Environmental and anthropogenic changes in and around the Budongo Forest Reserve

Chapter · January 2012

CITATIONS
11

READS
1,096

8 authors, including:

Fred Babweteera
Makerere University
28 PUBLICATIONS **1,552** CITATIONS
SEE PROFILE

Douglas Sheil
Wageningen University & Research
509 PUBLICATIONS **25,952** CITATIONS
SEE PROFILE

Vernon Reynolds
University of Oxford
123 PUBLICATIONS **7,850** CITATIONS
SEE PROFILE

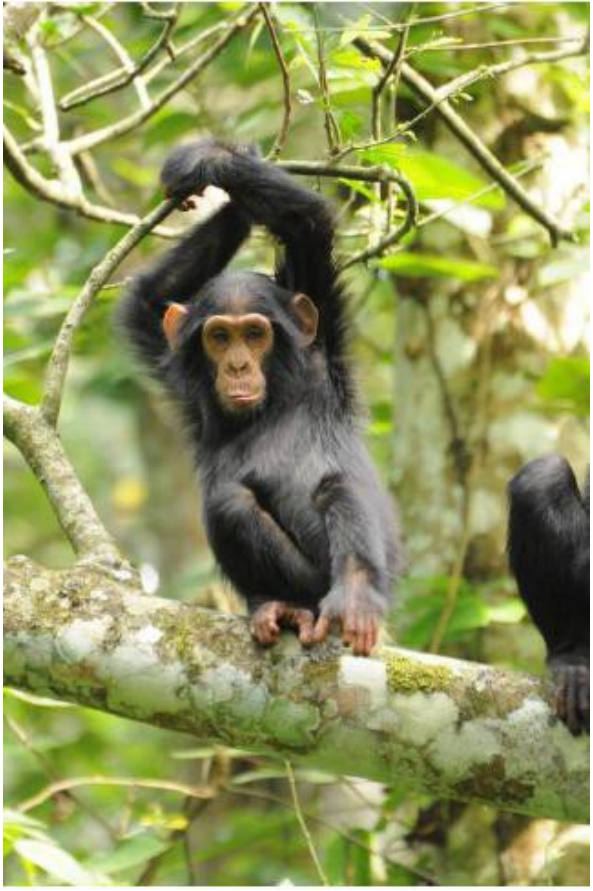
Andrew J. Plumptre
KBA Secretariat
251 PUBLICATIONS **8,748** CITATIONS
SEE PROFILE

In: The Ecological Impact of Long-Term Changes... ISBN: 978-1-61122-780-2
Editor: Andrew J. Plumptre, pp. 31-53

Chapter 3

ENVIRONMENTAL AND ANTHROPOGENIC CHANGES IN AND AROUND BUDONGO FOREST RESERVE

F. Babweteera, D. Sheil, V. Reynolds, A. J. Plumptre, K. Zuberbuhler, C. M. Hill, A. Webber and M. Tweheyo



Chimpanzees, an important seed disperser in Budongo Forest Reserve– A.Plumptre/WCS.

INTRODUCTION

Budongo Forest Reserve (BFR) is a medium altitude, moist semi-deciduous forest, covering an area of 825 km^2 of which about 50% is forest and the rest is grassland (Figure 3.1). Budongo has for a long period been the centre for studies in tropical silviculture and botanical work in the East African region (e.g. Eggeling 1947, Plumptre 1996, Sheil *et al*. 2000, Babweteera *et al*., 2000).

Budongo Forest Reserve (31^o 22' – 31^o 46' E and 1^o 37' – 2^o 03' N) was gazetted by the British Colonial Administration in the early 1930s although timber extraction started as early as 1910. Initially the logging planned to remove all old timber trees over 1.3 m DBH followed by felling smaller trees 80 years later. The ultimate aim was to create a two-stage uniform crop of trees which would be felled over a 40 year polycyclic interval. However, due to the slow recovery of valued timber of suitable sizes harvesting was changed to monocyclic felling on an 80 year rotation and the felling limit lowered to 85 cm DBH (Dawkins, 1958 and

Philip, 1965). Enrichment planting with mahoganies (*Khaya anthotheca* and *Entandrophragma* spp.) was carried out between the 1940s and 50s but was quickly abandoned after it was found that many seedlings died and that natural regeneration in logged areas was as good as that in planted areas. Later planting of saplings was started but elephants often ate and killed these. Consequently, during the 1950s and 1960s arboricide treatments were carried out on trees with low market value („weed species"), together with climber cutting, to open up the canopy and encourage the spread of mixed forest which favoured regeneration of the mahoganies. However, the treatments were stopped in the 1970s when more tree species became marketable and the cost of the arboricide became too high.

Due to political instability in Uganda between 1972 and 1985, the main logging company, Budongo Sawmill, stopped its activities during that period. After the wars it was found that pitsawing was more economical and because the Forest Department did not have the manpower to control access to the Forest, the two sawmills that tried to establish themselves could not compete. As a result all of the timber produced at present is by pitsawing. This management history has had a significant effect on the ecology of the forest. Most important was the change in forest types (Plumptre 1996) which is described in detail in the following sections. A key change to the wildlife was the deliberate hunting of elephants (*Loxodonta africana africana*) by the Uganda Forest Department in the 1950s and 1960s and the Ugandan army that led to local extinction of the species in the late 1970s, which in turn led to significant changes in forest vegetation.

Around the southern edge of the forest, land use patterns have drastically changed over the last 40 years. Data from the 2002 population census (covering the period 1991 – 2002) indicates a shift from 2.4% to 3.6% annual population growth rate for Masindi District. This is higher than the national average of 2.5% (UBOS 2007). Subsistence farming was the major land use practice prior to the refurbishment of Kinyara Sugarcane Works in the early 1990s. Kinyara Sugar Works provided employment opportunities to various immigrants fleeing conflicts in northern Uganda and southern Sudan. This coupled with the high population growth rate among the indigenous people, created a population rise in the area leading to land shortage, clearance of forests/woodlands and increased cases of illegal activities within the Budongo Forest. The immigrant communities have caused social, cultural and economic changes in the area.

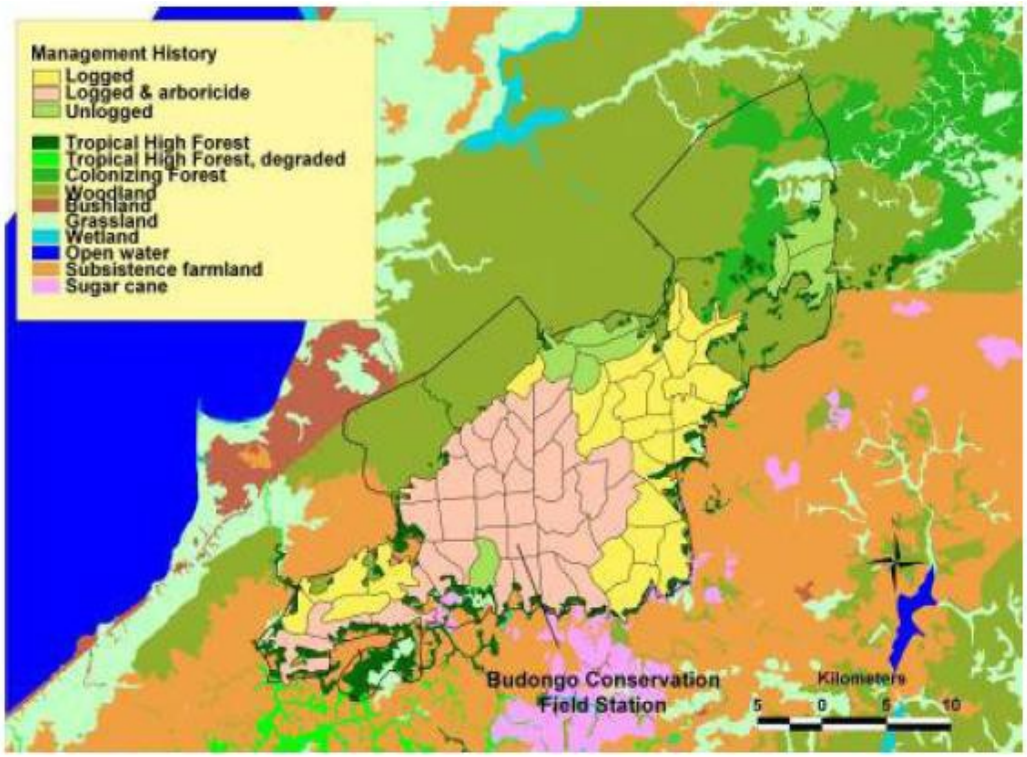


Figure 3.1. Map of Budongo Forest Reserve showing the core research area of Budongo Conservation Field Station and the management history of the different compartments in the forested parts of the reserve. The reserve boundary (outer line) is also shown indicating where the reserve includes non-forest habitat types.

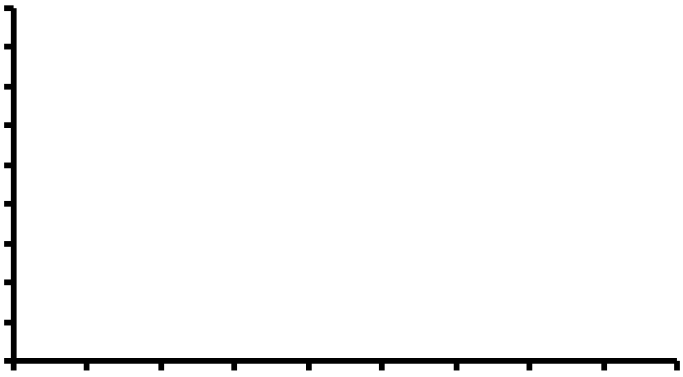
One of the major changes brought about by immigrants was the switch from subsistence agriculture with local traditional people working the land while living on their own land, to workers in a cash economy living far from their birthplaces in shacks on newly acquired land or in new villages (Lauridsen, 1999). In addition, a large area to the south of BFR has been converted to sugarcane fields thus escalating the land shortage crisis given that there is less land available for growing food crops.

CLIMATIC CHANGES

Annual rainfall in Budongo Forest Reserve averaged 1,620 mm over the past fifteen years (Figure 3.2). There was a slight increase in annual rainfall between 1992 and 1997. Longer term rainfall data for Budongo (Busingiro 1933-57 and Nyabyeya 1944-89) were examined in Sheil (1997) in which it was shown that, while rainfall is variable there have been no consistent trends over the middle decades of the twentieth century. There does seem to have been a "noisy" decline from 1960 to 1980. However, there was an increase in the number of rain days between 1992 and 2008 (Figure 3.3).

Maximum and minimum temperatures in Budongo have averaged 27.7^0C and 16.4^0C respectively. Over the sixteen year period (1993 – 2008) there was a steady decline in

minimum and maximum temperatures between 1993 and 1997 and thereafter an increase until 2008 (Figure 3.4). An analysis of 5-year average minimum temperatures revealed an increase in minimum temperatures from 15^0C in 1993 – 1997 to 16.9^0C in 2004 – 2008. However, 5-year average maximum temperatures were variable.



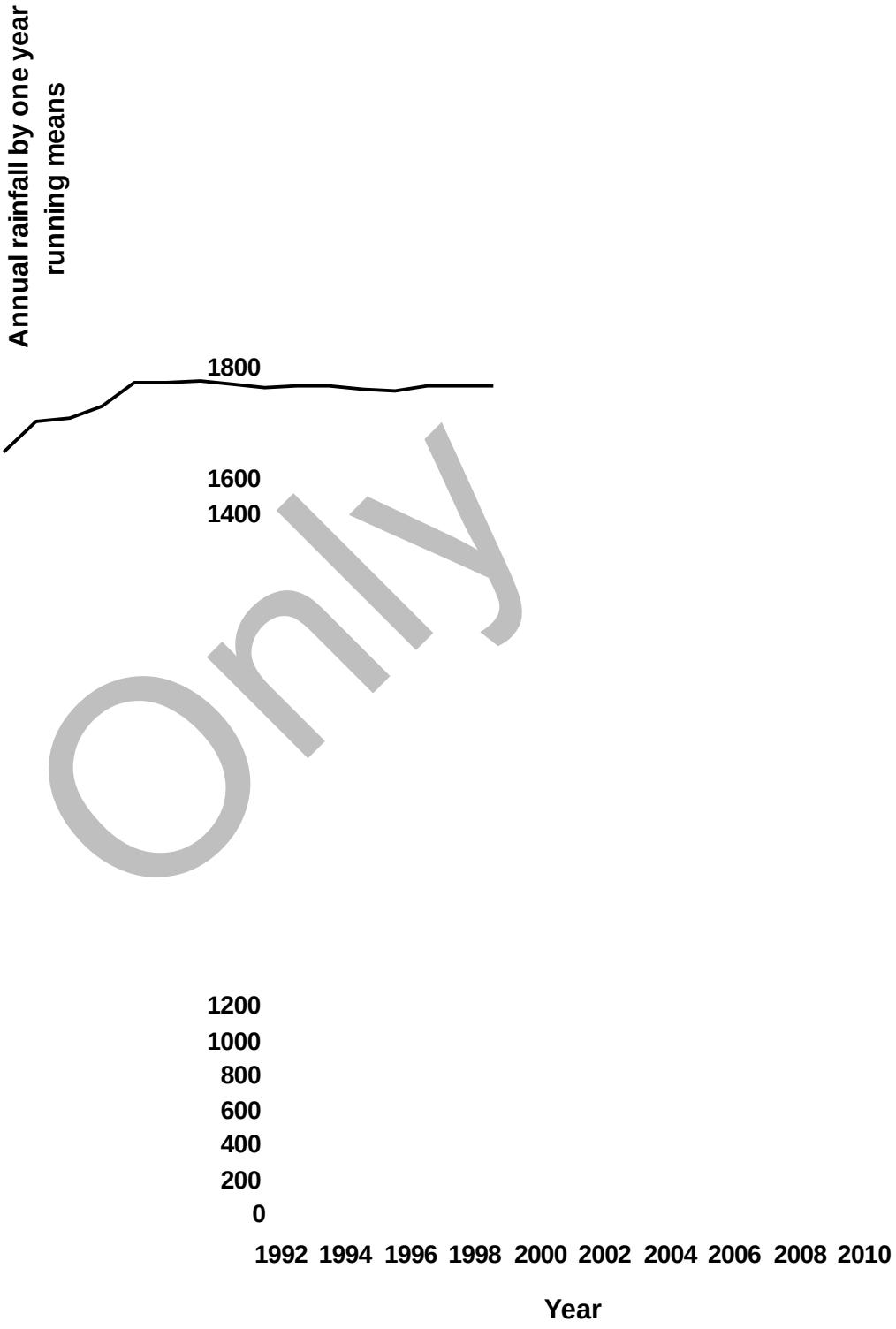
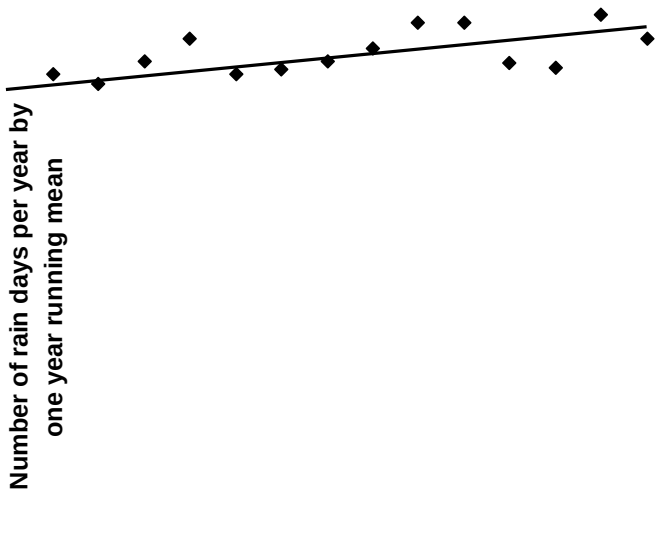


Figure 3.2. Annual rainfall recorded at the Budongo Conservation Field Station.



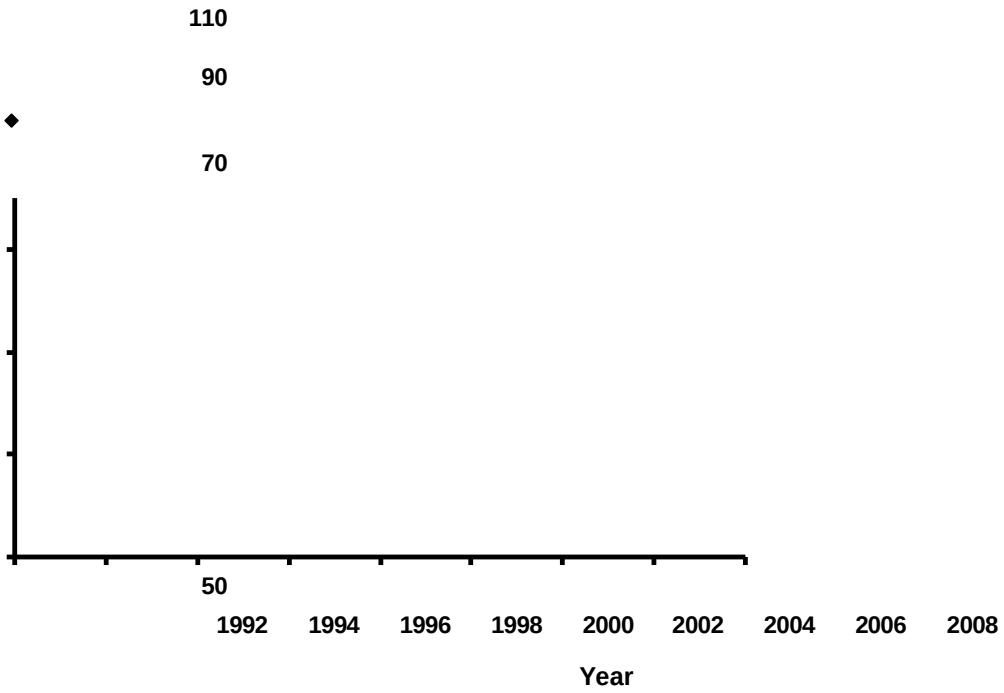
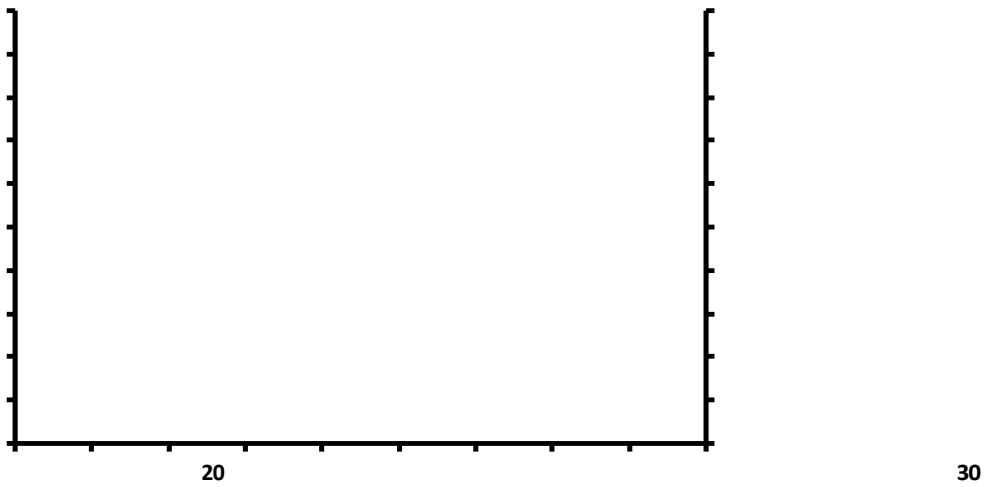


Figure 3.3. Number of rain days per year recorded at Budongo Conservation Field Station in Budongo Forest Reserve between 1993 and 2007.



Annual maximum temperature by one year running means (^{0}C)

Annual minimum temperature by one year running means (^{0}C)

19

18

17

16

15

14

29

28

27

26

25

24

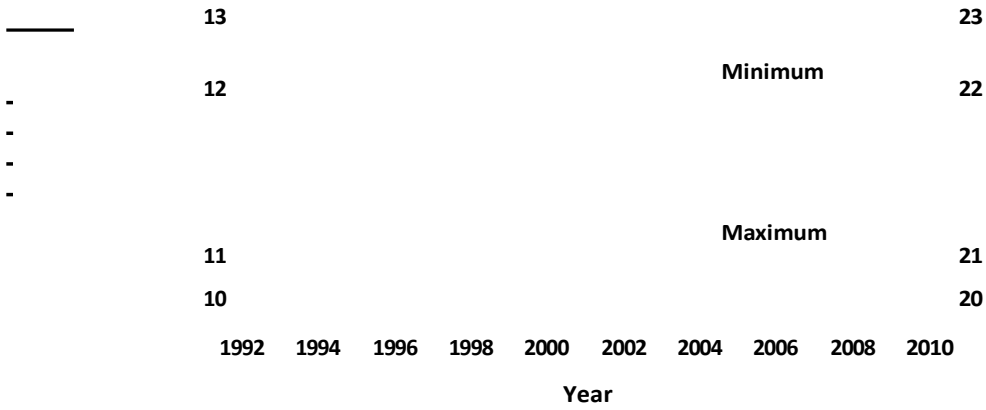


Figure 3.4. Annual minimum and maximum temperature (^{0}C) recorded at Budongo Conservation Field Station in Budongo Forest Reserve.

VEGETATION CHANGE

Expansion of Tree Cover

Ground based and aerial observations suggest that during the first half of the 20th century, and likely for many decades and even centuries before, the southern portion of Budongo was slowly expanding outwards into the grasslands. Such observations are documented in Harris 1934, Eggeling 1947 (who examined documents from 1910 and imagery from 1931, see his map 2), Sheil 1996 (see especially the analysis of imagery from 1951, 1960 and 1988 in Appendix A1). This forest expansion was blocked by roads and, in recent decades, has been

locally reversed by agricultural expansion. In addition, many of the woodlands around the forest are of relatively recent origin and likely result from changed burning practices in the surrounding landscape along with changes in land-use practices.

Effects of Silvicultural Practices on Forest Types

Comparison of aerial photographs taken in 1951 (before arboricide treatment began) and 1990 show a spread of mixed forest at the expense of the *Cynometra* forest (Plumptre 1996). In some areas this was the direct result of arboricide treatment but it also occurred in untreated areas where logging had opened up the canopy. Analysis of species composition in the different compartments indicated that the community of trees in the majority of compartments in the east of the forest differed from those in the west. Location was a better predictor of species composition than was logging history. A detailed inventory of eight compartments across the east-west gradient also showed that there were nearly twice as many

species of trees per unit area in the compartments in the west compared with the east of Budongo Forest (Plumptre 1996). From this study, two key findings are worth noting. Firstly, it is concluded that the management history of Budongo Forest did affect the distribution of forest types and expanded the mixed forest type that contained the prized timber species, such as the mahoganies. This increase in mixed forest at the expense of the *Cynometra* forest, has been beneficial for frugivorous animals including some primates (i.e. led to increased densities of fruit trees). For instance, Plumptre and Reynolds (1994) showed that the density of two monkey species, *Cercopithecus mitis* (Wolf, 1922) and *C. ascanius* (Audebert, 1799) were positively correlated with the percentage of mixed forest in a compartment. Secondly, crude measures of disturbance such as the volume of arboricide applied or volume of timber removed are not useful for predicting the species composition of the forest after logging. Instead the forest composition before logging, which varies according to geographical position in the forest, had more influence on species composition post-logging.

Monitoring Vegetation Changes Using Permanent Sample Plots

In addition to the use of aerial photographs, vegetation changes have also been monitored through permanent sample plots. The permanent plots in Budongo Forest may be the oldest surviving research plots in the humid tropics. They have played a significant role in the interpretations of forest change not just at Budongo but in general theories of tropical forest succession, stability and species diversity. W.J. Eggeling together with his colleagues established a range of vegetation sample plots during the 1930s and early 1940s in order to examine composition, productivity and natural processes of change (Sheil 2003). Eggeling eventually published an account of the plot-based work (Eggeling 1947) which asserted that the main forest types could be understood as a successional progression from *grasslands*, to a *colonising forest*, to a *mixed forest*, to the near monospecific *ironwood forest* climax of *Cynometra alexandri.* According to this view, changes in species composition were associated with stand level properties, such as a progressive increase in overall canopy height and preponderance of large buttressed stems. Crucial in terms of subsequent reference was the assertion that species richness first rose and later fell with successional status (Eggeling 1947).

Table 3.1. Plots maintained and re-measured in 1992 – 93

Plot	Vegetation in 1940	Vegetation in 1992	Arboricide interventions	Net Basal Area Loss m^2ha^{-1} (min - max estimate)
1	*Terminalia* grassland	Mixed (with *Maesopsis*)	1955, 56, 58	8 - 15
2	Colonising (with *Maesopsis*)	Mixed	1960, 64	6 - 10
5	Mixed	Mixed	1960, 64	25 - 30
6	Mixed	Mixed	1956, 58, 59	15 - 25
7	Ecotone to Ironwood	Ecotone to Ironwood	None	None

Five of the original plots have been maintained and stem diameters were re-measured in

1992-93 (Table 3.1). Stem diameters were measured at 1.3 m but buttressed, fluted or deformed stems were measured at 3m. Where multiple measurements have been taken, the highest point has commonly been used for analysis, and is known as the „diameter at reference height" (drh). For growth data by time interval the highest point measured in the consecutive periods was taken. In the 1992-93 evaluation, we measured stems using all known previous points of measurement. A full list of species including notes on their ecological guilds, characteristic height, successional status and commercial timber significance, along with a description of the major changes seen in the plots, is provided in Sheil *et al*. (2000). Further information regarding the plots and the assessment methods are available in Eggeling (1947) and Sheil (1995a; 1997; 1998), and Sheil *et al.* (2000).

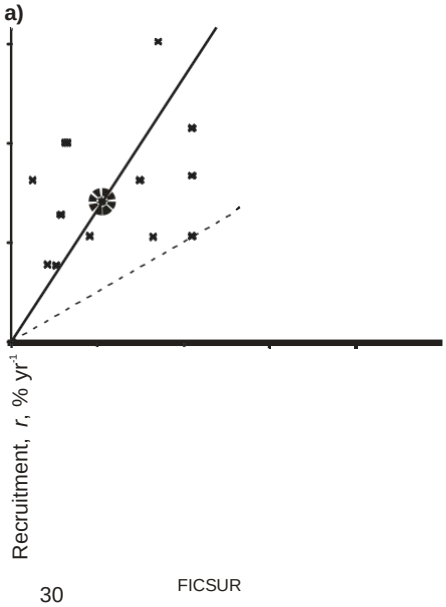
One hundred and eighty-eight tree species, including two exotics and one unnamed taxa, have been recorded from the combined data sets. This represents over 80% of Budongo"s recognised forest tree flora. The time series observations added forty species not recorded in Eggeling"s initial evaluations (Eggeling 1947). Some species (e.g. *Tetrorchidium didymostemon* (Baill.) Pax & K.Hoffm. and *Trichilia martineaui* Aubrev. & Pellegrin) have dramatically increased their representation in samples Sheil *et al.* 2000). Though possibly chance fluctuations, these species" changes appear to be part of a more general change in forest composition.

In all the plots there was high variation in mortality and recruitment rates of different species. Recruitment and mortality rates for the more common species are correlated in both of the better data sets, the „late successional" Plot 7 and the „early successional" Plot 15. This indicates a dynamic component to compositional maintenance (Figure 3.5). As total stem number is increasing, species by species recruitment rates are also generally outpacing mortality.

Despite the long history of the sample plots the data remain inadequate to fully address

certain critical phenomena. For example, the mortality rates of some species, such as *Cynometra*, appear so low that simple estimates imply they may live longer than 500 years (Sheil *et al*. 2000). The persistence of such species is hard to examine as, senescence and catastrophes aside, we can expect current adult populations to reflect climatic conditions centuries ago – and steady state models or a century of data seem of questionable relevance given known climate flux. Another important observation is the role of large trees in determining forest dynamics. For instance, it was observed that loss of only seven stems in Plot 7 contributes more than 60% of basal area mortality during the 53 year observation period (Sheil *et al*. 2000). Such change is closely linked to canopy cover and therefore to understorey illumination.

Community level tree species richness is singled out for more detailed evaluation. The unimodal pattern of species-richness in the original comparative plot-series is paralleled by a similar rise-and-fall in stem-densities, but rarefaction confirms that the unimodal pattern in richness is observed for fixed stem-counts (Table 3.2). A similar rise and fall is found with Fisher's α (Table 3.2). The proportion of species occurring in both large and small stem-size-classes increases across the series. As richness declines in later succession, low abundance species occur predominantly in larger stem-sizes (Sheil 2001). All five time-series show a rise in species richness ranging from 12 to 177 % ha^{-1} (drh ≥ 10 cm, over 50-60 years).



PILTHO

10 ALBZYG ERYABY

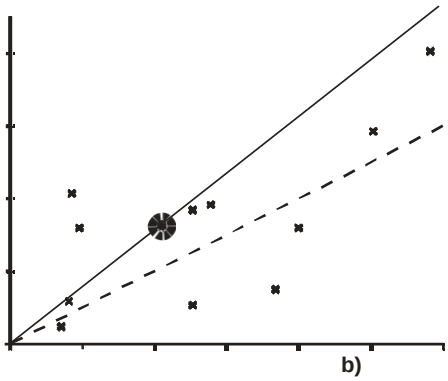
GREMOL CUSARB

ALL STEMS
ACAHOC
DICCIN

TERGLA

DOMDAW

0
0 10 20
Mortality, *m*, % yr^{-1}



b)

4

3

2

CELMIL
ALL STEMS

Plot mean
r : *m*

LASMIL

FUNELA

CHRPER

1:1

RINBEN
CELZEN

1

CELDUR KHAANT

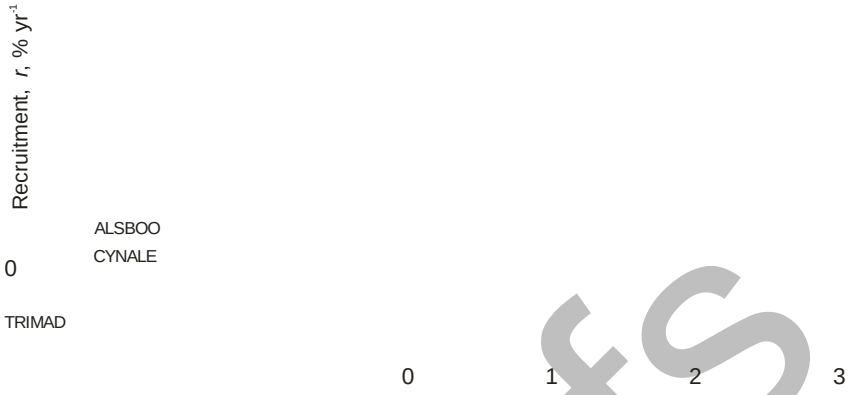


Figure 3.5. Recruitment and mortality in (a) plot 15 and (b) plot 7. Dotted line shows the overall plot mean, full line shows one-to-one equality. For plot 15 the plotted values represent annualised mortality (*m*) and recruitment (*r*) rates between 1944 and 1950 for those species with stems of 10 cm diameter and larger that provide data for both rates. There is a significant relation between the magnitude of gain and loss by species ($\tau = 0.488$, $p = 0.013$*, n = 15). For plot 7 stems are 20 cm diameter and larger and are summarised for the period 1939 to 1993, for those species that provide data for both rates. The scale on the Y axis is reduced. Species names are designated by six-letter codes provided in (Sheil *et al*. 2000) as ACAHOC = *Acacia hockii* De Wild. ALBGRA = *Albizia grandibracteata* Taub. ALBZYG = *Albizia zygia* (DC.) J.F.Macbr. ALSBOO = *Alstonia boonei* De Wild. ANNSEN = *Annona senegalensis* Pers. subsp. *senegalensis* LeThomas. CELDUR = *Celtis durandii* Engl. (Arguably = the Malagasy species *Celtis gomphophylla* Baker). CELMIL = *Celtis mildbraedii* Engl. CELZEN = *Celtis zenkeri* Engl. CHRPER = *Chrysophyllum perpulchrum* Mildbr. ex Hutch.& J.M.Dalz. COMCOL = *Combretum collinum* Fresen. subsp. *binderanum* (Kotschy) Okafor. CUSARB = *Cussonia arborea* A.Rich. CYNALE = *Cynometra alexandri* C.H.Wright. DICCIN = *Dicrostachys cinerea* (L.) Wight & Arn. subsp. *cinerea*. DOMDAW = *Dombeya dawei* Sprague. DOMKIR = *Dombeya kirkii* Mast. ERYABY = *Erythrina abyssinica* DC. subsp. *abyssinica*. FICSUR = *Ficus sur* Forssk. FUNELA = *Funtumia elastica* (Preuss) Stapf. GREMOL = *Grewia mollis* Juss. KHAANT = *Khaya anthotheca* (Welw.) C.DC. LASMIL = *Lasiodiscus mildbraedii* Engl. PILTHO = *Piliostigma thonningii* (Schumach.) Milne-Redh. RINBEN = *Rinorea beniensis* Engl. STEKUN = *Stereospermum kunthianum* Cham. TERGLA = *Terminalia glaucescens* Benth. TRIMAD = *Trilepisium madagascariense* DC.(=*Bosqueia phoberos*).

The disturbed plots achieved higher tree diversity than was encountered in even the richest dryland forest sites in the first half of the century. Contrary to expectation a rise was also recorded in the undisturbed late successional plot 7 (in 1940 c. 42 species ≥ 10 cm drh ha^{-1} rising to c. 47 in 1993). The lowest species density observed was a 1940s record of c. 10

species ≥ 10 cm diameter ha^{-1} in monodominant *Cynometra* forest and the highest record (outside of swamp) is a c. 61 ha^{-1} recorded in 1992 in Plot 15 (Table 3.2, and Sheil (2001)).

Biomass

A ground check of all five plots and a re-measurement of plot 7 (by Edward Mitchard) was undertaken in November 2008. Observations suggest that all plots, including plot 7 have suffered from illegal timber cutting. Cutting in plot 5 and 6 is especially severe with the majority of larger trees now gone and with areas of the plot dominated by thickets (DS pers. obs.). Initial evaluation of plot 7 implies that biomass is still accumulating despite the loss of two or three large trees (Edward Mitchard pers. comm. to DS 2008) and thus appears to be increasing in biomass as are many other forests across Africa (Lewis *et al*. 2009). Many of the biases that have accompanied earlier accounts of such forest change now appear to be less plausible explanations of these changes which have also been noted in the American tropics and elsewhere (Phillips and Sheil 1997, Phillips *et al*. 2002, Lewis *et al*. 2004, Sheil 1995a, Sheil 1995b). It thus appears that a global phenomenon is involved.

Exotics

Observations show that a number of exotic tree species are established in and around Budongo. *Cassia spectabilis* is found in a number of areas around the forest edges and within disturbed forest around the southern portions of the reserve. It does not pose any clear threat to well established forest cover. *Broussonetia papyrifera* is well established within the research area and is scattered over several hectares. Apparently several of the frugivorous animals, including the chimpanzees, now value this resource and make it likely that dispersal

in open areas will allow wider spread over time. However, the indigenous species appear to be recovering in areas that were once dominated by *Broussonetia papyrifera* (Babweteera personal observation). Guava trees, *Psidium* sp. have also been noted in the south of the forest (Sheil 1998). *Lantana camara* has also been observed in large openings within the forest and at the forest edges.

Determinants of Forest Change

The recent expansion of the forest (over a century and more) suggests favourable conditions that were not always present. Given the likely longevity of many species it is not clear to what extent we can expect a 'steady state' as temperatures and rainfall vary over the centuries. Such changes if influential will leave their impression on the successional procession of the forest over time – allowing some compositional imprint over the expanding

forest that can be seen in the analysis of age location and composition. It would be valuable if we could find ways to date recruitment episodes in the larger trees found in the forest. In addition, atmospheric change is a plausible explanation for some observations of changing forest dynamics across the globe (Korner 1998; Lewis 2006; Phillips and Sheil 1997; Stephenson and van Mantgem 2005). There are various other factors that may be involved for example the changing nature of solar radiation (Stanhill and Cohen; Wild *et al*. 2005). This is likely to be a major topic of future research.

Interventions within the forest, and surrounding landscape, have certainly impacted biota, influencing a myriad of ecological processes. Seed rain has certainly changed with the establishment of exotics. There is likely a general shift in seed production associated with forest harvesting, with for example an increased seed rain of pioneers and weedy species from tracks and other disturbed areas. Changes in fauna are considerable amongst the larger herbivores. Elephants were relatively common in Budongo in the past. During the 1950s the major impact of elephants on the regeneration of commercially important species led to significant investment in control measures. Since the early 1970s elephants have been more or less eliminated from the central and southern portions of the reserve. This loss means that these animals no longer have the pronounced effect they once had on understorey vegetation – such an explanation can be examined in greater depth and has been the subject of a number of investigations.

The hypothesis that it is the loss of elephants (in addition to timber harvesting and silvicultural practices) which is responsible for much of the vegetation change at Budongo has been addressed in several publications (Sheil 1998, Sheil 1996, Sheil and Ducey 2002, Sheil and Salim 2004, Laws 1970, Laws *et al*. 1975). In brief, the plot based changes; both in terms of structure (increased density of the understory vegetation) and composition (species apparently selected by and vulnerable to elephants increase in relative abundance) are as would be predicted. Alternative explanations, such as changed tree-fall gap dynamics, suggest additional patterns of change (reduced basal area, and spatially localised patterns of understorey growth) that are not corroborated by the data – though multiple factors are certainly at work. Acceptance of this „elephant loss causing change" hypothesis suggests that, as long as elephants remain absent, Budongo"s vegetation, even if it were once more free of other anthropogenic disturbance and interference, will remain distinct (denser undergrowth, different composition) from the vegetation communities seen in the early 20th century.

In reality, many environmental changes contribute to both the accumulation and erosion of diversity, at many spatial and temporal scales. Even if artefacts can be removed from the picture, site-histories, contexts, scales, long-term processes, and species-pool dynamics need greater emphasis in our understanding of landscapes, communities and species richness (Sheil 1999). Such an understanding is necessary to draw appropriate inferences – for example in recognising that under some conditions the Intermediate Disturbance Hypothesis is sufficient to predict that *degradation* of old-growth forest increases tree species richness (c.f. Sheil 1996, 1999).

Table 3.2. Summary of tree diversity and richness in Budongo's permanent plots (after

(Sheil 2003))

Plot	Area (ha)	Stems	Species	Genera	Families	Estimated[a] species-counts per ha	Rarefaction estimated[b] species per 200 stems	Fisher's Alpha[d]
Eggeling's series								
1	*1.48*	*473*	***35***	*32*	*22*	*31*	*26*	8.72
2	*1.48*	*556*	***34***	*33*	*23*	*30[c]*	*24*	7.98
3	*1.48*	*762*	***38***	*35*	*23*	*35*	*27*	8.41
4	*1.48*	*778*	***58***	*50*	*25*	*51*	*33*	14.49
5	*1.48*	*752*	***58***	*50*	*20*	*52*	*36*	14.65
6	*1.48*	*617*	***53***	*45*	*20*	*47[c]*	*36*	13.88
7	*1.48*	*699*	***49***	*40*	*23*	*42[c]*	*29*	12.00
8	*1.48*	*548*	***31***	*25*	*16*	*26[c]*	*20*	7.11
9	*1.48*	*593*	***11***	*10*	*8*	*10[c]*	*9*	1.91
10	*1.48*	*349*	***25***	*22*	*16*	*21[c]*	*19*	6.16
11 (swamp)	*1.48*	*562*	***80***	*71*	*29*	*68*	*52*	25.50
Dated observations								
2, in 1992	*1.86*	*982*	***63***	*57*	*30*	*53*	*38*	15.01
5, in 1992	*1.86*	*808*	***69***	*57*	*22*	*58*	*44*	18.04
6, in 1992	*2.12*	*846*	***70***	*58*	*24*	*57*	*44*	18.11
7, in 1976	*1.86*	*981*	***57***	*47*	*27*	*45*	*29*	13.18
7, in 1978	*1.86*	*975*	***57***	*47*	*27*	*44*	*29*	13.20
7, in 1992	*1.86*	*1090*	***60***	*49*	*28*	*47*	*29*	13.66
7, in 1993	*1.86*	*1087*	***60***	*49*	*28*	*47*	*29*	13.67
15, in 1944	*1.86*	*382*	***25***	*21*	*18*	*22[c]*	*22[c]*	5.99
15, in 1950	*1.86*	*699*	***35***	*30*	*14*	*32*	*28*	7.75
15, in 1992	*1.86*	*921*	***74***	*61*	*19*	*61*	*45*	18.95

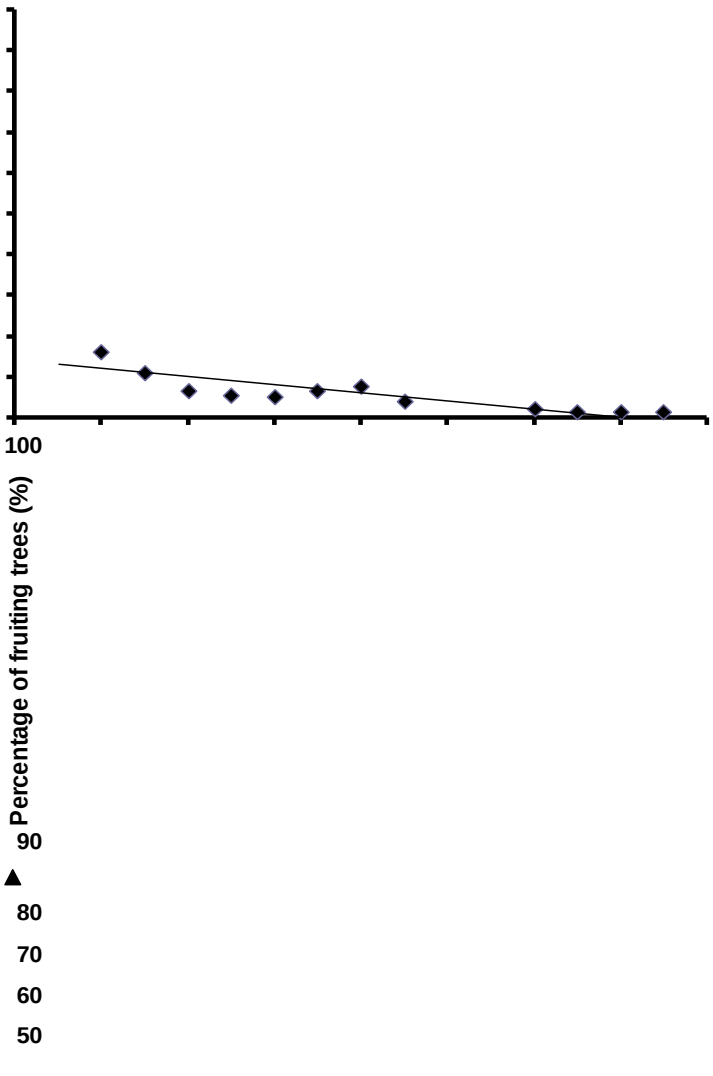
Notes:

[a] Estimated according to Hurlbert"s method (Hurlbert 1971) – but see [c].

[b] Based on Hurlbert"s method and using the stems ha^{-1} as the reference number – but see [c].

[c] In these cases the Hurlbert method cannot be applied and the estimate is provided by a „linear" interpolation of the log of species number and the log of stem numbers (see (Sheil 2001)).

[d] a widely used index of community richness that is believed robust to sample sizes (see *(Parmentier et al*. 2007)).



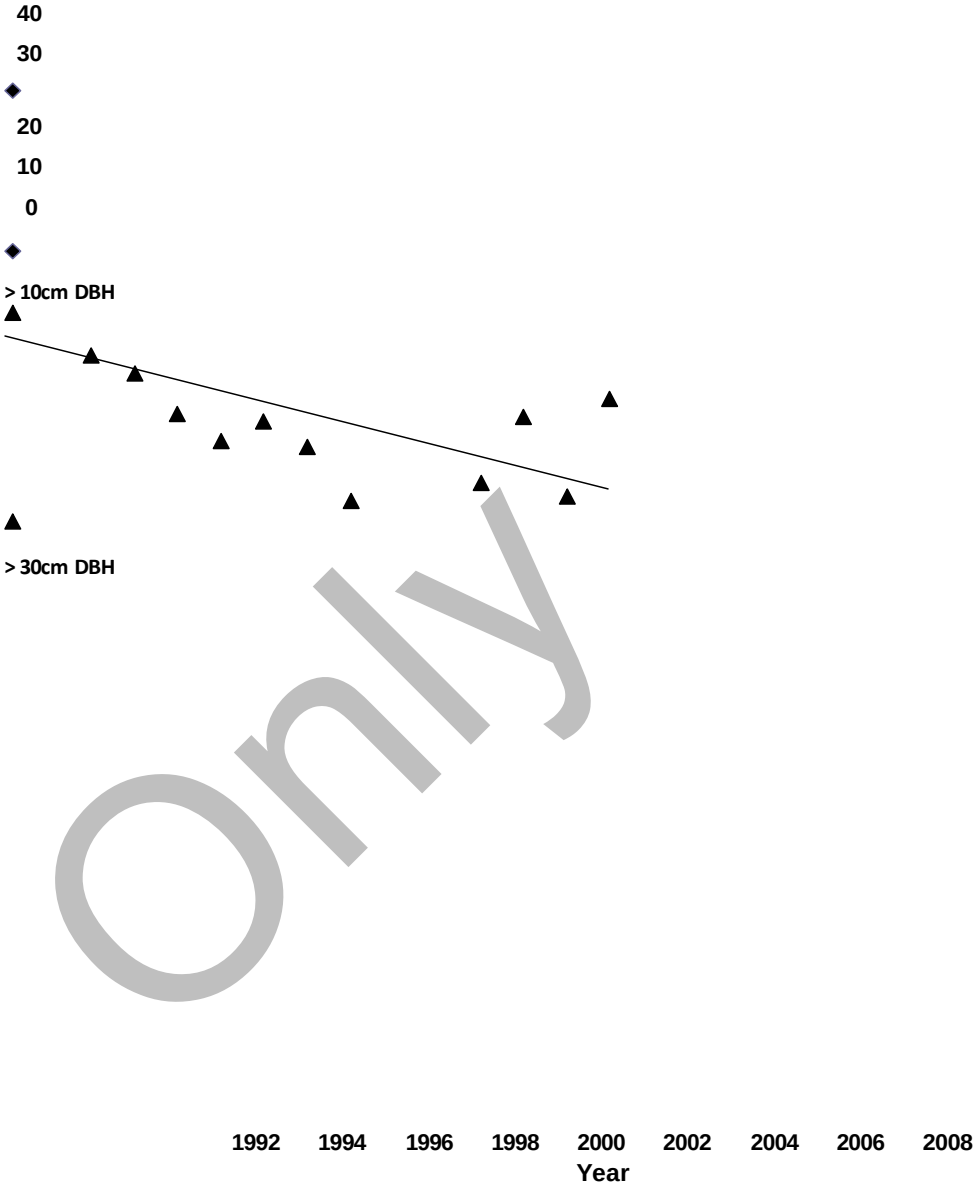


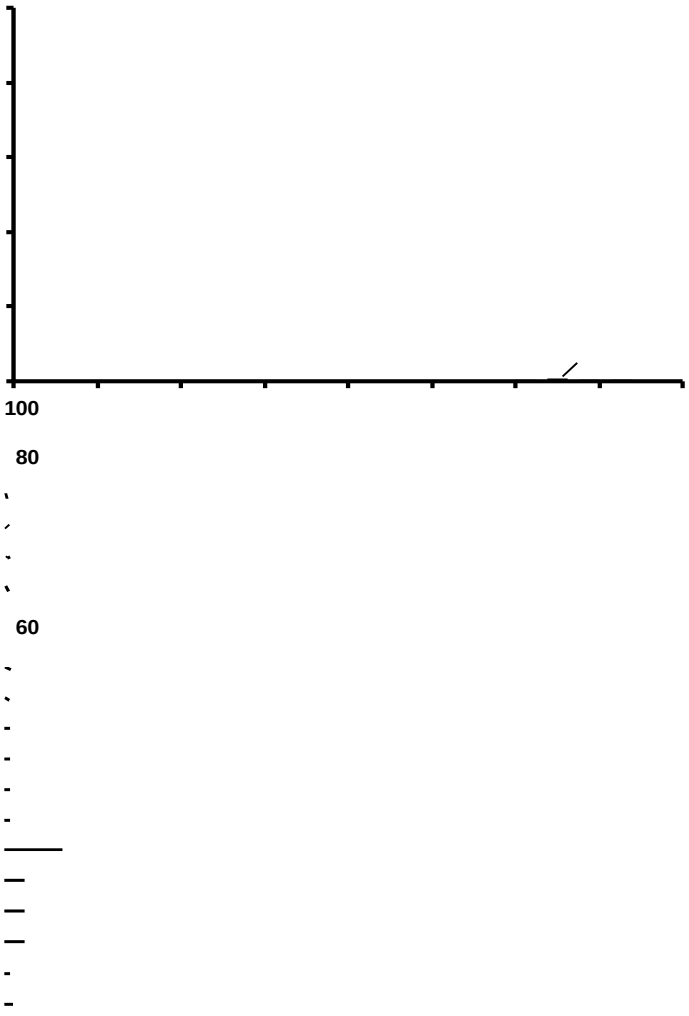
Figure 3.6. Percentage of trees observed fruiting over a 15 year period in Budongo Forest Reserve for all trees greater than 10 cm and 30 cm Diameter at Breast Height (DBH).

CHANGES IN TREE PHENOLOGY

Tree phenology has been monitored since 1993. Over 1400 individual trees (> 10cm dbh) located along ten 2-km transects in logged and unlogged compartment are monitored every month. During the monthly visits a record is made for each tree whether it is fruiting or not. The percentage of fruiting trees per year was determined. Fruiting peaks during the April – May wet season. The fruiting phenology records indicate that over the last fifteen years the proportion of fruiting trees (> 10cm dbh) has declined from 17% to less than 2% each year (Figure 3.6). However, Plumptre (1995) showed that most species of trees usually fruit once they are larger than 20-30 cm DBH (some need to reach 50-60 cm DBH) so it is probably better to confine the analysis to trees larger than 30 cm DBH. Analysis of trees > 30cm dbh also shows a reduction in number of fruiting trees (Figure 3.6).

A consideration of four tree species that fruited quite often in the early 1990s showed that all four tree species have experienced significant reduction in fruiting pattern (Figure 3.7). Moreover, the four tree species constituted up to 40% of the population of trees monitored for phenology. With the exception of *Funtumia elastica* (a wind dispersed tree species), the three other species have registered more than a 60% decline in the number of trees fruiting per annum.

Tutin and Fernandez (1993) showed that there is a significant relationship between annual minimum temperature and annual fruit production in some tropical forest trees. The changes that took place in minimum temperatures in the 1990s may have had some effect on phenology (Figure 3.4) but there could be other reasons such as changes in pollinator populations or in other environmental factors such as cloud cover. At present we don"t know what is causing this change. The observed reduction in proportion of fruiting trees is likely to have profound effects on the dynamics of the forests in relation to regeneration potential as well as increased cases of human-wildlife conflict due to reduced food availability.



40
20
Percentage of fruiting trees (%)
0
1992
1994
1996
1998
2000
2002
2004
2006
2008

Figure 3.7. Percentage of the most common trees observed fruiting per year over a 15 year period in Budongo Forest Reserve.

PRIMATE AND UNGULATE POPULATION CHANGES

Surveys of four primate species were conducted in Budongo Forest in 1992 and repeated in 1996, 2000 and 2009. The four primate species surveyed were chimpanzee *Pan troglodytes*, blue monkey *Cercopithecus mitis*, red tail monkey *Cercopithecus ascanius*, and black and white colobus monkey *Colobus guereza*. These surveys were conducted in seven compartments that were selected to represent different forest types in the Budongo Forest. Five 2-km long transects were established in each compartment. During each survey, transects were walked approximately every three weeks for 4 months. All animals encountered along the transects were recorded. Repeated walks of the transects were made to count the number of chimpanzee nests that were constructed over a determined time interval. All nests seen were marked with a ribbon and a stake below the nest with the top shaved to make it more visible. This marked nest count technique does not need a measure of nest decay rates and is more accurate (Plumptre and Reynolds, 1996). The perpendicular distance from the transect to the object being measured was taken using a range finder that could measure accurately up to 75 metres (beyond this distance objects were not recorded). Encounter rates (number of each animal recorded per kilometre walked) were calculated for all the transects. The perpendicular distance data for the transects were analysed using the computer package DISTANCE to obtain estimates of animal density with associated standard errors per km^2 (Buckland *et al*. 1993).

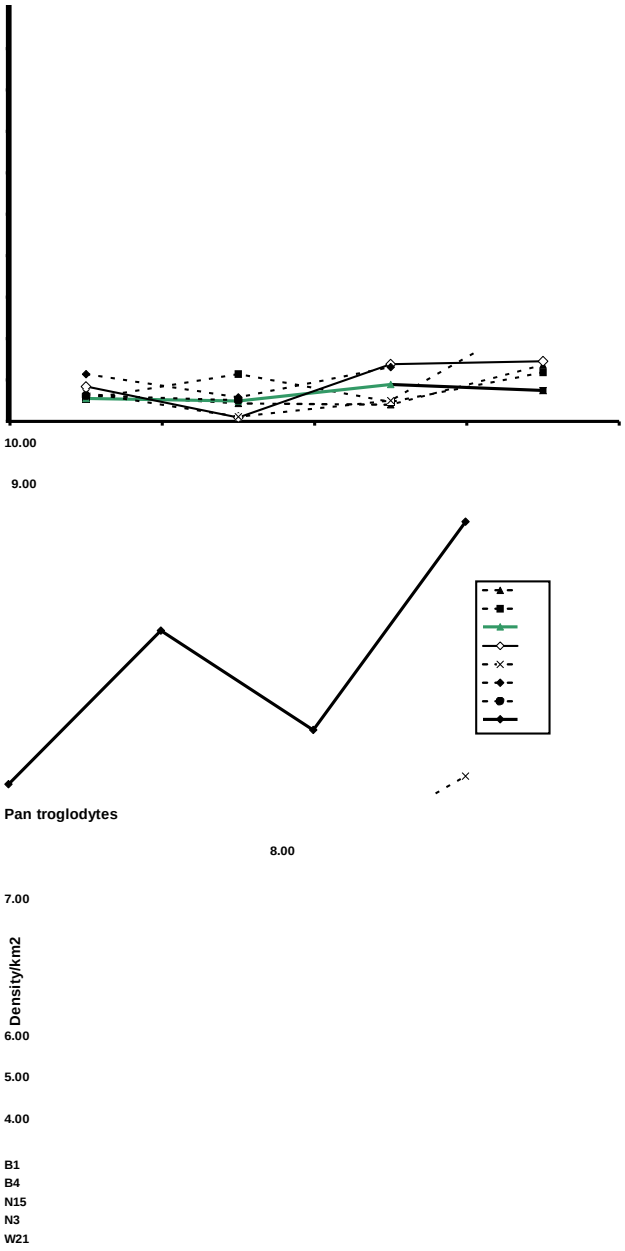
Over the seventeen year period there is no clear trend in changes in primate densities in Budongo Forest (Figure 3.8). Group densities of the monkey species remained relatively stable although in three compartments there was a significant increase in 1996. Chimpanzee density remained stable throughout the census in most compartments except Kaniyo-Pabidi (KP) where the density has increased significantly over time and in N3 where density was significantly lower in 1996 than in 1992 and 2009. The increase in KP may be linked to the habituation process of chimpanzees at this site which has increased protection of the site and

also made the chimps less fearful of human presence in the forest. In 1996 blue and redtail monkey densities increased in compartments N15, N3 and W21 but most of these were not significantly different. There are significant differences for blue monkeys between 2000 and 2009 in N3, 1996 and 2000 in W21 and 1996 and 2000 in KP where blue monkeys were not observed in 2000 and 2009. Significant increases in redtail group density occurred in N15 in

1996 compared with the other years, in N3 between 1996 and 1992 and 2009, and between 1996 and 2000 in W21. There was a significant decline in group density of colobus monkeys in N15 after 1996 and between 1996 and 2000 in N11.

Encounter rates of duikers also peaked in 1996 for many compartments and it is possible

that the increases observed may have been related to the increased fruit availability at this time (see above) compared with recent years (Figure 3.8). Where snare removal programs have been carried out (particularly in N3) there does seem to have been a stabilization of the population of duikers and in the case of blue duikers a gradual increase in encounter rates indicating that the snare removal may be influencing their populations.



N11
K4
KP

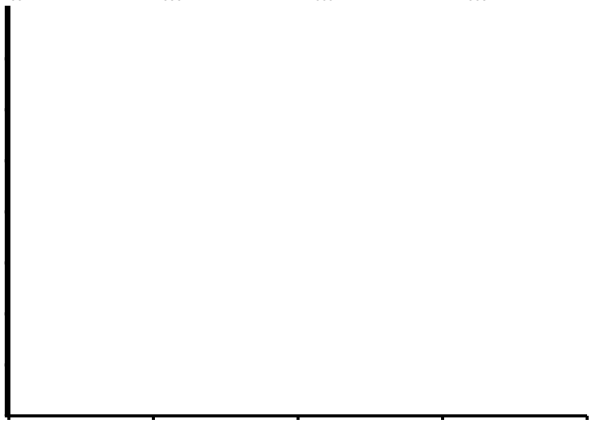
3.00

2.00

1.00

0.00

1992 1996 2000 2009

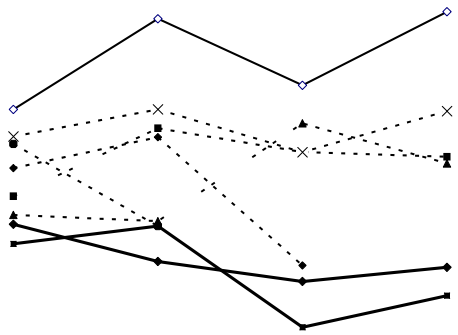


Year

16.00

Colobus guereza

14.00



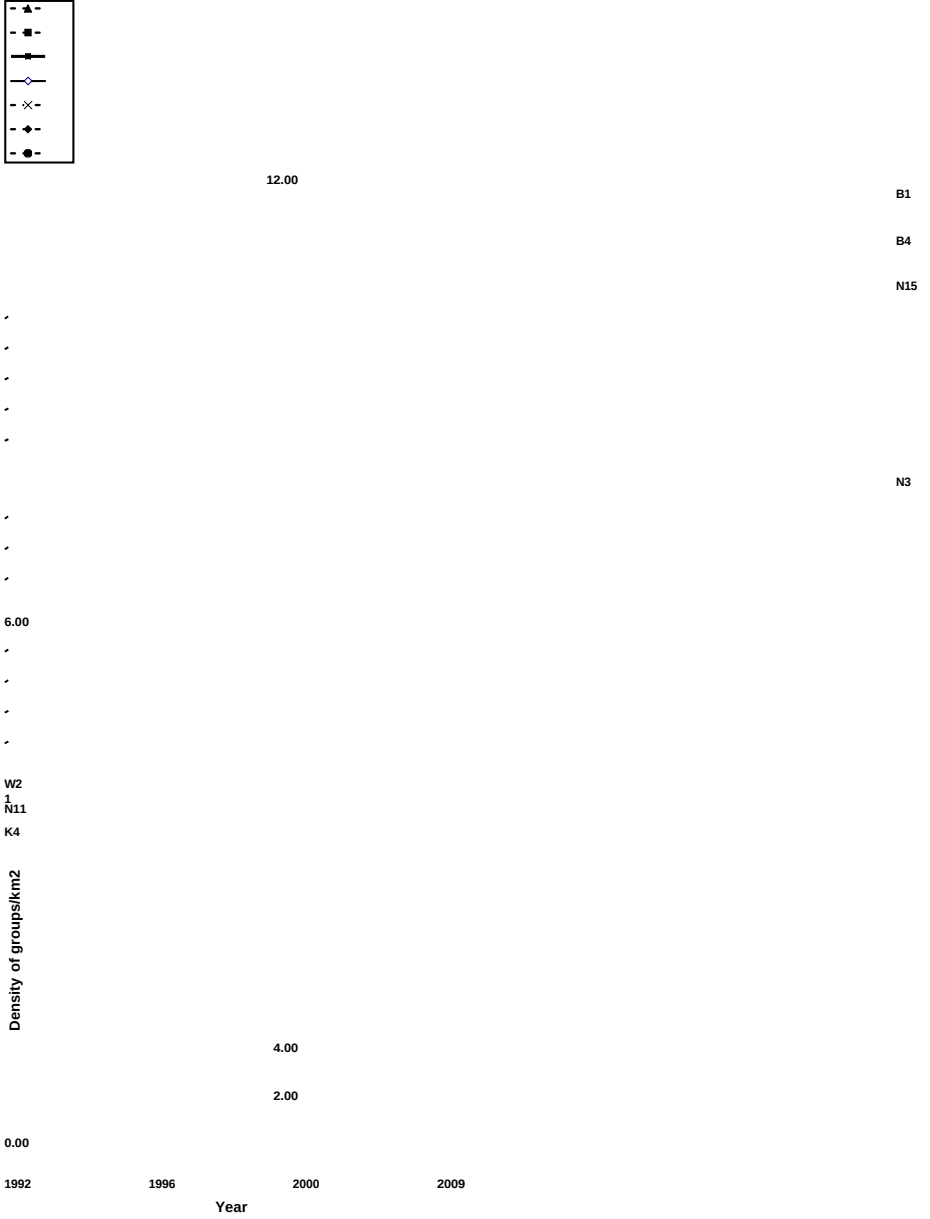
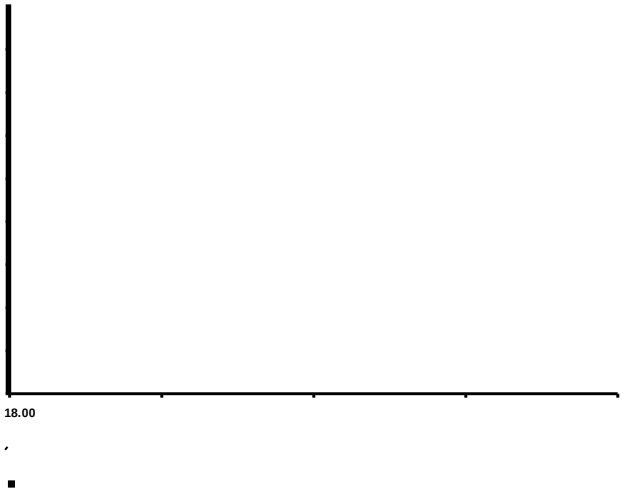
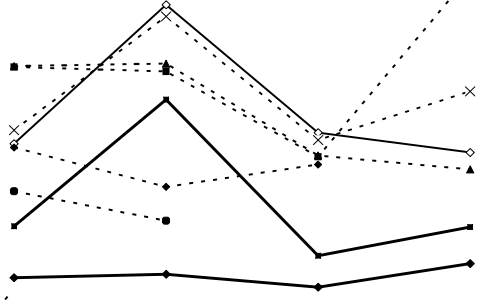
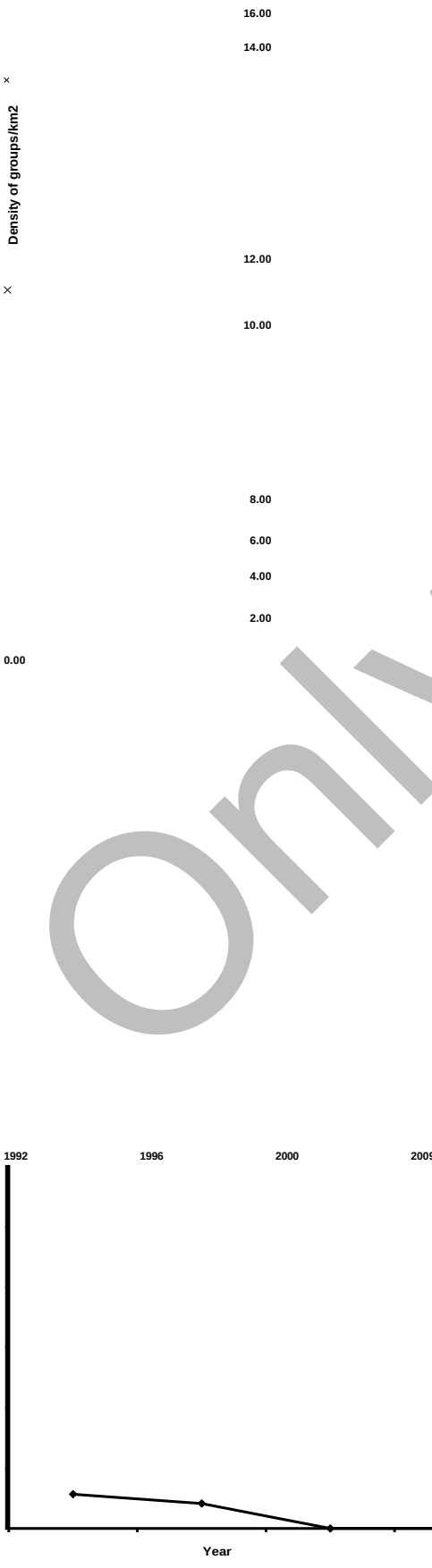


Figure 3.8. (Continued)






16.00
14.00
Density of groups/km2
12.00
10.00
8.00
6.00
4.00
2.00
0.00
B1
B4
N15
N3
W21
N11
K4
KP
1992
1996
2000
2009
Year

30.00

,

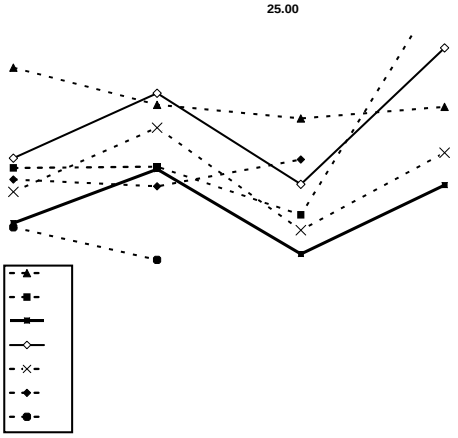
,

Cercopithecus mitis

,

,

25.00



Density of groups/km2

20.00

B1

B4

15.00

10.00

N15

N3

W2

1

N11

K4

5.00

0.00

1992 1996 2000 2009

Year

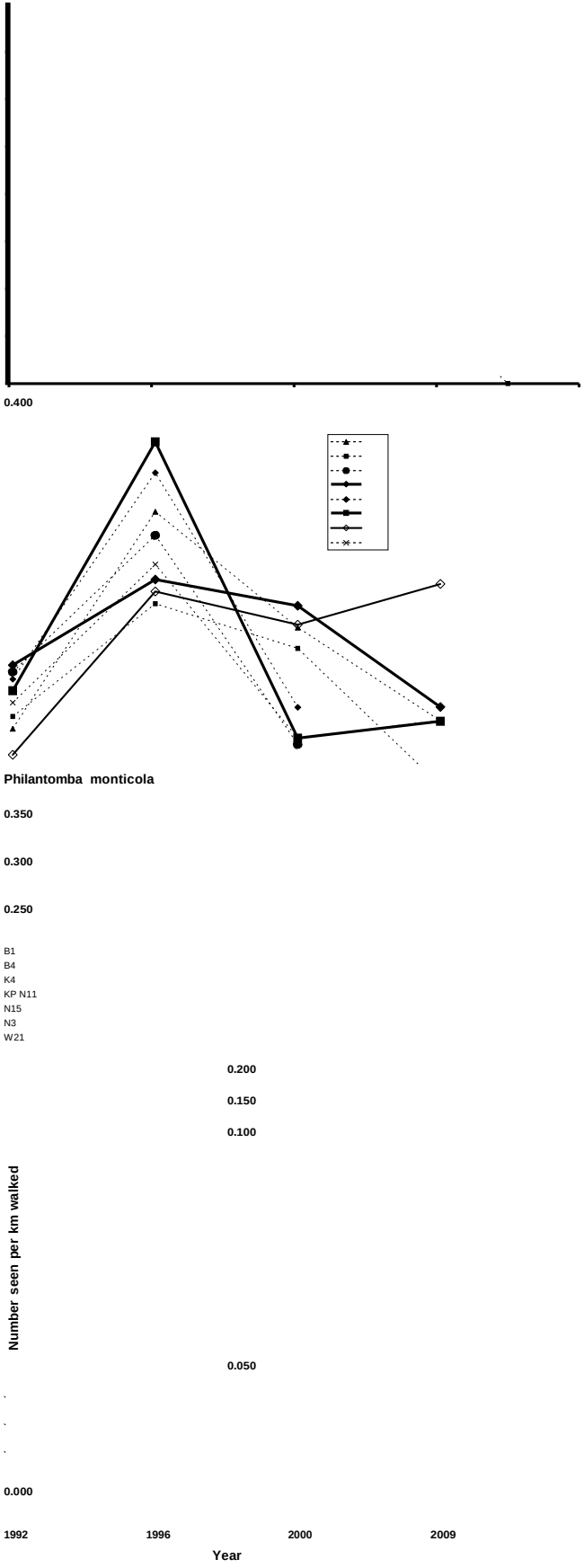
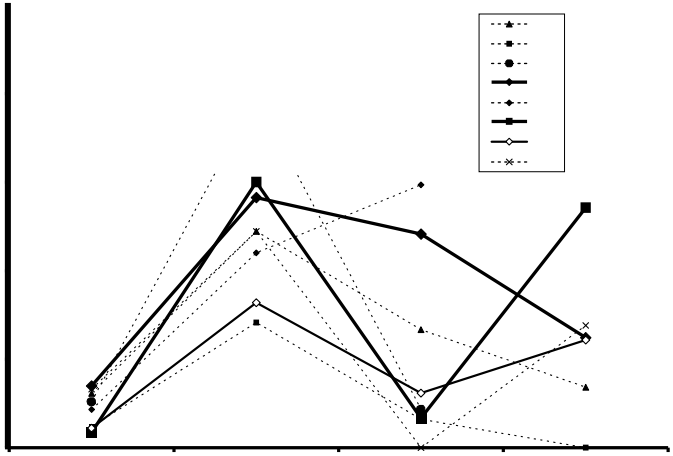


Figure 3.8. (Continued)



0.250

0.200

0.150

Cephalophus callipygus

B1
B4
K4
KP N11
N15
N3

W21

0.100

Number seen per km walked

0.050

0.000

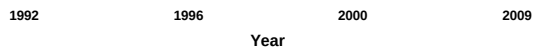


Figure 3.8. Changes in density of monkey groups and chimpanzees and changes in encounter rates per km walked of duikers in 1992,1996,2000 and 2009. Dotted lines: logged; Solid thick lines: nature reserves - unlogged; solid thin line – logged in 1953 but protected by research station over past 20 years.

LOCAL COMMUNITIES AND CONSERVATION

Demographic Patterns

According to the most recent population census in 2002, Masindi District has more than 56 different ethnic groups (UBOS, 2007). Masindi District is part of the Bunyoro Kingdom, homeland of the Banyoro, who are the numerically dominant ethnic group, comprising nearly 30% of the district‟s population. Other ethnic groups represented within the district include Alur, Acholi, Lugbara, Okebu, and Langi. This striking ethnic diversity is a consequence of repeated waves of migrants arriving in the district, including refugees and internally displaced persons. Villages around the southern edge of the BFR are similarly ethnically diverse, though in studies of human-wildlife conflict within these villages the Banyoro are often in the minority with people from the Alur and Lugbara dominating study populations. This is most likely a reflection of the fact that (i) many labour migrants arrived in the area from northern Uganda during the 1960s, recruited to work in the forestry industries locally, and (ii) the Banyoro traditionally allowed incomers to occupy land close to the forest edge, forming a buffer between Banyoro cultivated lands and wildlife known to reside in the forest (Beattie, 1960). Hill (2005) found that these northern tribes and particularly those from Congo were

reportedly more likely to hunt wild animals for meat and provided a good buffer to the Banyoro farmers to reduce crop raiding by wild animals from the forest.

Approximately 70% of the population primarily dependend on agriculture as their main source of household income (Hill, 1997; Webber 2006). Around the BFR, field holdings are in general very small, with median household landholdings of 0.7ha in 1993/94 (range 0.15-

14.58ha) (Hill, 2000), and median household landholdings in 2004 – 2005 of 0.37ha (Webber, 2006). This apparent decline in farm size during a 10 year period is certainly consistent with local claims that land is becoming scarce as a consequence of both natural population growth and immigration into the local area.

Patterns of Human-Wildlife Conflict

Locally people cultivate a range of different crops. Maize and cassava dominate food crops. Tobacco and, more recently sugar cane, are also grown as cash crops. Farmers living around BFR are exposed to varying levels of risk from forest animals; the majority experience few raids but those cultivating maize close to the forest edge without guarding measures in place are vulnerable to persistent damage. This supports previous assumptions that maize may be favoured by raiding wildlife and that farms in close proximity to animal habitat are at increased risk of crop damage (e.g. Dardaillon 1987; Naughton-Treves 1996; Hill 2000; Gillingham and Lee 2003; Weladji and Tchamba 2003; Priston 2005).

Around BFR eleven species of wild and domestic vertebrate (body weight > 2kg) have been recorded foraging or trampling on 17 different crop types. During a 13 month study wild

animals caused 62% and domestic animals 33% of all crop damage recorded (the remainder was caused by pigs but it was not possible to determine whether they were *Potamochoerus* sp. or *Sus scrofa*). Primates are responsible for forty percent of all raids. As at other sites (Else 1991; Andama and McNeilage 2003), baboons cause the most loss of any vertebrate. They damage subsistence crops (maize and cassava) and cash crops (tobacco) and are, therefore, capable of contributing to significant food shortage and economic hardship. Monkeys (*Cercopithecus aethiops sabaeus*, *C. ascanius*, *C. mitis stuhlmannii*, and *Colobus guereza*) in contrast, are responsible for low levels of damage throughout the agricultural season; although peaks of loss are associated with maize development (Webber 2006). Chimpanzees also consume human foods but their damage is responsible for less than 1% of all damage recorded around BFR (Hill 2005, Webber 2006). They have been recorded eating sugar cane, a cash crop grown in this area, but are not numerous enough to cause considerable economic loss. However, primates are not the only large vertebrates recorded to damage crops around BFR; bush pigs are responsible for a high number of raids and the second highest amount of damage for all wild species.

Farmers claim that human-wildlife conflict has increased locally over time. They link this reported increase in human-wildlife conflict with deforestation as a consequence of increased land clearance for cultivation (Tweheyo *et al.*, 2005). Empirical data, confirming or refuting claims that crop damage by wildlife is an escalating problem are not available. However, it is well documented that many factors influence farmers" perceptions of risk of crop damage by wildlife, and also their willingness, and capacity, to tolerate crop or livestock losses to wildlife. Therefore, irrespective of whether human-wildlife conflict rates are actually increasing or not, changing cultural, social and economic conditions that influence livelihood security, size of land holdings and land tenure, and access to and control over natural resources influence local perceptions of risk (Naughton-Treves, 1999; Archabald and Naughton-Treves 2001; Hill, 2004; Goldman 1996, cited in Naughton-Treves, 2005).

Developing effective and acceptable human-primate conflict mitigation tools is a priority, likely to encourage more positive views of primates, and greater tolerance of the crop damage

they cause, among local farmers. Beginning in 2001 Budongo Forest Project (BFP) piloted a live trap project within villages along the southern edge of the BFR. Live traps were installed at various points along the forest edge, and were to be managed and maintained by local committees. Using a live trap allowed for the release of endangered and/or non-pest species; species classed as vermin by the government of Uganda could be killed. Two years later work by Webber highlighted some of the reasons why this particular intervention programme was unsuccessful in the longer term. Based on data from semi-structured interviews (N = 97), focus groups (N = 7) and participant observation, the main areas of failure were (1) inadequate involvement of key stakeholders in the planning and development stages which contributed to the lack of a sense of community „ownership" of the live traps installed, (2) inadequate demonstration of value/benefit of the traps prior to farmers assuming responsibility for them, (3) lack of effective monitoring and evaluation of the traps to identify potential obstacles to their successful uptake within the local communities, and (4) the

absence of long-term funding commitment by conservation agencies (Webber *et al.*, 2007). However, whilst this intervention is not perceived locally as a successful intervention it has improved communication between wildlife authorities, research organisation and local people (Webber *et al.*, 2007), which is likely to have a positive impact on local attitudes towards wildlife and perhaps local wildlife and conservation agencies. Consequently it is important to understand any people-wildlife conflict in the context of social and cultural milieu rather than as an isolated phenomenon only linked with the economic components of people"s lives. Effective mitigation strategies must take into account how and why people view crop losses the way they do, what they expect from any interventions, and who is expected to take responsibility for the day-to-day delivery and management of such activities, as well as in the longer term.

FUTURE THREATS AND OPPORTUNITIES TO THE FOREST

In former times, before the population expansion of the last 20-30 years, the forest edge was considered unsuitable by local farmers for crop-growing because of crop-raiding by animals such as pigs and baboons, coming out of the forest, often at night. With the advent of out-growing of sugarcane, farmers became more concerned to guard their crop against raiding animals because this was now a cash crop. This process has changed the land-use pattern around the forest and is due to the revival and expansion of the Kinyara Sugar Works Ltd (KSWL). Not only is most of the area to the south of the forest now under sugarcane, but plantings of sugarcane have extended right up to the southern and south-western forest edge due to cultivation by out-growers, a process that is encouraged by KSWL.

In the 1990s, farmers started to recognize there was an increased opportunities to make money in Uganda and as a result became more focused on increasing their incomes. As a result, farmers employed armed guards to guard their crops and many crop-raiding animals, mainly baboons, were killed. This had two effects: attitudes to forest animals hardened, and it became necessary for an expanded community conservation education programme for local village people. Nevertheless, at least one case of a sugarcane guard spearing an adult male chimpanzee from the Sonso community to death is on record (O"Hara 2003), and there are probably other cases that have remained unrecorded.

Another, potentially ruinous, threat from sugarcane is a change of the use of Budongo from natural high forest to sugarcane plantation. Bush *et al*. (2004) showed that forest in Uganda contribute the equivalent of about 5% of GDP to people living around them and up to

30% of their annual income to the household. It might seem unlikely that a forest like Budongo would be converted from a hugely valuable forest, serving the local population as a catchment area for rainfall, and a source of many non-timber forest products such as poles for building and firewood, and medicines of many kinds. But we have seen in recent years an effort made to convert a large part of Mabira Forest Reserve located in central Uganda into sugarcane. Quite apart from the uses of Budongo mentioned above, the forest has the potential to earn Uganda revenue from a suitably engineered carbon trading scheme. This should be the focus of the Government˝s and the National Forestry Authority˝s efforts in years to come. With a carbon trading scheme in place, Budongo Forest Reserve could once again become one of Uganda˝s main earners of foreign currency.

In addition with the reduced commercial value of the forest, due to the illegal removal over the last 20 years of its large crop of mahogany trees, the perceived value of the forest to the country is decreasing. The National Forest Authority (NFA) examined the value of Budongo in the late 1990s, at a time when the future of the Budongo Sawmill was being decided. The conclusion reached was that the sawmill not financially viable because it needed access to a larger volume of timber. Consequently, the sawmill was closed. However, illegal logging has continued targeting other commercial timber species. This further depletes the commercial value of Budongo. With the growing demand for timber from the booming construction industry we are likely to experience an escalation in illegal timber harvesting. This pattern is almost inevitable due to inadequate capacity within NFA to deal with illegal activities coupled with limited supply of timber from the plantation sector. There is a need to quickly revamp the plantation sector to supply the much needed construction timber and reduce the pressure on the forest. The Sawlog Production scheme that has been encouraging the private sector to invest in plantations is the first project to really succeed in promoting plantations in the country.

Ecological changes also threaten the forest. The loss of major forest architects such as the elephants and also the reduction in fruiting of trees are leading to changes with unpredictable consequences for the future of the forest. There is a need to undertake more research on these changes and to continue to monitor how the forest is adapting to them.

REFERENCES

Andama, E, & McNeilage, A. (2003). Integrated Wild Vertebrate Pest Management Around Two Tropical Forest Parks in Uganda. *Integrated pest management conference Proceedings*, 8-12 September, 2002, Kampala, Uganda. Makerere University, National Agricultural Research Organization (NARO) and IPM/CRSP

Archibald, K, & Naughton-Treves, L. (2001). Tourism revenue-sharing around national parks in Western Uganda: early efforts to identify and reward local communities. *Enviro- nmental Conservation, 28,*135-149.

Babweteera, F., Plumptre, A.J., & Obua, J. (2000). Effects of gap size and age on climber abundance and diversity in the Budongo Forest Reserve, Uganda. *African Journal of Ecology, 38,* 230-237

Beattie, J. (1960). Bunyoro: An African Kingdom. In: G. Spindler & L. Spindler (Eds.). C*ase Studies in Cultural Anthropology*. Holt, Reinhart and Winston, Inc., New York.

Buckland, S.T., Anderson, D.R., Burnham, K.P., & Laake, J.L. (1993). *Distance Sampling: Estimating Abundance of Biological populations*. Chapman and Hall, London.

Bush, G, Nampindo, S., Aguti, C., & Plumptre, A. (2004). *The Value of Uganda's Forests: A livelihoods and ecosystems approach.* Wildlife Conservation Society, Albertine Rift Programme EU Forest Resources Management and Conservation Programme

Dardaillon, M. (1987). Seasonal feeding habits of the wild boar in a Mediterranean wetland, the Camargue (Southern France). *Acta Theriologica, 32,* 389-401.

Dawkins, H. C. (1958). The management of tropical high forest with special reference to Uganda. *Imperial Forestry Institute* Paper 34, University of Oxford.

Eggeling, W.J. (1947). Observations on the ecology of the Budongo rain forest, Uganda. *Journal of Ecology, 34,* 20-87.

Else, J G. (1991). Nonhuman primates as pests. In: H.O. Box (Ed.). *Primate Responses to Environmental Change.* Chapman & Hall, London. Pp: 115-165

Gillingham, S, & Lee, P.C. (2003). The impact of wildlife-related benefits on the conservation attitudes of local people around the Selous Game Reserve, Tanzania. *Environmental Conservation, 26,* 218-228.

Goldman, A. (1996). Pest and disease hazards and sustainability in African agriculture. *Experimental Agriculture, 32,* 199-211.

Harris, C.M. (1934) *Provisional Working Plan Report for the Bunyoro Forests, Uganda.* Forest Dept, Government of Uganda, Kampala.

Hill, C.M. (1997). Crop-raiding by wild vertebrates: the farmers' perspective in an agricultural community in western Uganda. *International Journal of Pest Management,*
43, 77-84.

Hill, C.M. (2000). A conflict of interest between people and baboons: crop raiding in Uganda. *International Journal of Primatology, 21,* 299-315.

Hill, C.M. (2004). Farmers' Perspectives of Conflict at the Wildlife-Agriculture Boundary: Some Lessons Learned from African Subsistence Farmers. *Human Dimensions of Wildlife, 9,* 279-286.

Hill, C.M. (2005). People, crops and primates: a conflict of interests. In: J. D. Paterson & J. Wallis (EDs.). *Commensalism and Conflict: The Human-Primate Interface*, Norman, Oklahoma: American Society of Primatologists. Pp: 40-59.

Hurlbert, S.H. (1971). The non-concept of species diversity: a critique and alternative parameters. *Ecology*, *52,* 577- 586.

Korner, C. (1998). Tropical forests in a Co-2-rich world. *Climatic Change, 39,* 297-315.

Lauridsen, M. (1999) *Workers in a forest: understanding the complexity of incorporating local people in modern management*. Unpublished M.Sc. thesis, University of Copenhagen.

Laws R.M. (1970). Elephants as Agents of Habitat and Landscape Change in East-Africa. *Oikos, 21,* 1-15.

Laws R.M., Parker I.S.C., & Johnstone R.C.B. (1975). *Elephants and their habitats: The ecology of elephants in North Bunyoro, Uganda*. Clarendon Press,Oxford, England

Lewis, S.L., Phillips, O.L., Sheil, D., Vinceti, B., Baker, T.R., Brown, S., Graham, A.W., Higuchi, N., Hilbert, D.W., Laurance, W.F., Lejoly, J., Malhi, Y., Monteagudo, A., Vargas, P.N., Sonke, B., Supardi, N., Terborgh, J.W., & Martinez, R.V. (2004). Tropical forest tree mortality, recruitment and turnover rates: calculation, interpretation and comparison when census intervals vary. *Journal of Ecology, 92,* 929-944.

Lewis, S. L. (2006). Tropical forests and the changing earth system. *Philosophical Transactions of the Royal Society B-Biological Sciences, 361,* 195-210.

Lewis, S.L., Lopez-Gonzalez, G., Sonke, B., Affum-Baffoe, K., Baker, T.R., Ojo, L.O., Phillips, O.L., Reitsma, J.M., White, L., Comiskey, J.A., Djuikouo, M.-Nl., Ewango, C.E.N., Feldpausch, T.R., Hamilton, A.C., Gloor, M., Hart, T., Hladik, A., Lloyd, J., Lovett, J.C., Makana, J.-R., Malhi, Y., Mbago, F.M., Ndangalasi, H.J., Peacock, J., Peh, K.S-H., Sheil, D., Sunderland, T., Swaine, M.D., Taplin, J., Taylor, D., Thomas, S.C., Votere, R., & Woll, H. (2009). Increasing carbon storage in intact African tropical forests. *Nature, 457*, 1003-1006.

Naughton-Treves, L. (1996). *Uneasy neighbors: wildlife and farmers around Kibale National Park, Uganda*. Unpublished PhD, University of Florida.

Naughton-Treves, L. (1999). Whose animals? A history of property rights to wildlife in Toro, Western Uganda. *Land Degradation & Development, 10*, 311-328.

Newmark, W. D, Leonard, N.L., Sarike, H.I., and Gamassa, D.M. (1993). Conservation attitudes of local people living adjacent to five protected areas in Tanzania. *Biological Conservation, 63*, 177-185.

O"Hara S.J. (2003) Anthropogenic killing of a study community chimpanzee in Budongo Forest, Uganda. *Newsletter of the Albertine Rift Conservation Society, 10*, 11.

Parmentier, I., Malhi, Y., Senterre, B., Whittaker, R.J., Alonso, A., Balinga, M.P.B., Bakayoko, A., Bongers, F., Chatelain, C., Comiskey, J.A., Cortay, R., Kamdem, M.N.D., Doucet, J.L., Gautier, L., Hawthorne, W.D., Issembe, Y.A., Kouame, F.N., Kouka, L.A., Leal, M.E., Lejoly, J., Lewis, S.L., Nusbaumer, L., Parren, M.P.E., Peh, K.S.H., Phillips, O.L., Sheil, D., Sonke, B., Sosef, M.S.M., Sunderland, T.C.H., Stropp, J., Ter Steege, H., Swaine, M.D., Tchouto, M.G.P., van Gemerden, B.S., van Valkenburg, J. & Woll, H. (2007). The odd man out? Might climate explain the lower tree alpha-diversity of African rain forests relative to Amazonian rain forests? *Journal of Ecology, 95*, 1058-1071.

Philip, M. S. (1965). *Working plan for the Budongo Central Forest Reserve. Third revision 1964-1974*. Government printer, Entebbe, Uganda.

Phillips, O., & Sheil, D. (1997). Forest turnover, diversity and CO_2. *Trends in Ecology & Evolution, 12,* 404-404.

Phillips, O.L, Malhi Y., Vinceti, B., Baker, T., Lewis, S.L., Higuchi, N., Laurance, W.F., Vargas, P.N., Martinez, R.V., Laurance, S., Ferreira, L.V., Stern, M., Brown, S., & Grace, J. (2002). Changes in growth of tropical forests: Evaluating potential biases. *Ecological Applications, 12,* 576-587.

Plumptre, A. J., & V. Reynolds. (1994). The effect of selective logging on the primate populations in the Budongo Forest Reserve, Uganda. *Journal of Applied Ecology, 31,*
631-641.

Plumptre, A.J. (1995). The importance of "seed trees" for the natural regeneration of selectively logged tropical forest. *Commonwealth Forestry Review 74,* 253-258.

Plumptre, A.J. (1996) Changes following 60 years of selective timber harvesting in the Budongo Forest Reserve, Uganda. *Forest Ecology and Management, 89,* 101-113.

Plumptre, A.J. & Reynolds, V. (1996). Censusing chimpanzees in the Budongo Forest. *International Journal of Primatology 17,* 85–89

Plumptre, A., & Cox, D. (2006). Counting primates for conservation: primate surveys in Uganda. *Primates, 47,* 65-73

Priston, N.E.C. (2005). *Crop raiding by Macaca ochreata brunnescens in Sulawesi: reality, perceptions and outcomes for conservation*. DPhil, Biological Anthropology, University of Cambridge.

Reynolds, V. (2005) *The Chimpanzees of the Budongo Forest*. Oxford University Press, Oxford.

Sheil, D. (1995a). A Critique of Permanent Plot Methods and Analysis with Examples from Budongo Forest, Uganda. *Forest Ecology and Management, 77,* 11-34.

Sheil D. (1995b). Evaluating Turnover in Tropical Forests. *Science*. *268,* 894-894.

Sheil, D. (1996). Species richness, tropical forest dynamics and sampling: Questioning cause and effect. *Oikos, 76,* 587-590.

Sheil, D. (1997). Long-term growth and rainfall in a Ugandan moist forest: seasonal rhythms and flexing stems. *Commonwealth Forestry Review, 76,* 121-127.

Sheil, D. (1998). A half century of permanent plot observation in Budongo Forest, Uganda: histories, highlights and hypotheses. In: F.Dallmeier, & J. A. Comiskey (Eds.). *Forest Biodiversity Research, Monitoring and Modeling: Conceptual background and Old World case studies* M.A.B. UNESCO, Paris. pp 399-428.

Sheil, D. (1999). Tropical forest diversity, environmental change and species augmentation: After the intermediate disturbance hypothesis. *Journal of Vegetation Science, 10,* 851-860.

Sheil, D., Jennings, S., & Savill, P. (2000). Long-term permanent plot observations of vegetation dynamics in Budongo, a Ugandan rain forest. *Journal of Tropical Ecology,*

16,
765-800.

Sheil, D. (2001). Long-term observations of rain forest succession, tree diversity and responses to disturbance. *Plant Ecology, 155,* 183-199.

Sheil, D. & Ducey, M. (2002). An extreme-value approach to detect clumping and an application to tropical forest gap-mosaic dynamics. *Journal of Tropical Ecology, 18,* 671-
686

Sheil, D. (2003). Observations of long-term change in an African rain forest. In: H. T. Steege (Ed.). *Long-Term Changes in Tropical Tree Diversity as a Result of Natural and Man Made Disturbances*: *Studies from the Guiana Shield, Africa, Borneo and Melanesia*. Tropenbos, Wageningen, Netherlands. pp 37-59.

Sheil, D. & Salim, A. (2004). Forest tree persistence, elephants, and stem scars. *Biotropica, 36,* 505-521.

Stanhill, G., & Cohen, S. (2001). Global dimming: a review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences. *Agricultural and Forest Meteorology, 107,* 255-278.

Stephenson, N. L.,& van Mantgem, P.J. (2005). Forest turnover rates follow global and regional patterns of productivity. *Ecology Letters,8,* 524-531.

Tutin, C. E. G. & Fernandez, M. (1993). Relationship between minimum temperature and fruit production in some tropical forest trees in Gabon. *Journal of Tropical Ecology, 9,* 241-248.

Tweheyo, M., Hill, C.M., and Obua, J. (2005). Patterns of crop raiding by primates around Budongo Forest Reserve, Uganda. *Wildlife Biology, 11,* 237-247.

UBOS -Uganda Bureau of Statistics (2007). 2002 *Population and Housing Census Analystical Report, Masindi District*. UBOS, Kampala

Webber, A.D., (2006). *Primate Crop Raiding in Uganda: actual and perceived risks around Budongo Forest Reserve*. Unpublished PhD Thesis, Oxford Brookes University.

Webber, A.D., Hill, C.M., & Reynolds, V. (2007). Assessing the failure of a community- based human-wildlife conflict mitigation project in Budongo Forest Reserve, Uganda. *Oryx, 41,* 177-184.

Weladji, R.B., & Tchamba, M.N. (2003). Conflict between people and protected areas within the Benoue Wildlife Conservation Area, North Cameroon. *Oryx, 34*, 72-79.

Wild, M., Gilgen, H., Roesch, A., Ohmura, A., Long, C.N., Dutton, E.G., Forgan, B., Kallis, A., Russak, V., & Tsvetkov, A. (2005). From dimming to brightening: Decadal changes in solar radiation at Earth's surface. *Science, 308*, 847-850.