensure that only new nests were included in the density estimate, all the nests recorded on the first census and nests in decay states of 3 or greater (nests had started losing leaves) from the second census were excluded from the analysis. All the remaining nests had initial decay states of 1 or 2 (nests were fresh with either green or dry leaves [see Plumptre & Reynolds, 1996]).

Vegetation transects (200 m by 10 m) were established at each study site (12 transects at Kanyawara K-30, 5 at Kanyawara K-15, 9 at Kanyawara K-14, and 4 at Dura River, Mainaro, and Sebatoli [Chapman & Chapman, 1997]) producing a total sampling area of 7.6 ha. Each tree greater than 10 cm diameter at breast height (DBH) within 5 m of each side of the trail was individually marked and measured. This produced a sample of 1,173 trees at Kanyawara K-30, 244 trees at Kanyawara K-15, 1,085 trees at Kanyawara K-14, 338 trees at Dura River, 293 trees at Mainaro, and 322 trees at Sebatoli. Large, fleshy fruit tree species were defined as those producing large (>1.5 cm in length), fleshy drupes, berries, or figs, regardless of whether they were known to occur in the Kibale chimpanzee diet or not.

The relationship between chimpanzee density and large, fleshy-fruit tree density was analyzed using a linear regression (1-tailed). This analysis was used to show the quantitative strength of the relationship, although caution should be used when interpreting the results due to the limited sample size (N = 6). With this in mind, a Spearman Rank Correlation (1-tailed) was also performed.

## RESULTS

A total of 496 nests were used to determine chimpanzee nest densities for each of the six sites within Kibale National Park (Table I). The three unlogged sites (K-30, Dura, and Mainaro) have higher chimpanzee densities than the three logged sites (Sebatoli, K-14, and K-15 [see also Chapman et al., 2000]).

A total of 34 tree species were determined to produce large, fleshy fruits. Chimpanzee nest density was weakly positively related to large, fleshy-fruit tree density ( $R^2 = 0.447$ ,  $P = 0.07$ ;  $Y = 0.0168X + 0.168$ ; Fig. 1). A positive nonparametric correlation was also obtained for this relationship ( $r_s = 0.829$ ,  $P = 0.02$ ).

## DISCUSSION

The IUCN Primate Specialist Group suggests that two of the most needed actions for conserving primates are to establish the patterns of distribution of the African fauna through basic surveys and to establish protected areas [Oates, 1996a]. In light of how little is known of chimpanzee distribution [Teleki, 1989], Hall et al. [1998] advocate the use of forest reconnaissance as a cost-effective alternative to transect sampling to assess ape densities. The forest reconnaissance method entails using existing human and wildlife trails, ridge tops, and streams to record large mammal signs and to gain a broad overview of vegetation and topography. Hall et al. [1998] found that gorilla nest site encounter rates on line transects correlated strongly with encounter rates on forest reconnaissance.

Our data from Kibale indicate that relative chimpanzee densities can be predicted from information on the abundance of trees that produce large, fleshy fruits, an important component of chimpanzee diet. This approach does not require that all trees at the unsurveyed site be identified to the species level; rather, the criteria for inclusion is the production of large, fleshy fruits, a character that may be known by the local people or can be determined from general floras of the region. This may offer a quick, reasonably reliable method of estimating potential chimpanzee densities in previously unsurveyed habitats, provided there is no hunting of chimpanzees. This method would only require at most a few days to quantify the density of trees that produce large, fleshy fruits along a number of short transects placed throughout the forest. An analogous approach using identified chimpanzee food species appears to work within sites (i.e., nest density is related to food tree density within the Kibale sites), but not between them (i.e., a compilation of feeding data from 12 other sites failed to predict nest

**TABLE I. The Number of Nests, Census Area, Number of Days, and Density of Chimpanzees Calculated from Marked Nest Counts for Six Different Sites Within Kibale National Park**

Site	No. of nests	Census length (km)	Census width (m)	No. days	Density (no. nests/km <sup>2</sup> /day)
Sebatoli*	39	4.2	30	275	1.12
K-15*	21	4.0	20	322	0.82
K-14*	20	3.6	20	322	0.86
K-30	46	4.0	20	322	1.78
Dura	261	4.1	40	328	4.81
Mainaro	109	3.9	30	329	2.83

\*Sites where logging had occurred in the past.

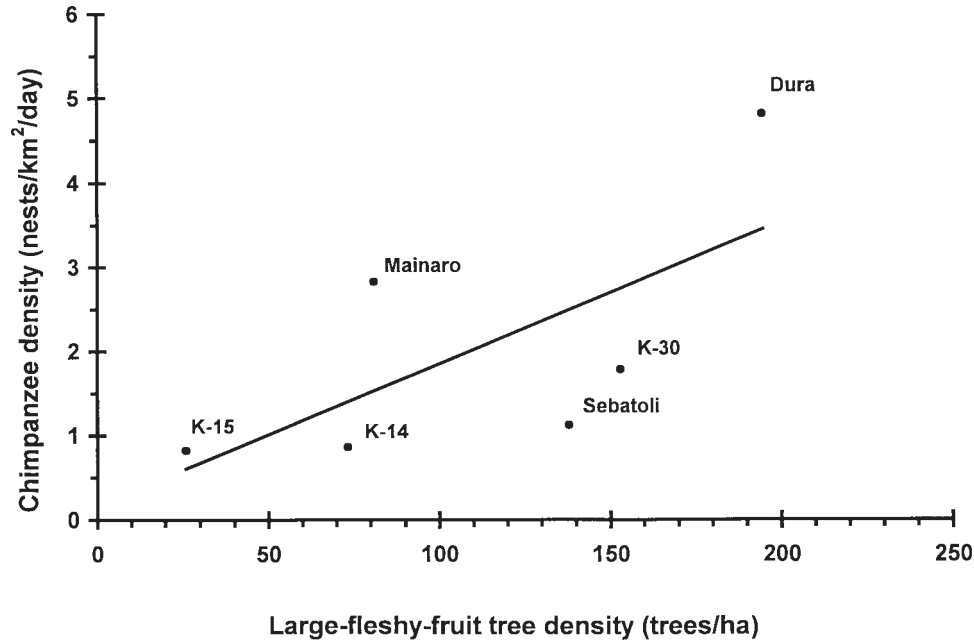


Fig. 1. Chimpanzee nest density vs. large, fleshy-fruit tree density at six sites within Kibale National Park, Uganda.

density at the Kibale sites (Wrangham, Chapman, and Balcomb, unpublished data). Thus this alternative approach is of limited use for rapid assessments of habitats.

Since our data indicate a positive relationship between chimpanzee density and large, fleshy-fruit tree density, it is likely that a combination of two techniques, the forest reconnaissance method to identify the presence or absence of chimpanzees, and quick density estimates of large, fleshy-fruit trees, may provide an effective and efficient means of determining appropriate chimpanzee habitat in which to allocate conservation efforts. Once resource-rich habitats are identified, additional, more time-intensive techniques, such as nest counts, could be conducted to determine if the actual chimpanzee density is near that predicted from the large, fleshy-fruit tree density. If the population is below what would be expected, this may indicate urgent need for conservation efforts to be allocated to these areas. However, further investigation would be necessary to determine the cause of the low chimpanzee population density before allocating conservation efforts to that area. For example, chimpanzee densities may be reduced in areas where they are hunted and therefore may not be at the density predicted from the large, fleshy-fruit tree density when surveyed. However, once legal protection of the habitat and the chimpanzees is enforced the chimpanzee density should be able to recover to that predicted by their food abundance.

The relationship between large, fleshy-fruit tree density and chimpanzee density may also serve as a method to select areas for chimpanzee re-introduction. As chimpanzee numbers continue to decline, the conservation of chimpanzees through the re-introduction of wild-born, confiscated chimpanzees may become

increasingly important [Chivers, 1991]. Determining habitat quality of the re-introduction site is an essential component of successful re-introductions [Caldecott & Kavanagh, 1983; Chivers, 1991]. In a review of chimpanzee rehabilitation projects, Hannah and McGrew [1991] report that most of the chimpanzees adapted well to the demands of their new environments, and that at least some animals were able to survive in a natural environment without provisioning. In four out of the six reviewed cases, a free-ranging, reproducing chimpanzee population became established on different islands in Tanzania, Gambia, and Liberia [Hannah & McGrew, 1991]. If the long-term goal is to establish a population of chimpanzees that can survive without provisioning or other forms of human aid, then it is important to select a site with the appropriate food availability.

Chimpanzee densities may not always be at the level predicted from their food tree density due to factors such as human and non-human predation, disease, or other forms of environmental degradation. Thus, whether one is surveying unknown habitats to select areas for protection of existing chimpanzee populations or for re-introduction of wild-born chimpanzees, additional assessment and reconnaissance in the area should be conducted to assess the impact of these other potential factors on the success of these conservation efforts. For instance, when selecting areas for reintroduction, there are a number of factors in addition to food resources that must be considered, such as the importance of release into vacant habitat to avoid disease transmission, local community response, and cascading biological change [Beck et al., 1994].

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