Forest Cover Survey
Arabuko-Sokoke Forest,
Kenya, 2006

A Conservation Research Report

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by

A Rocha Kenya

on behalf of the
Arabuko-Sokoke Forest Research & Monitoring Working Group

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— *A Rocha Kenya Occasional Research Report #6* —

July 2007

I. INTRODUCTION

Arabuko-Sokoke Forest (ASF) is recognized as one of the world's highest conservation priorities due to its high levels of endemism and rarity of plant and animal species, and because of the current threats facing its survival. A number of studies have been conducted to date in ASF, which have included assessments of disturbances and foxrest cover (such as Kelsey & Langton 1984, Davis 1993, Wairungu *et al.* 1993, Blackett 1994, Wright 1999, Robertson & Luke 1993, Muchiri *et al.* 2001, Mbuvi *et al.* 2004 and Glenday 2005). Additionally, official reports of observed incidences of illegal activities have been brought regularly to management by the various stakeholders of the forest. Through these sources of evidence it is known that concerning levels of disturbance are still taking place in ASF. Such disturbances include logging of selected tree species such as *Brachylaena huillensis* and *Brachystegia spiciformis* for the wood carving trade and building industry. Other studies (e.g. Fanshawe 1995) have looked to use trends in the population of certain species (e.g. East Coast Akalat) as potential indicators of the condition of the forest. However, no survey has been carried out specifically and systematically to assess levels of disturbance and vegetation cover within ASF and to monitor these over time.

For this reason the ASF Research and Monitoring Group commissioned this forest cover / disturbance survey with the potential of it becoming an integral part of the regular monitoring programme of Arabuko-Sokoke Forest. The study follows the basic methodologies used in the Tanzanian Eastern Arc Forest surveys and was carried out with support funding from ICIPE.

The overall aims were to provide:

1) an overview of the status of ASF in terms of its forest cover and illegal activity such as pole and tree cutting, snaring and charcoal burning and in doing so to provide…

2) a tool for the Kenya Forest Service (KFS) and Kenya Wildlife Service (KWS) to guide their management decisions to ensure this national treasure is not lost.

The questions that we tried to answer were:

1) Is there illegal activity in ASF?
2) How much is there?
3) Where is it taking place?
4) What species are being impacted?

This report includes both cut stems and other measures of disturbance.

METHODOLOGY

Transects of 1000m x 10m (1 hectare) were used to record the intensity of the disturbance types and basic vegetation structure/cover within the forest.

Selection and location of transects (see Map 1)

A stratified random sampling approach was used. Three zones were selected namely:

a) an 'Edge' zone ('E') – a 3km-wide strip around the edge of the forest which represented the area most accessible to communities living around the periphery,
b) a 'Nature Reserve' ('N') zone – an area under specific protection and thus assumed to be least accessible to human disturbance
c) an 'Internal' zone ('I') – neither Edge nor Nature Reserve

Additionally, the three main habitat types found in ASF were taken into account when designating the transects to ensure these variations in vegetation structure were acknowledged. These were:

a) Cynometra forest and thicket ('C')
b) Brachystegia woodland ('B')
c) and Mixed forest ('M')

Transects were orientated in a north-south direction, except at the northern and southern ends of the forest as indicated on the map. This was to align them with the assumed 'contours of disturbance' where intensity of disturbance is expected to decrease with distance from the edge of the forest and the communities.

A total of 39 transects were carried out, representing 0.095% of the forest area, and were distributed across each zone as follows: 23 (59%) in the forest Edge section, 10 (26%) in the Interior and 6 (15%) in the Nature Reserve. According to habitat type, 23 (59%) occurred in Cynometra forest/thicket, 7 (18%) occurred in mixed forest and 9 (23%) in Brachystegia woodland/forest.

Due to logistical constraints, two of the transects, both in the mixed forest of the nature reserve, were only 500m in length. Any calculations below of relative levels of disturbance, or per area measures are adjusted accordingly.

The sampling intensity was calculated using the Tanzanian Eastern Arc forest protocol, i.e. where sampling intensity should be not less than 0.1%, equivalent to 1 transect per 1000 ha, with a minimum of one transect per habitat type. Thus 39 transects were the minimum number required to satisfy this requirement. The distance required between transects per zone and per habitat was calculated as **d = a/n**, (where d = distance between transects (m); a = habitat area (ha) and n = number of transects). Using this, the minimum distance between transects worked out at:

Zone:	**Cynometra**	**Brachystegia**	**Mixed**
Nature Reserve	770 m	n/a	n/a
Internal	1,088 m	n/a	n/a
Edge	1,033 m	945 m	945 m

Transects were positioned evenly across the forest, visually located by zone and habitat using a map of the forest and ArcView GIS package. GPS co-ordinates for the starting points of each transect were obtained from the map in ArcView.

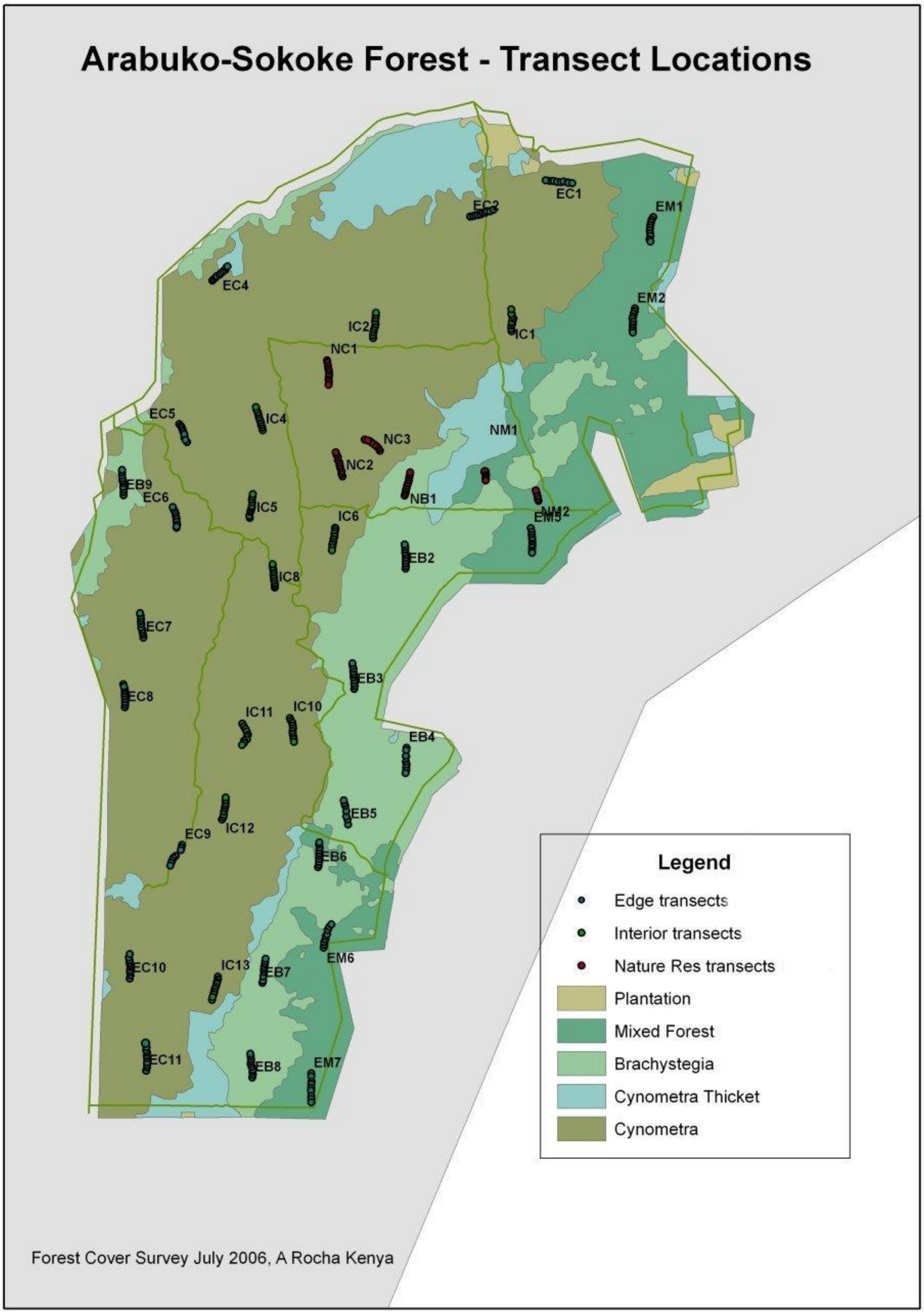
Transect Codes

Transects were assigned codes for ease of reference, derived from the zone and habitat in which they occurred. The first letter of the code describes the zone and the second the habitat type, followed by the transect number. Thus transect '2' in the 'Edge' zone in 'Cynometra' habitat would have a code 'EC2'.

PFM zones

Transects found in the three PFM areas were as follows:

1) Kakuyuni/Mijomboni section on the north-eastern boundary: EM1-2
2) Ngerenya/Chumani/Roka/Matsongoni section on the eastern and south-eastern boundary: EM5-7; EB2-8
3) Dida section on the south-western boundary: EC7-10



Map 1. *Transects sampled in Arabuko-Sokoke Forest for this study. Transects are labelled according to zone (E=Edge, I=Interior, N=Nature Reserve) then habitat (B=Brachystegia, C=Cynometra, M=Mixed Forest) and followed by the transect number. The zones are also made clear by the different font colour. A number of the transects were conducted in the opposite direction to that intended which accounts for bunching in certain areas.*

Types of data recorded

Each 50m section of transect was marked out using a 50m length of rope and a compass to give the direction. All occurrences of disturbance, both new and old, were recorded within a 5m width each side of the rope. Basic vegetation / habitat indices were also recorded at the end of every 50m section:

Every self-standing pole or tree (i.e. not lianas or creepers) above 5cm diameter at breast height (dbh) was recorded within a distance of 5m from the mid transect line. Each was recorded as one of three categories: live, cut or naturally fallen. Within the live category a distinction was made between:

- poles (5≥15cm dbh),
- trees (15≥50cm dbh and ≥3m in height) or
- large trees (dbh ≥50cm and ≥3m in height).

Additionally, 'trees' and 'large trees' were recorded as

- 'timber' (those with straight trunks) or
- 'non-timber' (those with twisted stems unsuitable for use as timber).

For cut trees and large trees, an age since cutting was estimated as either

- 'freshly cut' - for those cut within three months prior to the sampling date, or
- 'medium cut' - for those cut between 3-12 months prior to sampling, or
- 'old cut' - for those cut more than one year before.

For analysis however, 'freshly' and 'medium' cut were combined and called 'new cut', i.e. stems that were cut <1 yr prior to the sampling date. Species names for cut stems were meant to have been recorded in order to document species being targeted for cutting. However, this was not done and should be incorporated in the next survey.

Other types of disturbance were recorded along the 50m sections as either: animal remains (A), charcoal burning (B), cultivation (C), fire damage (F), campsite (K), disturbance noise (chopping or sound of voices) (N), pit sawing (P), root removal (R), snares, traps or pitfalls (S), tracks/paths (T), already cut timber/planks/poles (W), or other if none of the above (O). Details of these were recoded in the samplers' notebooks.

Additional vegetation data were collected every 100m, namely

a) an estimate of canopy height
b) vegetation density by means of the chequerboard method, whereby the number of visible squares were counted on a board of 5x5 squares from a distance of 5m at a height of 1.5m above the ground
c) an estimate of canopy cover.

A regeneration plot of 2x2m was sampled every 100m where seedlings > 50cm height were identified to species level as far as possible.

Field team

The work was carried out by two teams representing all key institutions, namely Forest Department (now KFS), Kenya Wildlife Service (KWS), Arabuko-Sokoke Forest Guides Association (ASFGA), Kenya Forest Research Institute (KEFRI) and Forest Adjacent Dwellers Association (FADA; community volunteers) through NatureKenya (NK). The project design, training and reporting was undertaken by A Rocha Kenya. Two teams of three to five were selected to undertake the survey, though some turnover of team members did occur over the sampling period. Funding to cover basic field costs was provided by ICIPE through Dr. Ian Gordon. Forest Department provided use of a vehicle for the majority of the sampling period and KEFRI for the first four to five days.

The work was carried out by two teams who were dropped by vehicle at the nearest point to a driving track. Data sheets (see Appendix 1) were produced to be completed by fieldworkers at the end of each day and notebooks were used to record further information. The data collected represent a significant effort on behalf of the field team, for whom it was an extremely difficult task given the dense, thicket-like nature of most of the forest habitat.

Duration

The fieldwork was conducted during June and July 2006.

RESULTS

In order to answer the principal questions regarding the whereabouts of any illegal activity in the forest, data for the number of cut stems and the occurrence of other disturbances were analysed according to the three zones identified. The same data is later analysed to see whether disturbance varies across the three habitat types.

COMPARISON BETWEEN ZONES

Relative abundance of live, naturally dead and cut poles / timbers / large timbers (RA)

This first measure gives an initial impression of the distribution of all cut and live stems in the forest. It takes into account the number of individuals of one category (live, naturally dead or cut) relative to the total number of individuals from all categories recorded in an area, using the formula:

$$\% RA = (ni / N) \times 100$$

Where:

RA is the relative abundance of a category,
ni / N is the proportional abundance of 50m sections containing a category of stems,
ni is the number of 50m sections containing that category of stem and
N is the total number of 50m sections along all transects of that zone.

The graph below does not show the category of live poles however, as they were far more numerous than any other class and would otherwise mask the trends of the other categories. This category alone accounted for 56% of the relative abundance in the Edge, 62% in the Interior and 75% in the Nature Reserve.

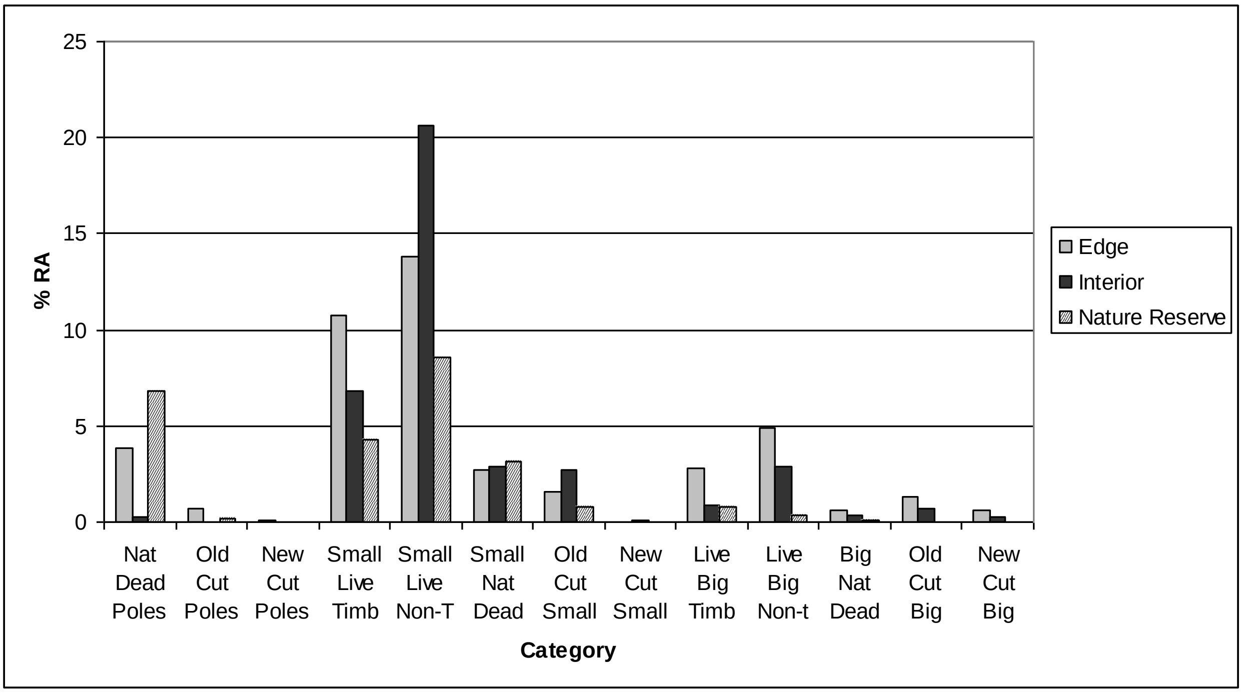


Figure 1. *Relative abundance of all stems as defined in the text for each category (excluding live poles).*

The raw numbers for the categories shown above were then analysed using Mann-Whitney tests. As expected in a forest with the structure such as ASF, there is a very high number of 'poles', as well as many more small trees than large (W = 197032.0, P<0.0001). This is because poles are naturally 'thinned out' as they compete for resources like light.

The results also show that there are many more live trees than dead. This is to be expected in any healthy forest.

Note however that the number of 'non-timber' trees were significantly more numerous than the 'timber' trees (W = 131098.5, P<0.0001). Interestingly, the difference between numbers of timber and non-timber was observed when comparing the small trees alone (W = 130733.5, P<0.0001), but not the large trees (W = 147702.5, P=0.2175).

Having ascertained a picture of the distribution of cut and live stems of different size classes, the data were then analysed for patterns of disturbance.

Relative Level of Disturbance (RLD)

This measure of level of disturbance calculates the percentage of 50m sections containing various forms of disturbance for each transect. The relative level of disturbance is given by the formula as above:

$$\% \text{ RLD} = (ni / N) \times 100$$

But in this case:

ni / N is the proportional abundance of 50m sections containing a form of disturbance and
ni is the number of 50m sections containing a form of disturbance for that zone.

Although this analysis does not take into consideration the intensity of a given form of disturbance within each 50m section, it gives an overall picture of the disturbance occurring within an area. Count numbers were then compared using chi-square tests. The data for the three zones were first compared for the presence of any disturbance, cut stems or other:

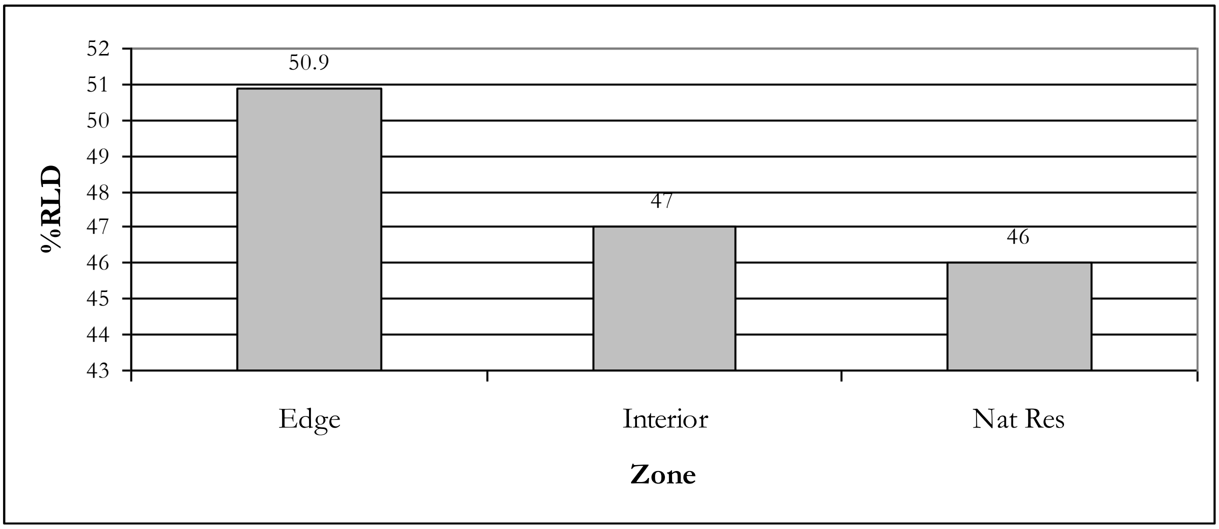


Figure 2. *Relative level of any disturbance for the three zones.*

Although the Edge zone shows slightly elevated RLD at 50.9%, there is no significant difference in the relative level of disturbance between zones ($\chi^2 = 1.31$, P = 0.519). All show high percentages of RLD indicating illegal human activity is widespread in these transects.

Given the apparent similarity across zones, the same measure was used for cut stems and other disturbances separately:

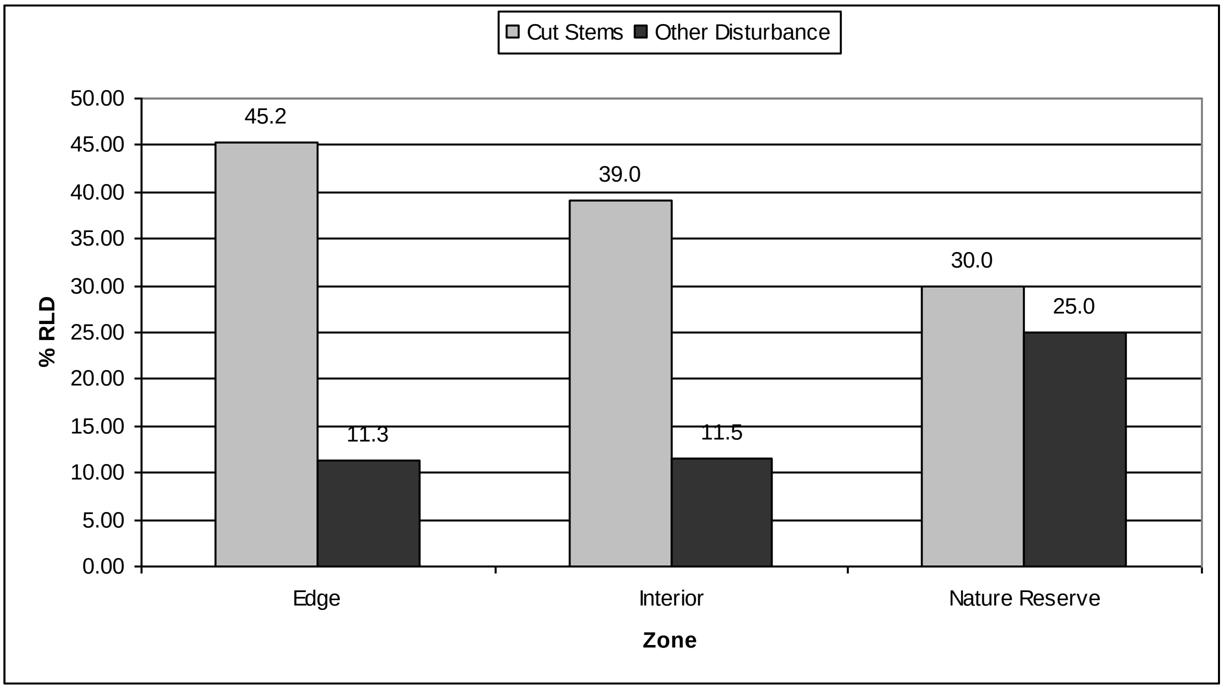


Figure 3. Relative level of disturbance across the three zones, for both cut stems and other disturbances.

Cut Stems

The RLD figures for cut stems (see Figure 3) indicate that there is a significant difference in this type of disturbance, with more stems being cut or damaged in the edge of the forest than elsewhere, and less in the nature reserve than the interior ($\chi^2 = 14.137$, P = 0.014).

Number of cut stems per hectare

While the RLD results give an indication of the pattern of disturbance, the number of cut stems per hectare takes into account the intensity of disturbance per area of forest. The number of individuals per hectare for any measure is calculated by dividing the total number of individuals of one category by the number of hectares covered by the disturbance transects:

Total no. of individuals per ha = total no. of individuals of one category/total no. of ha

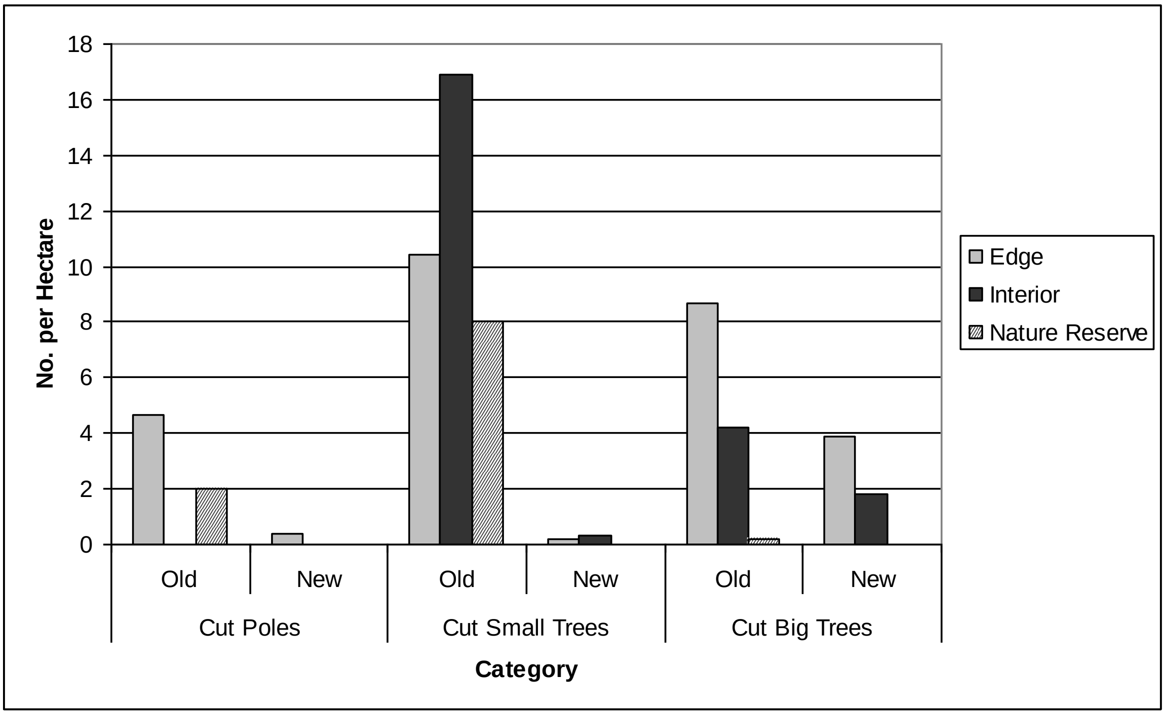


Figure 4. *Number of cut stems of each category per hectare for each zone.*

Figure 5 shows the same data but not separated according to tree type:

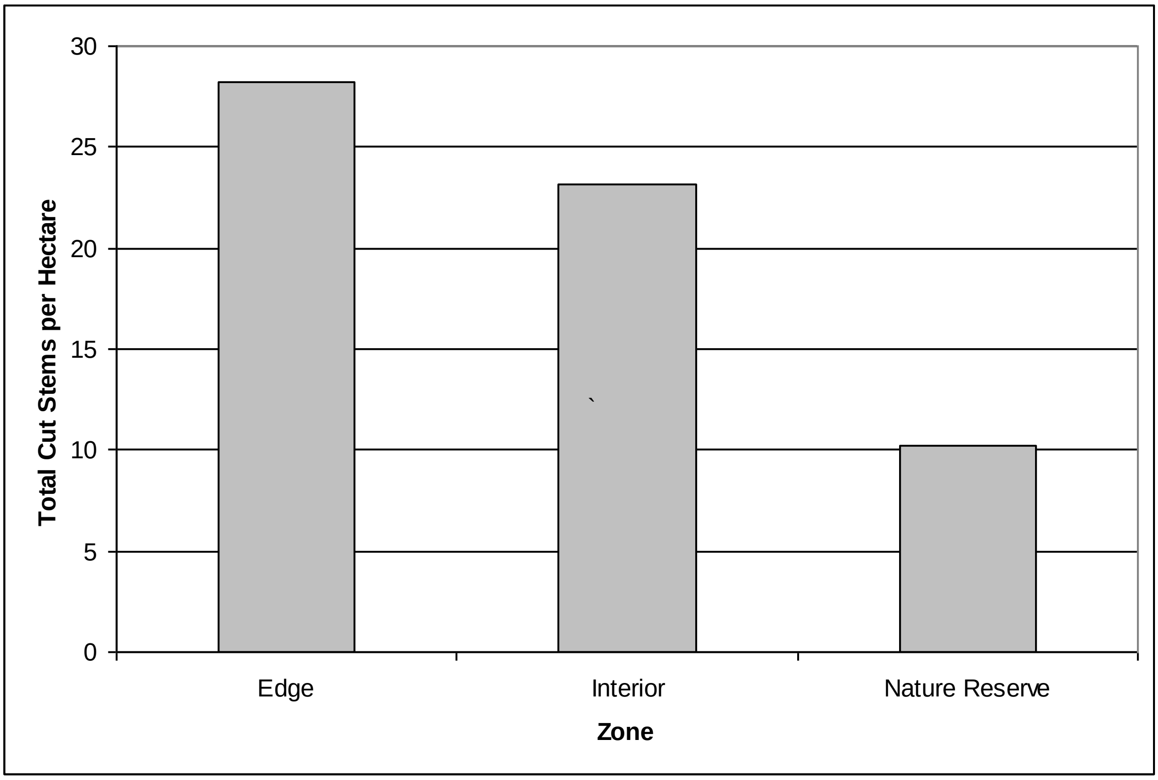


Figure 5. *Number of cut trees per hectare displayed by zone.*

As the data were non-normally distributed, Kruskal-Wallis tests were used to examine differences in the raw numbers of cut stems (not totals per hectare as shown) between zones. The area was still taken into account using this comparison however, as each raw data point was for the same area of forest and the number of data points in each group is reflected in the analysis. Like the RLD measurement, the number of all cut stems was highest at the edge, followed by the interior (H = 6.26, P = 0.044). However, while the edge had significantly higher numbers of cut poles (H = 12.29, P = 0.004) and big trees (H = 18.85, P < 0.001), the number of small trees cut was actually higher in the interior than at the edge (H = 3.92, P = 0.143). The large trees therefore seem to drive the overall trend of most cuttings taking place at the edge, but it is important to note that the interior is targeted considerably as well, especially for small trees.

Other Types of Disturbance

In complete contrast with the % RLD results for cut stems (Figure 3), the relative level of other disturbances was actually much higher in the nature reserve than the other two zones (χ^2 = 78.86, P < 0.001).

Number of other disturbances per hectare

As for cut stems, the levels of other disturbance types were calculated per area. Many of the prescribed categories of disturbance were not found at all throughout the survey and so were excluded from the graph. These were: animal remains (A), cultivation (C), fire damage (F) and root removal (R). Their absence is important to note however.

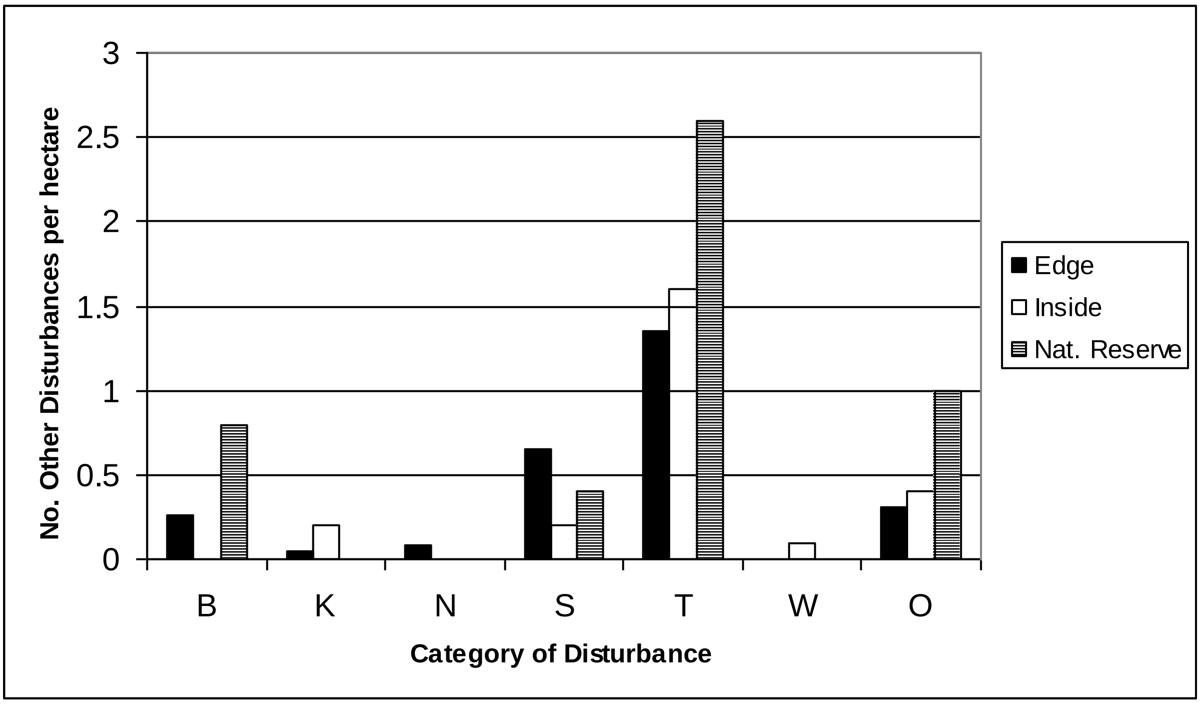


Figure 6. *Number of other disturbances per hectare in each zone. [Charcoal burning (B), campsite (K), disturbance noise (chopping or sound of voices) (N), snares, traps or pitfalls (S), tracks/paths (T), already cut timber/planks/poles (W), or other if none of the above (O)]*

Figure 7 shows the same data but not separated according to disturbance type:

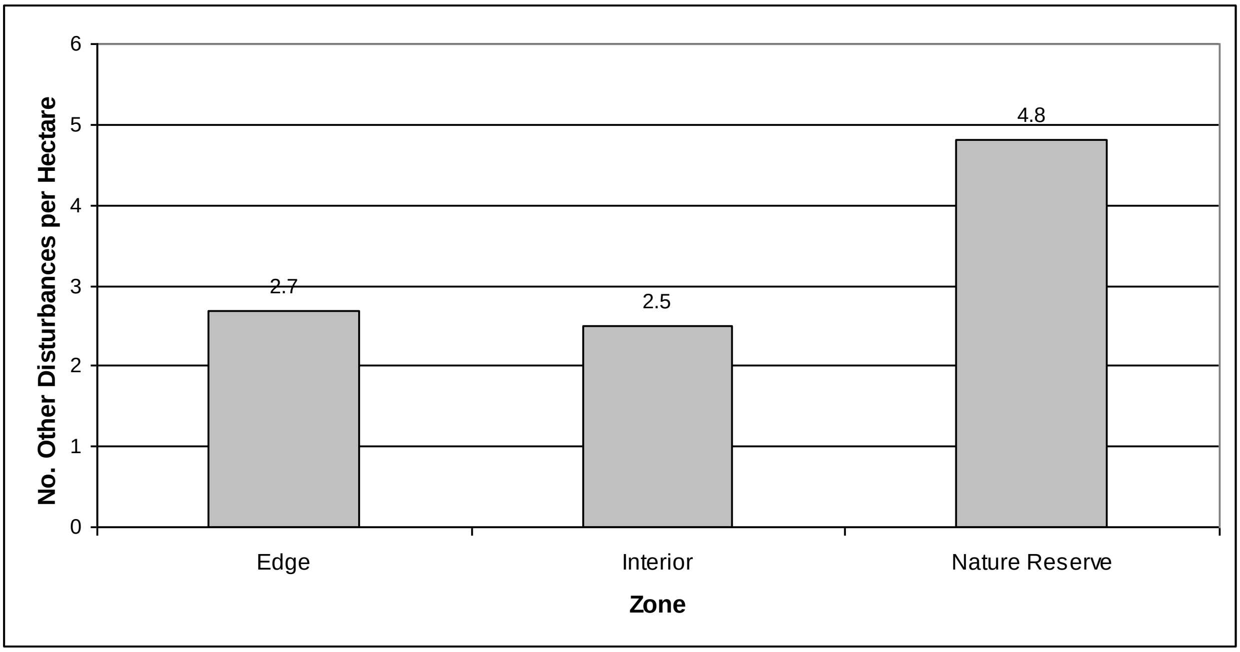


Figure 7. *Number of other disturbances per area for each zone.*

While the number of other disturbances per area seem to support the significant RLD result, an analysis of raw numbers of occurrences shows no significant difference between zones (H = 1.86, P=0.394). With the tracks removed from the analysis however, the rest of the disturbances show more of a trend (H = 4.58, P=0.101).

COMPARISON BETWEEN HABITATS

In the same way as for the comparison between zones, the RLD was calculated for all disturbances as well as cut stems and other disturbance separately. Overall, Brachystegia had far fewer occurrences of disturbance than the other habitats (χ_2 = 78.864, P = 0.001).

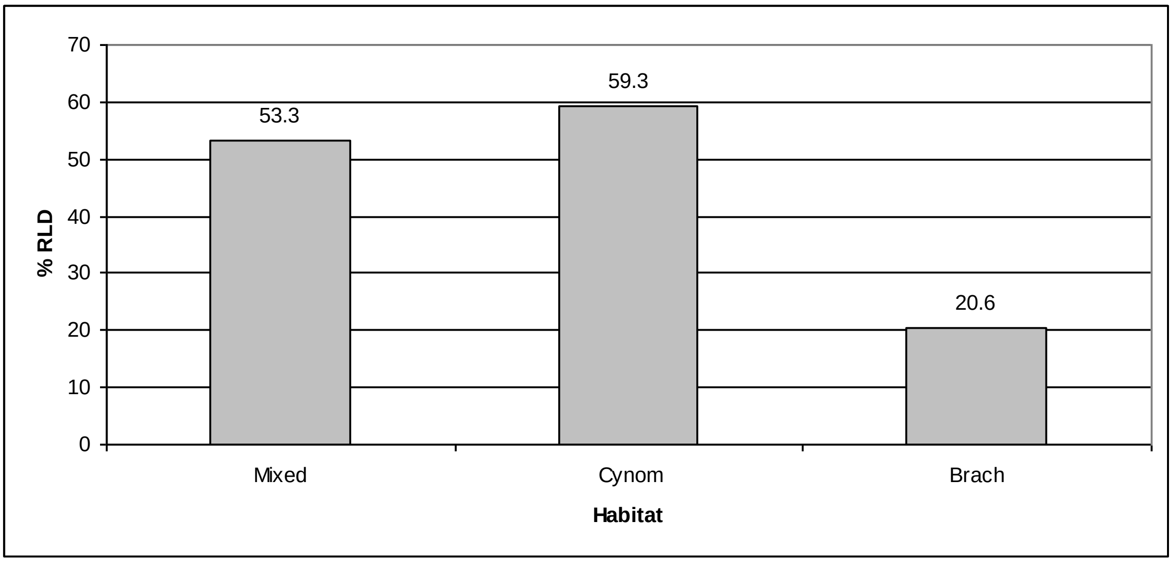


Figure 8. *Relative level of any disturbance for the three habitats.*

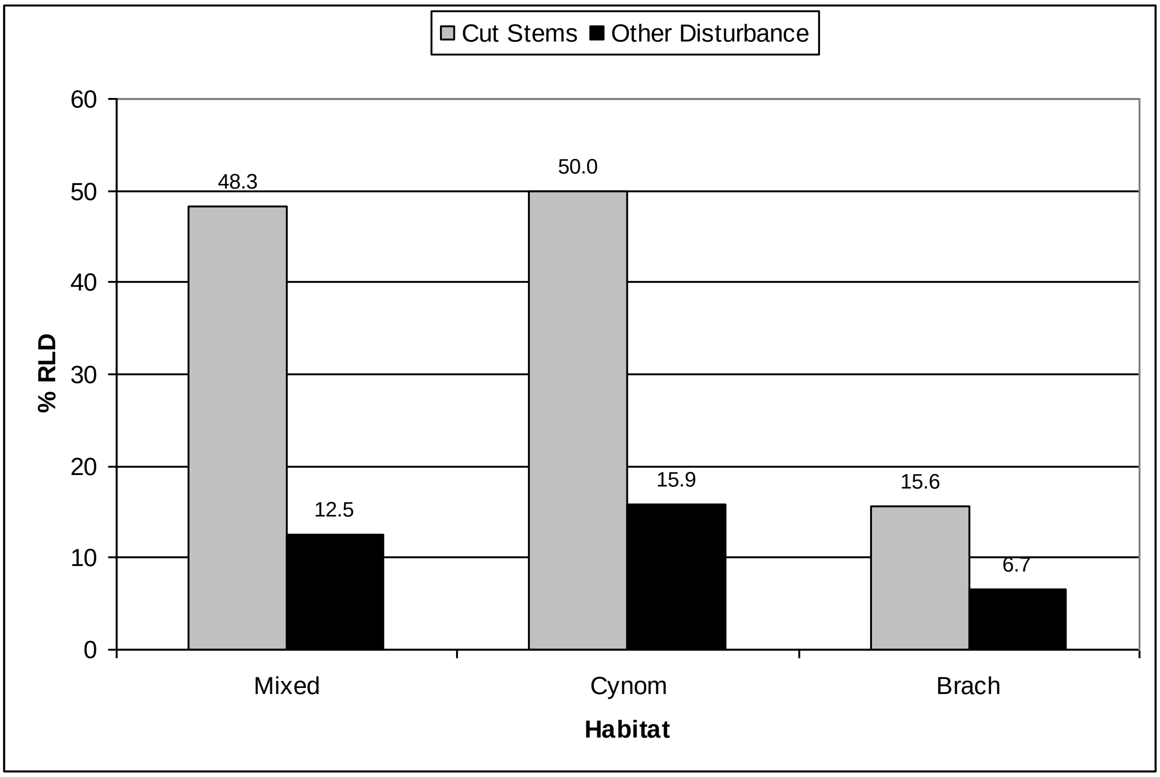


Figure 9. *Relative level of disturbance across the three habitats, for both cut stems and other disturbances.*

Cut Stems

The RLD results show that there are many more cut stems in the mixed and Cynometra forests than in the Brachystegia (χ_2 = 65.866, P < 0.001).

Number of cut stems per hectare

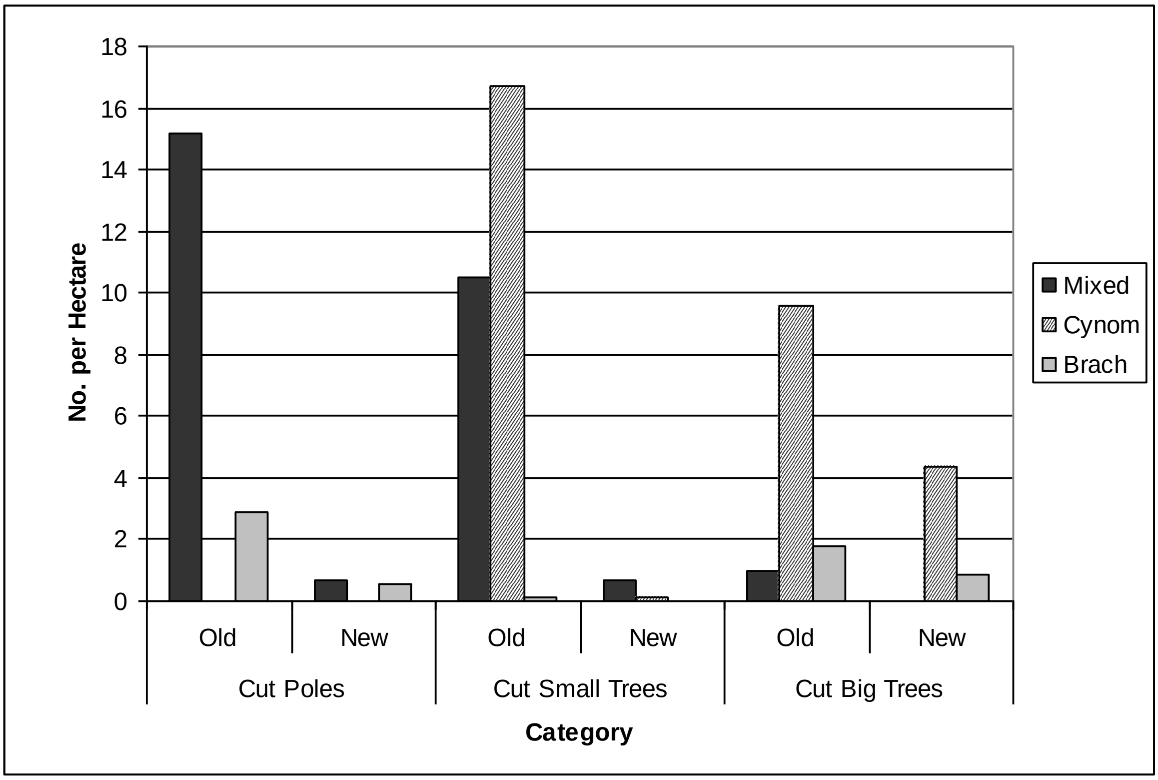


Figure 10. *Number of cut stems of each category per hectare for each habitat.*

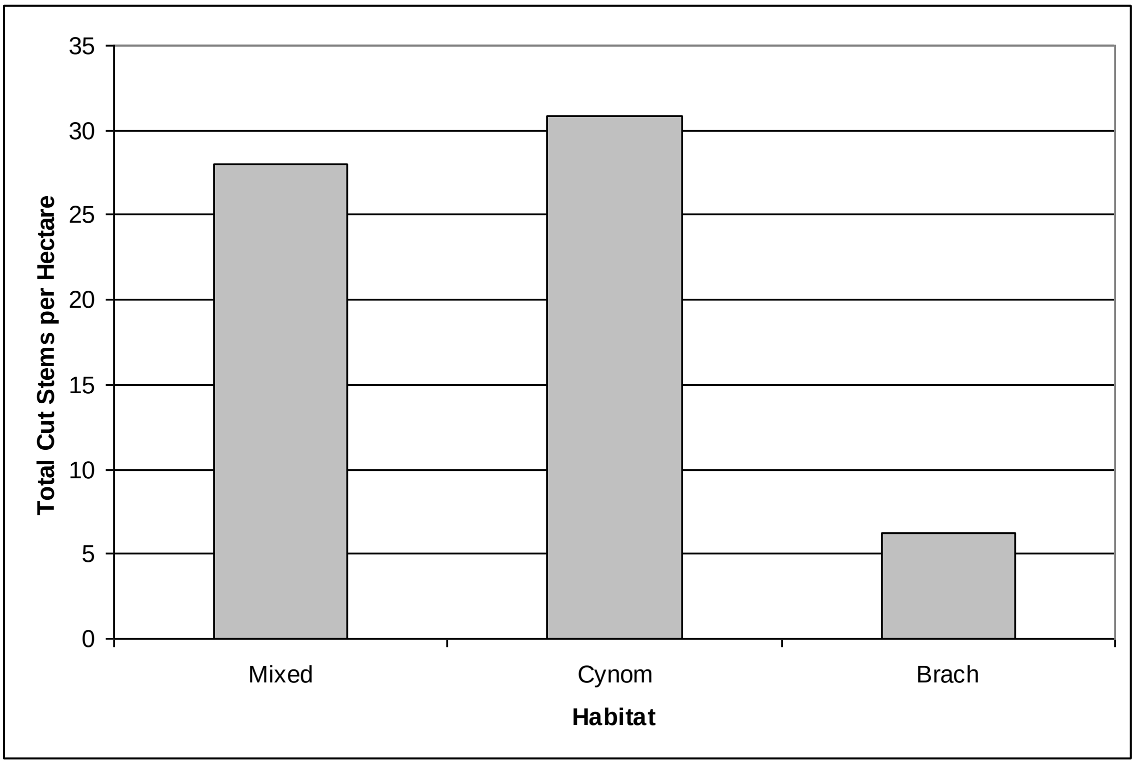


Figure 11. *Number of cut stems per hectare displayed for each habitat type with standard deviations.*

The analysis of numbers of all cut stems reveal the same result as the RLD analysis, with far fewer cut stems in the Brachystegia habitat than the other two ($H = 54.15$, $P < 0.001$). As for the various zones of the forest, the three size classes are targeted differently in each habitat. For poles, Cynometra is not targeted at all, and the only significant number of cut stems found were old ones in the mixed forest ($H = 91.44$, $P < 0.001$). For small and big trees however, the Cynometra is targeted most heavily, dominating the overall trend ($H = 49.92$, $P < 0.001$; $H = 33.94$, $P < 0.001$ respectively). In the mixed forest, it is the small trees and poles that are targeted, with very few larger trees cut.

OTHER TYPES OF DISTURBANCE

In terms of relative levels of disturbance, the pattern for other disturbances reflects that of the cut stems, with more disturbance in the mixed and Cynometra than Brachystegia ($\chi 2$ = 9.643, P = 0.008).

Number of other disturbances per hectare

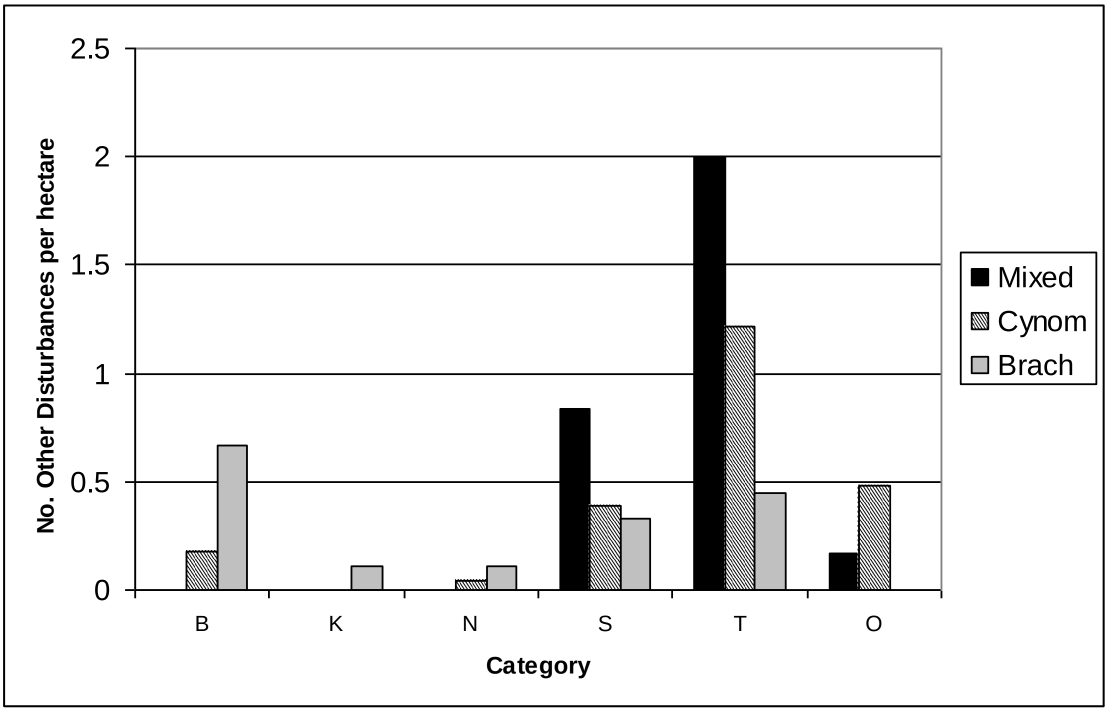


Figure 12. *Number of other disturbances per hectare in each habitat. [Charcoal burning (B), campsite (K), disturbance noise (chopping or sound of voices) (N), snares, traps or pitfalls (S), tracks/paths (T), already cut timber/planks/poles (W), or other if none of the above (O)]*

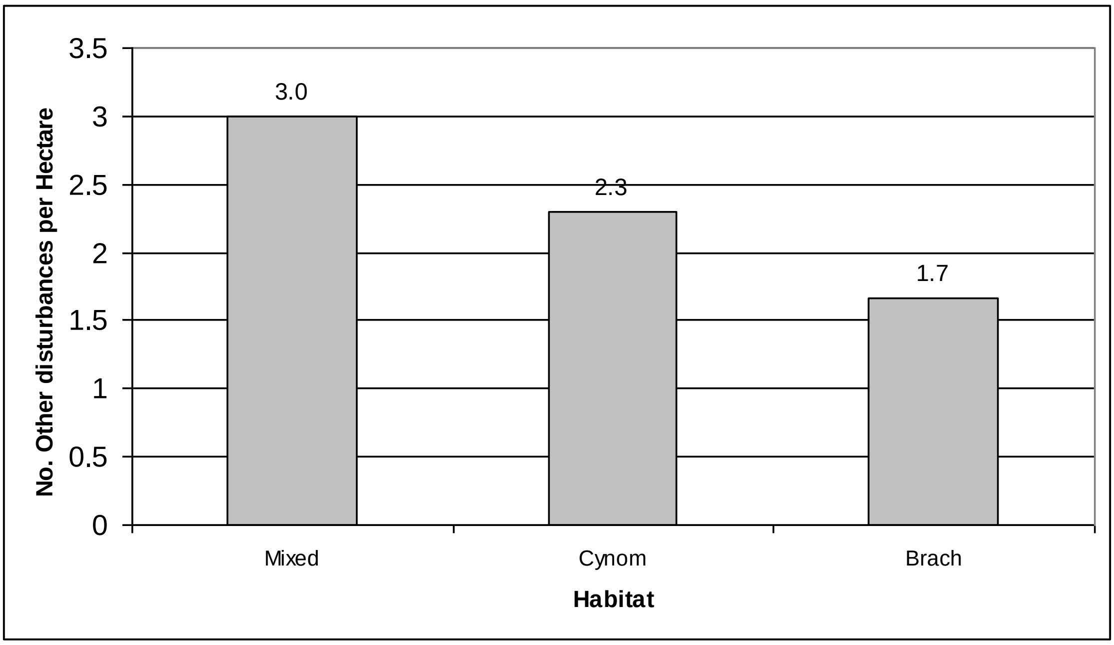


Figure 13. *Average number of other disturbances per area for each habitat.*

A comparison of the frequency of other disturbances with habitat supports that shown by the RLD above (H = 7.77, P=0.021). It should be noted however, that this trend seems to be caused by the presence of tracks alone, as on removing this form of disturbance, there is no difference across habitats (H = 0.52, P=0.77).

Locality of Disturbance in the Forest

Total numbers of cut stems per transect and their distribution are displayed in Map 2. These are also shown in Map 3 in terms of 'old' and 'new' cut stems – with a graphical cross reference in Figures 14 and 15.

The four highest numbers occurred in EC7 (100), EC9 (87), IC12 (80) and EM7 (67). Key areas of tree cutting are on the western side near Dida, Kaembeni and Nyari village areas, Ngerenya in the south east, Roka and Matsongoni also in the south eastern corner, Mijamboni to the north east and just c.2 kms in from Jilore Forest Station along the Jilore track. Of these, the recent cutting has occurred almost entirely around the Dida / Kaembeni areas.

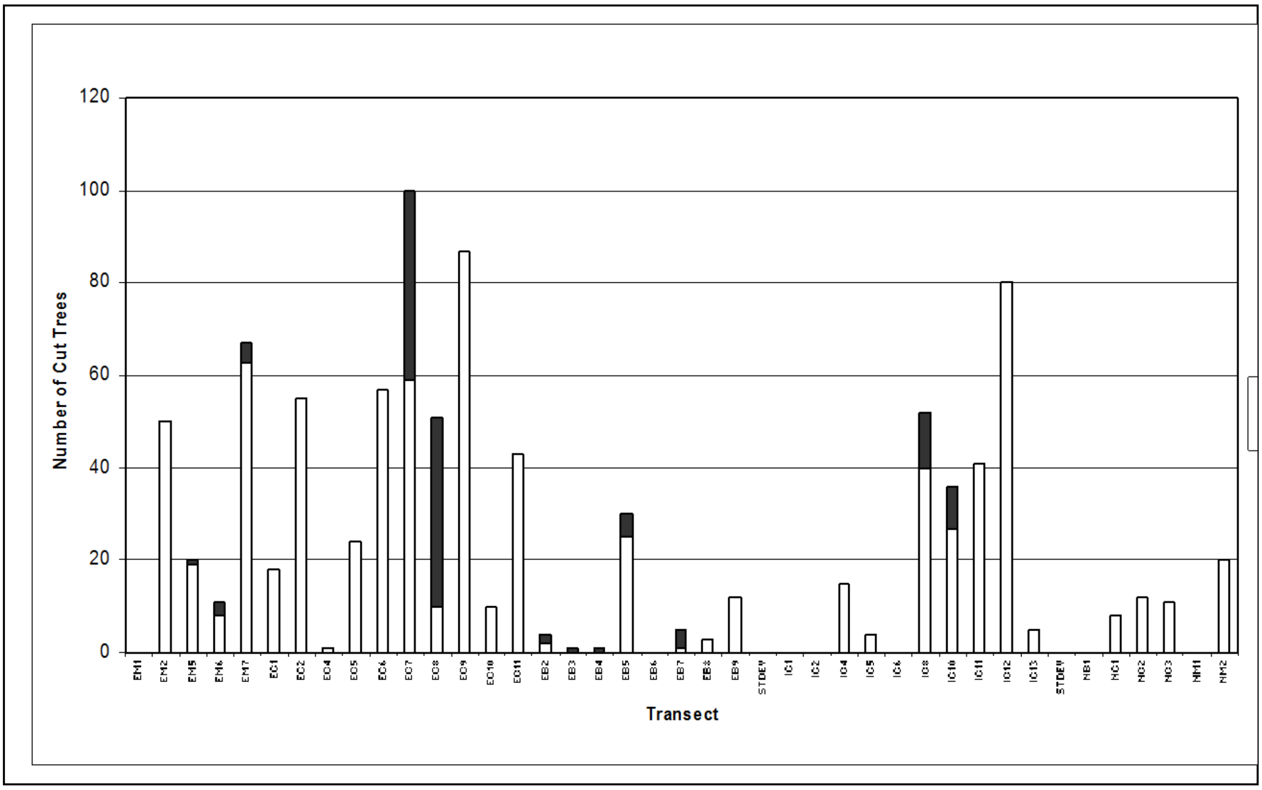


Figure 14. *Total number of cut trees per transect. The black portions indicate 'new' or recently cut trees (less than one year prior to survey) – see Map 3 for the distribution of the cut stems.*

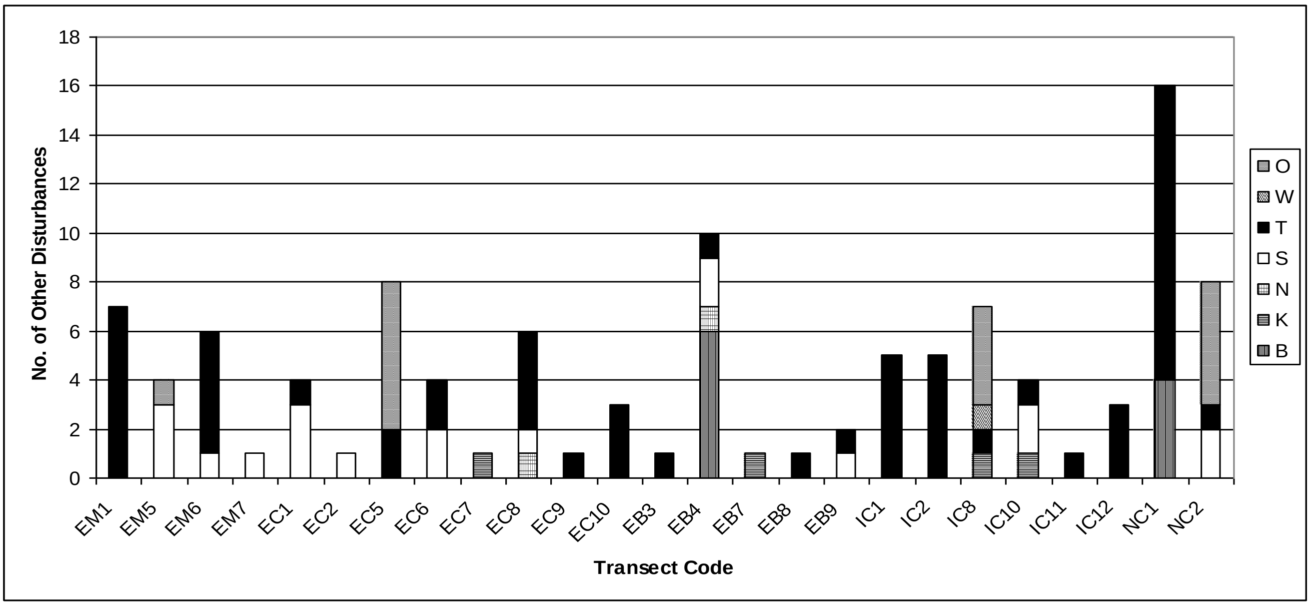


Figure 15. *All other disturbances per transect.*

Participatory Forest Management (PFM) zones

Contrary to what might be expected, there was no difference in the total number of cut stems between the PFM areas and others (W = 27692.5, P = 0.2036). In fact, the Dida PFM zone had the highest two transects of cut trees for the whole forest (Table 1).

Table 1 shows those transects which had more than 50 cut stems related to the PFM zones. Note EC9 has 87 cut stems (see Fig 7) – not displayed on the map.

Transects with more than 50 cut stems	PFM zone
EC2, EC6	-
EM2	Kakuyuni/Mijomboni
EC7, EC8, EC9	Dida
EM7	Chumani /Roka

A further result becomes apparent when examining the different age of the cuts. There were actually more old cut stems in non-PFM areas than PFM transects (W = 26285.5, P = 0.0082), but there were more new cuts in PFM areas (W = 31291.5, P<0.0001).

Effect of Paths

The data were then separated to examine whether areas with paths were more disturbed than areas without. There was no difference in the total number of cut stems between path and non-path transects (W = 20029.0, P = 0.0936), and if anything there were more cut stems where there were no paths. A simple presence/absence analysis also did not produce any significant differences for both cut stems (χ_2 = 3.227, P = 0.072), or other disturbances. Inspection of the percentage of 'disturbed' transects supported the finding that there are more transects with cut stems where there are no paths (42.5%) than where they are present (30.6%).

Age of Cuts

From both the path and PFM analysis, it is evident that different effects are observed according to whether the stems were cut recently (<1yr) or not. Figures 4 and 10 illustrate these differences. Firstly, there are many more cuts found that are over 1 year old than 'new' (W = 183716.5, P<0.001). Map 3 shows the distribution of the logging activity separated by time since cut. The map indicates that there is a substantially higher number of cut stems in the southern half of the forest than the north. Note however that the two '100%' newly cut transects on the western edge of the forest had only one cut stem each (see Map 2). Of the new cuts, the edge is targeted most (H = 10.06, P = 0.007), but there is no effect of habitat (H = 0.95, P = 0.622). For the older cuts on the other hand, there is no difference across the zones of the forest (H = 2.83, P = 0.243), but the Cynometra forest is targeted most heavily (H = 58.83, P < 0.001). It is particularly interesting to note that the old cuts are determined by habitat type and not zone, whereas more recent ones are determined by zone and not the habitat.

VEGETATION MEASUREMENTS AND FURTHER RELATIONSHIPS

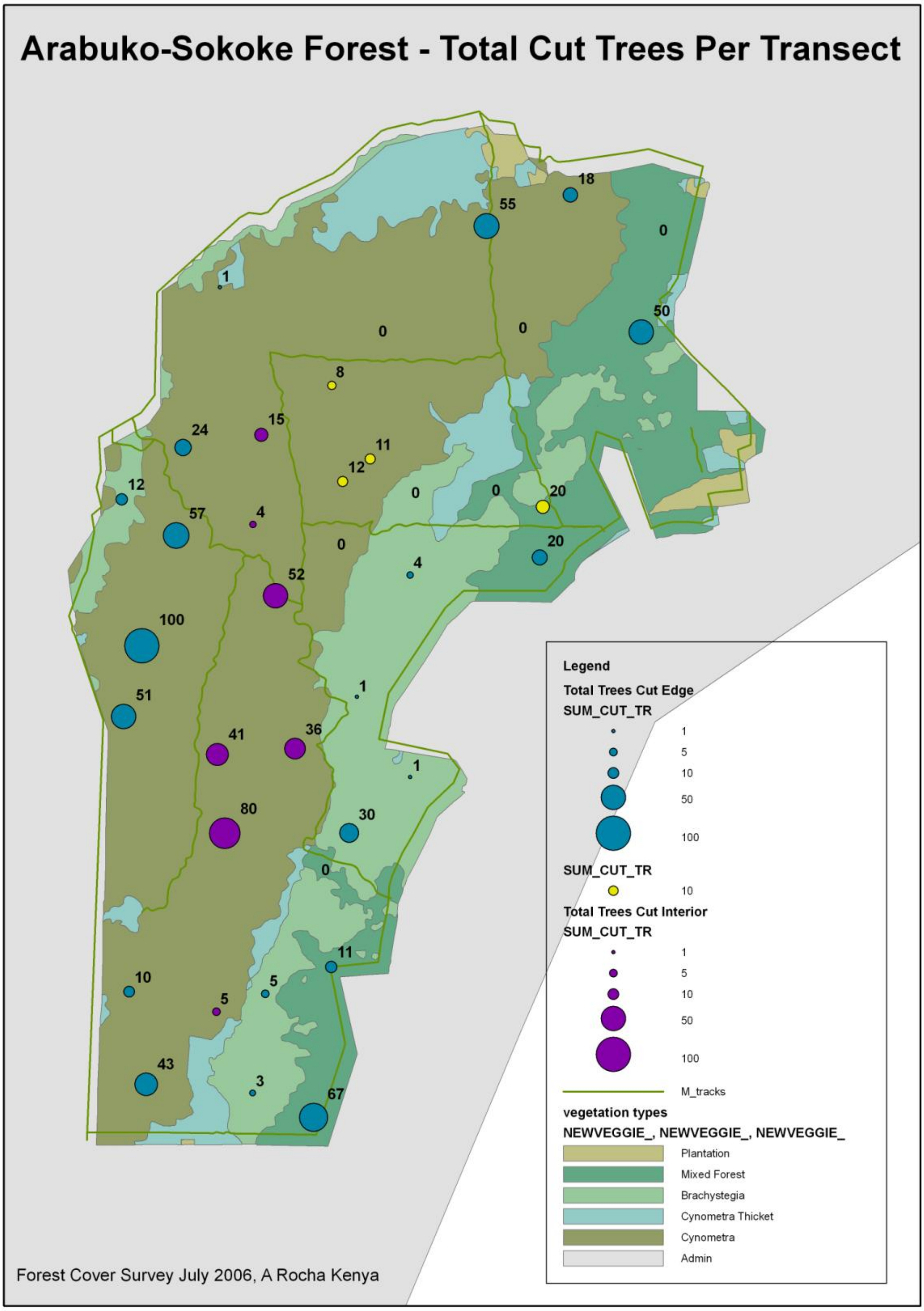
The measures of vegetation that were carried out along the transects were analysed to see whether there was a pattern in the vegetation that corresponds to the effects of disturbance in the forest. First, the three measures of vegetation (canopy cover, height, chequerboard) were examined for a correlation between them. It is important to note that the chequerboard value is an inverse measurement of the density of vegetation.

The correlative analysis showed that height and canopy cover were positively related ($P<0.001$), density showed a positive trend with canopy cover ($P=0.16$) but density was negatively related to height ($P<0.001$).

The vegetation measurements were then correlated with the measures of disturbance. The total number of stems cut was positively related to canopy cover ($P=0.050$) and density ($P<0.001$), but had no relation with height ($P=0.775$).

Interestingly, the number of other disturbances is not related to any vegetation measurements, and actually shows a negative trend with the total number of cut stems ($P=0.147$). In other words, it seems that other disturbances occur where stems are not cut and vice versa.

Finally, the total number of cut stems does not correlate with the total number of live trees ($P=0.188$). There is however, a very significant correlation between the number of live big trees and the number of big trees cut, both timber ($P=0.003$) and non-timber ($P<0.001$). The number of live small trees and those cut, whether timber or non-timber, do not correlate.



Map 2. *The number of all stems (poles and trees) cut per transect is indicated by size of circle (see key) and the actual number of cut stems is indicated next to the circle. Transects of the three zones are indicated in a different coloured circle. Edge (E) is blue, Nature Reserve (N) is yellow and Interior (I) is purple. Note EC9 not displayed – 87 cut stems.*

Estimated number of cut stems in the forest

Table 2 shows the actual number of cut stems per zone by size of tree and age of cut. An overall total of 933 trees (all sizes and all 'ages') were recorded as being cut of which 124 were 'new' (cut within one year). Given that the survey covered 0.1% of the forest area, an extrapolation to the whole forest would suggest that a total of 124,000 stems were cut between June/July 2005 and June/July 2006 and a total of 933,000 have been cut to date – excluding those stumps which have rotted away from old age.

Table 2. *Actual number of cut stems encountered for whole survey per zone and by size of tree and age of cut*

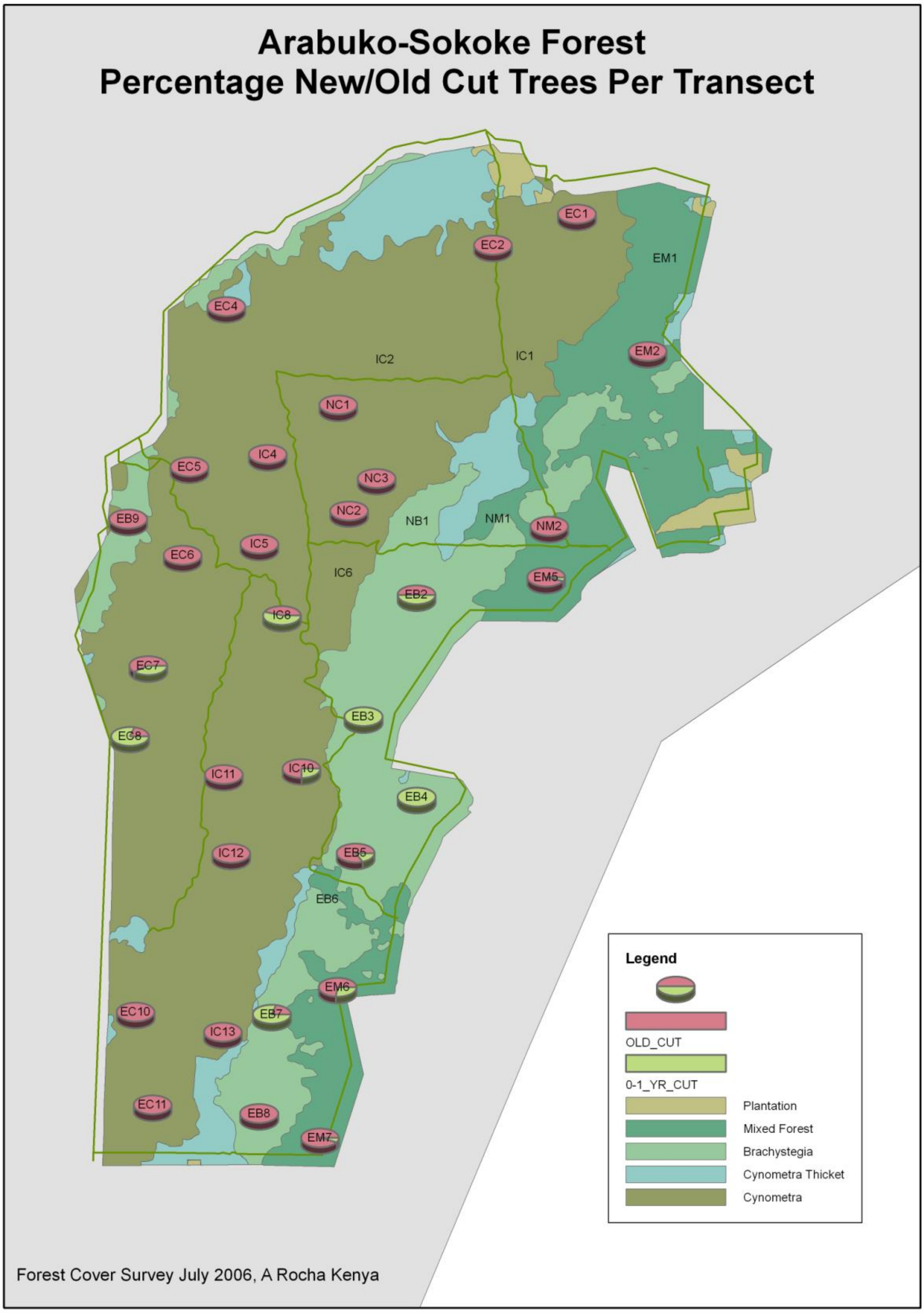
	Poles			Small cut trees			Big cut trees			Grand Total
	Old	**New**	**Total**	**Old**	**New**	**Total**	**Old**	**New**	**Total**	
Edge	107	9	**116**	240	4	**244**	200	90	**290**	**650**
Interior	0	0	**0**	169	3	**172**	42	18	**60**	**232**
Nature Reserve	10	0	**10**	40	0	**40**	1	0	**1**	**51**
Total	117	9	**126**	449	7	**456**	243	108	**351**	**933**

Selection of species logged

Data was collected for the species of the cut trees encountered and is tabled below (Table 3) and is what is predicted for ASF – *Brachylaena huillensis* in the Cynometra forest and *Brachystegia spiciformis* in the Brachystegia woodland. Note that EC7 and EC8 had a large number of big new trees cut.

Table 3. *Species of selectively logged trees in ASF by transect, size and age.*

Transect	Species	Small old	Big old	Big new	total
EC6	*Brachylaena huillensis*		57		**57**
EC7	*Brachylaena huillensis*	34	25	41	**100**
EC8	*Brachylaena huillensis*	5	5	41	**51**
EC9	*Brachylaena huillensis*	79	8		**87**
EC10	*Recorded as "most = B. huillensis" for whole section*	7	3		**10**
EC11	*Brachylaena huillensis*	32	8		**40**
EB7	*Recorded as "most = Brachystegia spiciformis" for whole section*	1	4		**5**
EB9	*Brachystegia spiciformis*		12		**12**
IC6	*Brachylaena huillensis*	5			**5**
IC8	*Brachylaena huillensis*	30	10	9	**49**
IC10	*Brachylaena huillensis*	17	10	8	**35**
IC11	*Brachylaena huillensis*	41			**41**
IC12	*Brachylaena huillensis*	75	4		**79**
IC13	*Brachylaena huillensis*	5	6		**11**
Total		**331**	**152**	**99**	**582**



Map 3. *Percentage of 'old' versus 'new' cut stems (poles and trees) per transect. Pink indicates percentage of old cut stems (> 1 year since cut i.e. those cut before June/July 2005) found at each transect and green shows percentage of new cut stems (<1 year i.e. those cut between June/July 2005 and June/July 2006). Note EC9 not displayed – 87 old cut stems.*

DISCUSSION

Structure of the Forest

The relative proportions of each size class of tree (many small trees and few large) and the proportion of there being many more live to dead trees was to be expected in a forest with the structure of ASF. Of interest is the higher number of live non-timber trees than timber trees. One possible reason for this is that the species involved are simply naturally more crooked and twisted than not. On the other hand it could mean that the trees of value to the timber trade are those which have already been cut out, but as specific data regarding the species of the cut stems was found to be somewhat unreliable, we cannot be convinced of this assumption. Either way, the relatively low levels of timber trees suggest that Arabuko-Sokoke does not have much potential for timber extraction though further, more detailed work is required to confirm the reasons for higher number of non-timber trees.

Levels of Disturbance

The study has shown that the relative level of all disturbances (both cut stems and other) is high in all three zones (Edge, Nature Reserve and Interior zones at 50.9%, 47% and 46% respectively). This confirms that illegal activities are continuing to take place in the forest at levels that are higher than desirable in a forest with the conservation status and value of Arabuko-Sokoke.

While the overall levels of disturbance do not differ between the edge, interior and nature reserve, separating disturbance by cut stems and other activity reveals significant differences across the forest. The overall number of cut stems was higher around the edge than the interior, and was least in the nature reserve. By contrast, the highest number of other disturbance was found *in* the nature reserve. However, tracks were counted as an ‘other’ type of disturbance and with these removed from the analysis any significant difference in other disturbance across the zones disappears. Having said this, while the nature reserve had the lowest number of cut stems, the fact that 30% of all transects carried out in it contained cut stems and that the highest levels of other disturbance were found there (25%) is still of concern given that it is supposedly a zone of zero extraction or disturbance.

The absence of animal remains, cultivation, fire damage, pit sawing and root removal across the whole survey seems positive. However, whilst at very low levels, the fact that charcoal burning is being recorded at all is disturbing as in this past this was not observed. What is also known though impossible to show from the results of this survey, is that trees are being cut in the forest and then the wood carried *out* of the forest and then charcoaled in the adjacent shambas. What is recorded therefore, is simply a ‘cut stem’ but the purpose for the cut tree is unknown.

The high numbers of cut stems around the edge suggest that people are choosing where to undertake logging activity according to accessibility. For small trees however, the interior had by far the highest number of cuts found, virtually all of which are old. Logging activity will therefore extend further into the forest, presumably depending on the value of the trees to be found there and it would appear that at the time of the survey, there was less activity deeper in the forest.

The indication of logging occurring deep into the forest is reinforced by the different disturbance levels observed in each habitat type. The interior of the forest contains more Cynometra forest and it was this habitat that had the highest relative level of all disturbances at 50%. Both cut stems and other disturbance activity were found at a higher frequency in Cynometra and Mixed Forest than in the Brachystegia. As for the different zones, further differences became apparent on examination of the different size classes. While Cynometra was targeted the most overall, the data sheets indicate that there was not even a single pole cut in this habitat though it was targeted quite substantially for small trees. This would explain why results show the interior zone with the highest levels of small trees cut. The poles that were recorded as being cut were predominantly in the mixed forest, which tends to be around the edge. The result that there were no cut poles in the Cynometra is very surprising and is one which should be looked into further considering that Cynometra comprises of a high density of small, 'pole-sized' trees, is the larger of the three main habitat types, makes up a longer perimeter with the communities where poles are heavily sought after for building etc. and the authors have found cut poles in the Cynometra during other unrelated survey work thus confirming that it does happen.

The survey allowed us to make an estimate of the actual levels of disturbance across the whole forest. Covering just 0.1% of the forest area, it is remarkable that the numbers of cut stems are as high as they are. The extrapolated figure of 124,000 cut stems in one year and 933,000 trees cut before mid-2006 should be viewed as an estimate. This is because cut stems may not be evenly spread throughout the forest. One query would be regarding the accuracy of species identification of cut trees as in this survey they were recorded exclusively as *B. huillensis* and *B. spiciformis*, whereas previous studies (e.g. Glenday 2005) showed a higher diversity of species cut.

An encouraging result revealed only two instances of bark-stripping occurred in the forest. Bark stripping of targeted species in countries where there is a thriving medicinal trade can be of such high severity that it can cause their local extinction.

Locations of Disturbance, Effect PFM Areas and of Paths

This study indicates that the majority of the cutting has occurred in the southern half of the forest. This perhaps reflects the greater distance from the main headquarters for the Forest Management and a possibly different patrolling regime to the northern section. Significant numbers of cut stems were also found near Jilore and Arabuko though these had been cut over a year before mid-2006. Using this data, it is possible for managers to focus patrols in the areas shown to have more logging activity in an attempt to reduce the illegal cutting. It should also stimulate action amongst managers to work more closely with the communities adjacent to these areas so as to stop such illegal activity.

Previous studies (e.g. Glenday 2005) have shown that the number of cut stems is higher along paths and tracks. The results of this survey appear to contradict this finding, with both total numbers of cut stems and presence/absence analysis showing no such trend. In fact, the percentage of transects with disturbance is higher away from paths than on transects containing them. One reason for this may be that no note was made during this survey to indicate the distance to the nearest major path but rather what was recorded was any path which the transect intersected. Furthermore without clear definitions of what was classified as a 'path', there may be times when animal tracks or paths were recorded as human paths thus confusing the conclusions drawn here. It is of interest, however, to note this as a possible factor that would need to be looked at in more detail in the next forest cover survey to ascertain which of the two conclusions is in fact correct. As indicated by the high number of certain trees cut in the interior of this forest, this result does, however, demonstrate that people undertaking disturbance activities will stray from the paths to do so and is something to be noted by forest managers while drawing up a patrolling strategy.

A striking result of this survey is that the PFM areas have no fewer cut stems than elsewhere in the forest. Furthermore, there is a contrast between the greater number of old cut stems in non-PFM areas and the more recently cut stems, of which there are actually more in the PFM areas (see Map 3). This clear result raises questions regarding the effectiveness of the PFM zones at deterring forest disturbance. Another possibility that must be considered is that because more people have been introduced into the forest through the PFM programme, it has led to an increased awareness and thus increased exploitation of forest resources.

Changing Patterns of Disturbance

As observed in the effectiveness of the PFM areas, the categorisation of age of the cut stems allows us to suggest some crude patterns with regard to how disturbance might be changing over time. While the old cut stems bear no differences across the three zones, there are far more of them in the Cynometra forest. By contrast, the more newly cut stems did not differ across the habitats, but were significantly higher at the *edge* of the forest. One option for this might be that specific trees, found in the Cynometra forest, were targeted in the past with people making the effort to cut them wherever they may be found. It seems that this is no longer the case, as perhaps the number of high value trees has dwindled (such as *B. huillensis*), so that people select trees by the ease of access (i.e. more towards the edge of the forest). This might also explain the relatively low number of live 'timber' trees.

Such patterns are of great relevance to policy-makers and managers in terms of mitigating disturbance in the forest, and should therefore be taken note of in future surveys. Estimating the 'age since cut' of stumps is a difficult procedure. Caution should be taken when using the 'old' cut stems data without knowing the species involved. This is because some species have far harder wood than others and so a stump will survive much longer than another which may rot and disappear within 5-10 years – for example there are examples of *Afzelia quanzensis* which were cut at least 40 years ago and the branches and stump are still very much there; *Brachystegia spiciformis* however rots to almost nothing within 7-8 years. Whilst two categories were used in the current analysis, for the purposes of active and regular monitoring, the category of freshly cut trees (<3 months) should be focussed on as an indication of the most current disturbed sites. A new categorisation has in fact been developed that uses a description of the condition of the cut tree (e.g. if it still has green leaves or they have turned brown or fallen off) which, so long as it is identified, allows one to set a more precise age once the decomposition rate is known for that species.

Interaction of Disturbance with Vegetation Characteristics

While perhaps not entirely relevant to policy regarding disturbance in the forest, it is interesting to note that from at least this one survey the data show the canopy cover to be related to both height and density, but negatively related to height of the canopy. Given these good correlations, it might be deemed possible to use just one of these measures, such as canopy cover, for a quick approximation of these parameters.

The fact that the total number of cut stems was positively related to canopy cover, and even more so to density suggests that disturbance activity is partly determined by vegetation characteristics, such as the thickness of the forest. A possible explanation for there being more cut stems where the canopy cover and density of the forest is greatest is where visibility is lowest, people are less likely to be seen when cutting. While not the case for poles or small trees, it was also observed that there was a higher number of cut big trees where there was a greater number of big trees living. This may simply be due to the fact that some areas of the forest are better for large trees than others so that you would therefore get more large trees cut where others exist. On the other hand, the pattern of other disturbance activity was not related to such vegetation parameters. While this may also be a confound of the inclusion of tracks in this category, activity such as the use of snares would not require such prolonged time in the area as tree cutting, and so might be less affected by visibility – this is assuming that 'visibility' is a factor taken into account by poachers in determining where they carry out their activities. This would clearly need further work to ascertain the relevance of this.

While not a significant result and confused by the presence of tracks, the pattern of other disturbances was negatively related to that of cut stems. In other words, it seems that other disturbances occur where stems are not cut and vice versa. What can be drawn from this is that it should not necessarily be assumed that other disturbances are going to be carried out where illegal logging is found to occur.

Conclusions and Moving Forward

The survey has proved useful in quantifying illegal activity in the forest. It has shown that logging is indeed continuing and to levels that are surely unacceptable in a reserve as globally significant as Arabuko-Sokoke Forest. Further, it has shown that a number of factors contribute to the location of disturbance within the forest, including accessibility, vegetation characteristics and the type of forest. For example, people are targeting Cynometra in the interior of the forest for small and big trees, but poles are mainly taken from the mixed forest which is near the edge.

The study also revealed some intriguing possible temporal patterns of change, such as the apparent shift from choosing to cut trees by habitat type, to choosing based on accessibility. This, however is almost impossible to ascertain given the different decomposition rates for difference species. However we would strongly recommend this survey be carried out by researchers and forest managers on a bi-annual basis particularly if more attention can be placed on better ageing and identification of cut stems. This would enable mapping and recording of disturbance that would assist with management of the forest, and especially with measurement of the success of conservation effort, such as in PFM zones.

The value of an unbiased, randomly selected survey carried out by the Forest Management Team members is clearly very significant in assisting in proper management of the forest. It is thus highly recommended that the Kenya Forest Service and Kenya Wildlife Service include such surveys as a matter of course in their budgets and work plans. The survey was very hard work and time-consuming given the very dense nature of the forest habitat and the methodology being used. While following existing trails and paths might make the survey easier to carry out, the significant levels of disturbance found away from the paths in this study suggest that this would leave disturbed areas of the forest not surveyed. Perhaps one way to reduce the effort needed to undertake the survey would be to reduce the vegetation parameters measured, as we have seen that one of these may well act as a suitable representative substitute. At the same time, we recommend that more consideration is given to identifying the species that are cut, as this would refine the process of locating where patrols and other efforts to stop disturbance of the forest should be carried out. Finally, attention should be paid to the numbers of cut stems, especially in the areas where they are surprisingly high, such as PFM zones, but equally efforts to reduce snaring, charcoal burning, fire damage and other damage to the forest should be treated separately.

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2007