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A history of change: causes of *miombo* woodland decline in a protected area in Malawi

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Summary

1. Tropical dry woodlands are thought to be declining as a result of human activity. Aerial photograph analysis showed measurable conversion of closed canopy *miombo** to sparse woodland in Lake Malawi National Park, Malawi, from 1982 to 1990. This multi-disciplinary study investigates the possible contributions to these impacts by local use of domestic fuelwood, construction poles and fuelwood for commercial fish smoking.
2. Domestic fuelwood use was measured in 30 households over an 11-month period. Domestic fuelwood is collected by women and is headloaded to the village. It comprises a large biomass of mainly dead wood and small branches over a wide species range. Mean total annual domestic fuelwood consumption by the total enclave population was less than half the mean annual production of fallen dead wood in the Park, estimated from three quadrats harvested monthly over an 11-month period.
3. Construction poles are mostly small, have extended durability and come from a broad species range. Fencing poles frequently take root to form live hedges. *Eucalyptus* trees are commonly grown for poles. Construction pole use appears sustainable and shows signs of substitution.
4. The 305 commercial fish smoking stations in the enclaves used less fuelwood annually than domestic fuelwood users. However, the men who undertake this activity target large branches and logs from a narrow species range, involving destructive felling of canopy species. 95% of men collecting fuel for fish smoking use cutting tools and three-quarters transport the wood by boat or bicycle.
5. The scale, size classes and species involved in commercial fish smoking suggest that this activity drives the observed degradation of closed canopy to sparse woodland. Traditional local fishing focused on small species sun-dried for preservation. Commercial fish smoking was introduced relatively recently by immigrants, along with gill netting that harvests larger fish requiring smoking for preservation. Demand for fish by ever-increasing urban populations underpins the continuing growth of the fish smoking industry.
6. Disaggregation of different wood use practices allows informed management policy for the Park. Currently, management targets and penalizes domestic fuelwood collectors. While seeking to reduce demand and provide alternative fuelwood sources, law enforcement and forestry extension should be reorientated to address the extraction of fuelwood for fish smoking.

Key-words: construction pole harvesting, fish processing, fuelwood use, sustainability.

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* *Miombo* woodland is characterized by the presence of leguminous trees of the genera Brachystegia, Isoberlinia and Julbernardia (Chidumayo 1997).

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Introduction

Dry woodlands including *miombo* make up over 40% of forest cover in the tropics, but have been less well studied than tropical rainforests. They are widely thought to be undergoing rapid degradation as a result of human activity (Grainger, in press). Fuelwood is an important woodland resource in the developing world. Simple calculations, based on patterns of wood use and per capita requirements, have been used to suggest how rapidly woodlands can disappear through fuelwood collection alone, precipitating the 'fuelwood crisis' fears of the 1970s (Eckholm *et al.* 1984).

However, the conventional wisdom is increasingly being challenged (Grundy *et al.* 1993; Leach & Mearns 1996). Poor data and poorly informed analyses have misrepresented and overgeneralized the nature of the 'energy crisis' and the 'fuelwood gap' analyses for the developing world (Mearns 1995). Conventional analyses may have seriously underestimated the amount of woody biomass available. Past calculations of biomass availability applied utilization limits for commercial timber, but the utilization limit for fuelwood incorporates much smaller branches and roots, which make up to 60% of the total wood in a tree (Leach & Mearns 1988). Furthermore, satellite remote sensing of wood stocks failed to include important sources such as trees grown on farmplots (Dewees 1995).

Research in West Africa has challenged population-driven models of deforestation by documenting the ways in which local populations enrich and manage their environment (e.g. Fairhead & Leach 1995 for forest status in five West African sites). Demographic factors alone do not explain human impacts: local preferences and patterns of wood selection affect the impact of harvesting on the resource base (cf. Hall & Rodgers 1986). While the quantity used is a key factor, this is coupled to the demand for the product, whether from rural or urban populations, or for subsistence or commercial purposes. It is also recognized increasingly that the collection of dead wood and the ability of many tree species to regenerate through coppicing, mitigate against the degrading effects of local harvesting practices (Nyerges 1989, 1996; Medley 1993).

LAKE MALAWI NATIONAL PARK

Concern over rapid and extensive woodland loss was a central factor leading to the establishment of Lake Malawi National Park in 1980 (Bell 1978). Fuelwood is an important resource for the five village enclaves within the Lake Malawi National Park (Fig. 1). These villages were not moved when the Park was established in 1980, but restrictions were placed on their use of natural resources from the Park. In the absence of alternative supplies of woodland resources, the villagers continue to exploit the surrounding woodland.

Several researchers and practitioners at Lake Malawi National Park suggest that growing village populations, and consequent increased demand for domestic fuelwood, have been responsible for woodland deforestation (Bell 1978; Bootsma 1987; Grenfell 1993). This is consistent with village censuses that show recent population growth within the village enclaves (Fig. 2). The villagers themselves recognize recent woodland decline. Discussions with the women, who are primarily responsible for domestic fuelwood collection, reveal that they find it increasingly difficult to gather fuelwood bundles. Tracked fuelwood collection trips averaged 4 h in duration and were undertaken on average every 4 days (Abbot 1996). Studies carried out between 1938 and 1945 in lakeside villages further north reported average fuelwood collection trips of 3·5 h once every 6 days (Berry & Petty 1992).

Park law enforcement activities focus on detecting and penalising the women who illegally collect domestic fuelwood from the Park. Given the importance both to the Park and to the local communities of this management issue, our research used a multidisciplinary study, drawing on ecological and anthropological methods, to examine the local harvesting of woody products and address the following research questions:

1. What are the patterns and impacts of domestic fuelwood collection?

2. To what extent is domestic fuelwood collection balanced by woodland production?

3. Are domestic fuelwood collectors the main cause of woodland decline?

4. What are the impacts of other forms of wood use?

Following aerial photographic analysis confirming decline, we examined the three main uses of wood in the villages: domestic fuelwood, construction materials for building houses, and the commercial use of fuelwood for fish smoking. For each resource, we used intensive, direct monitoring and weighing techniques to understand the collection, selection and use of woody products and the impacts of harvesting on the resource base. Previous studies in Southern Africa have relied primarily on questionnaire surveys and recall data, which are subject to the vagaries and inaccuracies of people's memories (Grundy *et al.* 1993; Vermeulen, Campbell & Matzke 1996).

Methods

The study was undertaken in Chembe and Msaka, the two largest villages within Lake Malawi National Park. Aerial photographic analysis was used to detect and monitor changes in the Park woodlands over an 8-year period, from 1982 (2 years after the establishment of the National Park) until 1990 (the most recent photographs available). Land cover was classified into sparse woodland (<50% canopy cover), closed canopy woodland (⩾50% canopy cover), village settlements and cultivated land.

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(a)

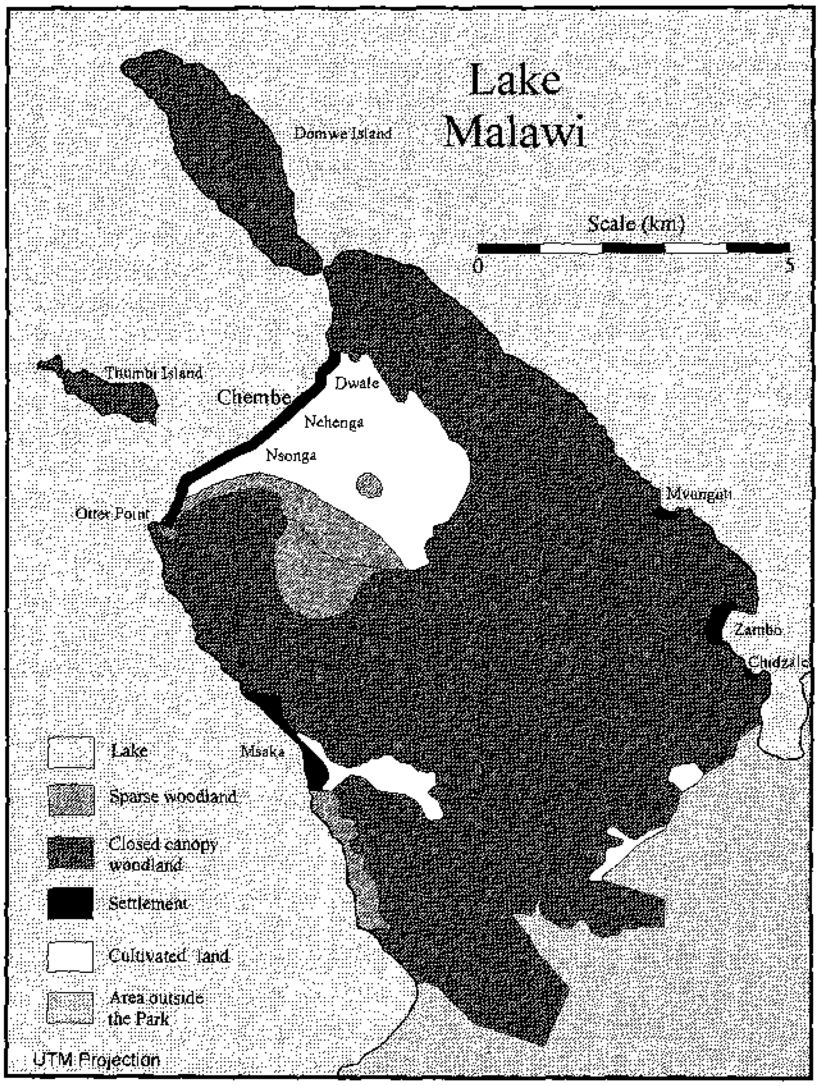

Fig. 1. Aerial photographic analysis of land-use change within Lake Malawi National Park. (a) 1982 and (b) 1990.

In Chembe, the largest village, 30 households were selected randomly and asked to participate in the study. A formalized questionnaire was used to establish household size by identifying and ageing all household members. Households consist of an extended family residing within one compound and eating together as a single unit (cf. Bender 1967).

A list of local tree names and their Latin equivalents was compiled during the study based on Binns (1972), but species nomenclature follows Coates Palgrave (1983). Each household was asked to list the tree species they were currently growing in their compounds and farmplots. All the trees were identified and their use(s) recorded.

The number of poles used to construct each house and compound was enumerated. Three different types of pole were identified: fencing poles, roofing poles and house supports. For each pole, the species and mid-point diameter were recorded. The durability of the species used for each type of pole was estimated by the head of the household. The occurrence of live fencing was recorded, where *miombo* species used as fence poles had taken root and grown.

A fuelwood survey monitored the flow of fuelwood through each of the target households over the same period of 7 consecutive days each month over a period of 11 months. On the morning of the first day of the weekly monitoring period, the fuelwood stockpile in the household was weighed. On a daily basis, all fuelwood bundles collected or bought by the household were weighed. In addition, an estimate of the weight of any wood that had been sold or donated to other households (e.g. during funerals) was taken. The fuelwood stockpile was re-weighed on the seventh and final day of the monitoring period. This schedule ensured a comprehensive examination of household fuelwood use while making only limited demands on the women's time.

(b)

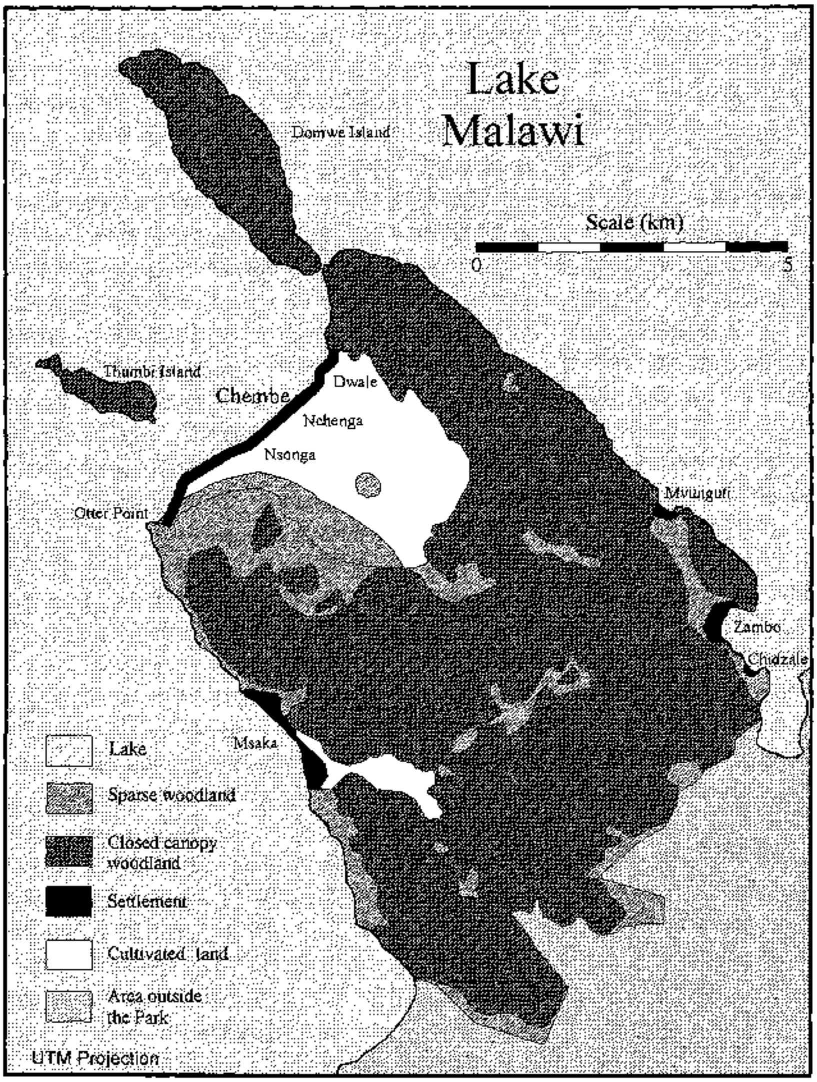

Fig. 1—*continued.*

Domestic wood use was then calculated from:

$$\text{Wood capita}^{-1}\ \text{week}^{-1} = \frac{\text{total weight of wood used week}^{-1}\ \text{in the household}}{\text{number of people resident in household}}$$

$$\text{Total domestic wood used year}^{-1} = \text{population of all enclaves (8440)} \times \text{wood capita}^{-1}\ \text{week}^{-1} \times 52$$

Species and size preferences for fuelwood were investigated by dissecting 30 randomly selected fuelwood bundles in Chembe. The number of branches that comprised each bundle was enumerated. For each branch, the species and mid-point diameter were recorded.

Fish smoking takes place in the villages, and the stations are often located along the beach. During the study, a one-off count of all fish-smoking stations in all five enclaves was undertaken. The ethnic group of the owner of the station was noted. The wood used by four of the fish-smoking stations in Msaka village was monitored for the same 7 consecutive days each month, over a period of 11 months (according to the schedule given for domestic fuelwood above). The species and mid-point diameter of each log were recorded. Total annual use of wood for fish smoking was calculated from:

$$\text{Total wood used for fish smoking year}^{-1} = \text{total number of stations} \times \text{amount used week}^{-1} \times 52$$

Focal group sampling (Altmann 1974) was employed to examine the tools and methods of transport used by fuelwood harvesters. On each trip, the tool each person used was recorded: panga knife (a wide-bladed knife), saw, axe, stick (sticks were used to knock dead branches out of trees) or by hand (where the individuals collected without tools). Fuelwood transport methods included: headloading or using bicycles, dug-out canoes and boats.

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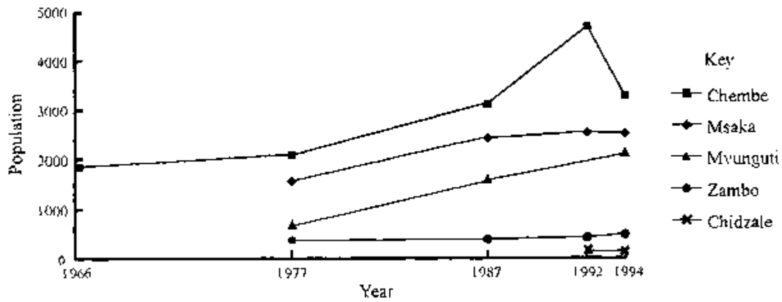

Fig. 2. Population change within the enclave villages of Lake Malawi National Park: collated census data from 1966 to 1994.

An estimate of the production of dead fallen wood was made using three permanent quadrats (Kent & Coker 1992), each of size 900 m^2. The quadrats were situated subjectively (cf. Shackleton 1993) to reduce the possibility of harvesting by villagers. The quadrats were located under closed canopy woodland in relatively inaccessible areas of the Park. Plots were not situated in sparse woodland because this was too accessible to the villages, and because closed canopy woodland is an order of magnitude greater in extent.

Trees marking the boundaries to each quadrat were clearly paint marked and the village chief requested people not to collect dead wood from with the plots. All the dead wood was removed from the quadrats 1 month before the survey began to provide a baseline. On the first day of each month, the wood on the ground of a size above the utilization limit (predetermined at a mid-point diameter of $\geqslant 2$ cm) was collected and weighed. The survey was undertaken each month for a period of 9 months. Annual production of dead wood was calculated from:

$$\text{Annual dead wood production} = (12x(1/n))N$$

where x = mean weight of dead wood produced quadrat^{-1} month^{-1}; n = quadrat size (km^2); N = area of woodland (km^2).

Results

WOODLAND DECLINE

The 1982 aerial photographs indicated low levels of sparse woodland within the Park, with just over 140 hectares (ha) of the area surveyed classified as sparse woodland (Table 1). The rapid loss of closed canopy and expansion in sparse woodland between 1982 and 1990 was striking (Fig. 1). While recognizing the problems of interpreting aerial photographs (cf. Wolf 1983), the analysis suggests that sparse woodland increased by 299% in 8 years. The population more than doubled during the period 1977–92 (Fig. 2), thus the conventional wisdom of population-led woodland decline, in response to increased fuelwood harvesting pressures in the Park, appears to be supported by the analysis of aerial photographs.

FUELWOOD USE

Systematic monitoring of household domestic fuelwood over an 11-month period suggested that there was no significant [ANOVA: F (d.f. = 10, 308) = 1·79, NS] seasonal pattern in household use of fuelwood (Fig. 3). Nevertheless, the largest difference was between the months of July, the coldest month, and November, the hottest (discussed in Abbot 1996). Thus, the present analyses used the mean fuelwood consumed capita^{-1} week^{-1}, averaged across the months for which the surveys were undertaken (Table 2).

Similarly, the quantity of wood used for fish smoking was averaged across the 11 months of the survey (86·8 ± 22·34 kg week^{-1} station^{-1}). Table 2 contrasts the mean quantities of wood used for construction, domestic fuelwood and fish smoking purposes.

Each villager consumed substantial quantities of fuelwood (10·1 ± 3·7 kg capita^{-1} week^{-1}) and the estimated annual consumption of fuelwood in the enclave villages was similarly large [4433 tonnes (t) year^{-1}]. These results appear to support the hypothesis that domestic fuelwood collection has a substantial impact on woodland communities.

Dead wood production was estimated at 10·4 ± 2·6 kg quadrat^{-1} month^{-1}, suggesting a mean production of fallen dead wood within the Park of 9481 t year^{-1} (Table 3). This estimate excludes the islands, which are not accessible to women fuelwood collectors, although they are used for collection of fuelwood for fish smoking.

It should be noted that the data represent fallen dead wood rather than wood mortality; dead wood in *miombo* remains aerial and attached to the tree for long periods before falling to the ground, often as the result of advanced decay. The data may overestimate dead wood production because in the absence of appropriate facilities for drying and storing the wood, the study did not correct for moisture content and thus wet season data may inflate the biomass data. However, it is probable that villagers harvested some fuelwood from within the permanent quadrats even though the village chief had requested them not to do so. Fuelwood harvesting would result in an underestimation of dead wood production.

Table 1. Monitoring vegetation and land-use change within Lake Malawi National Park: aerial photographic analysis from 1982 and 1990

	Total area of each land-use category (ha)		Net change as percentage area of land-use category	Area change as percentage of total area analysed
Year of photographs	1982	1990	1982–90	1982–90
Land-use category				
Closed canopy woodland*	6338	5926	−6·5	−6·2
Sparse woodland	141	621	+342·0	+7·3
Settlements	4	4	0	0
Cultivated land	104	35	−66·3	−1·1
Closed canopy woodland on islands	578	578	0	0

Total area analysed: 8222 ha.
Area of enclave villages (not gazetted within the Park): 1058 ha.
Area of Domwe, Thumbi West and Thumbi East Islands: 578 ha.
Area of National Park on Nankumba Peninsula: 6586 ha.
*The area of closed canopy woodland was deduced by subtracting the areas of all other land-use categories from the measured area of the National Park on Nankumba Peninsula.

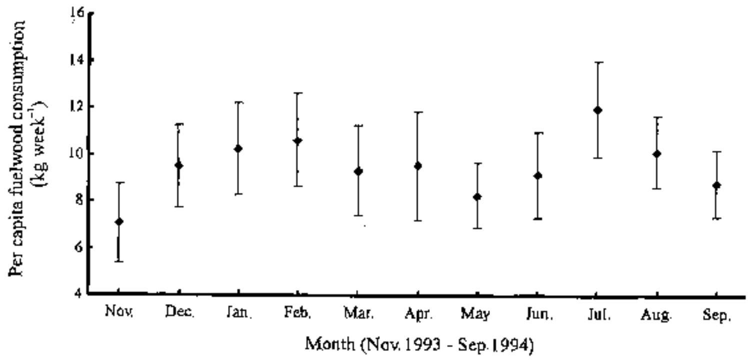

Fig. 3. Seasonal variation in domestic fuelwood consumption (n = 30). Error bars indicate 95% confidence intervals.

Table 2. Estimated quantities of wood used for domestic fuelwood, fish processing and house construction purposes

Wood use	Mean quantity	n	SD
Domestic fuelwood	10·1 kg capita^{-1} week^{-1}*	30	3·7
Construction materials	169 poles household^{-1}	59	77·47
Commercial fuelwood: fish processing	86·8 kg station^{-1} week^{-1}*	4	22·34

*Figures derived by calculating the mean amount of wood used by each station/household over the sampling period and then taking the mean of the summed household/station means.

Table 3. Comparing the production of fallen dead wood with domestic fuelwood consumption in the five enclave villages

Parameter	Mean	95% confidence intervals
Mean dead wood produced (kg) quadrat^{-1} month^{-1}	10·4	3·98–16·73
Estimated dead wood (t) produced on Nankumba peninsula year^{-1}*	9481	3646–15 325
Estimated domestic fuelwood (t) consumed by the five villages year^{-1}†	4433	4033–4872
Estimated fuelwood (t) consumed by fish processors in all five villages year^{-1}	1376	813–1935

*Area of Nankumba Peninsula covered by woodland (both sparse and closed canopy) is 68·7 km^2, excluding the islands.
†Assumes a total population of 8440 people consuming 10·1 kg person^{-1} week^{-1}.

The mean annual production of fallen dead wood in the Park was more than twice the mean annual domestic fuelwood consumption (Table 3). The most extreme maximum estimate of consumption (the upper confidence interval) exceeded the most conservative estimate of fallen dead wood (the lower confidence interval), but they were of the same order.

These results suggest the *miombo* woodlands are likely to provide a sufficient quantity of dead wood for the enclave villages if women select dead wood to make their bundles. However, this analysis does not incorporate the quality of the dead wood produced. Table 4 indicates the size and species preferences for domestic fuelwood and other woody resources used in the village. The mean mid-point diameter of the domestic fuelwood selected was small, less than 4 cm. Women also selected a wide range of species: 28 different species were recorded in the 30 bundles that were analysed, i.e. women used nearly one-third of the 95 different species recorded in the vegetation survey (Abbot 1996). However, one hardwood species, the canopy dominant *Brachystegia microphylla* Harms, was preferred and used most frequently.

While the quality of collected firewood was documented, dead wood produced was not recorded in terms of size or species. The experimental plots measured only the quantity of fuelwood above the utilization limit. It was observed, however, that the dead wood consisted primarily of branches of small mid-point diameter, rather than large logs or trunks of fallen trees (cf. Shackleton 1993).

TRACKING WOOD COLLECTORS

By tracking wood collectors, it was possible to detail the tools used and determine how women collect firewood. Women wood collectors had only limited tools for obtaining fuelwood: of 78 women, 39% collected by hand, 36% with a panga knife and 12% used sticks to dislodge dead branches still attached to the tree. Only 13% made use of axes suitable for felling trees. No trees were felled during the wood collection trips when women were tracked, although this may be an artefact of being observed. Much of the gathered wood was dead, although live wood was collected using panga knives or by breaking small branches.

CONSTRUCTION POLES

The enclave villagers collect poles from the *miombo* woodland for house and fence construction. The results from measuring 30 houses in Chembe indicated poles of small size classes were preferred (Table 4), although larger poles were selected for house supports (upholding the roof) than for fencing or roofing purposes. While large numbers of stems were used in house construction, these items have extended durability. Poles were selected from a wide species base,

Table 4. Size class, species preferences and estimated durability of wood selected for domestic fuelwood, fish smoking and construction purposes

			Construction		
	Domestic fuelwood	Fish smoking	Roofing poles	Fencing posts	House supports
Size class (%)*					
1	73·3	8·0	93·9	89·1	51·1
2	26·6	43·3	6·1	10·1	48·9
3	0·1	41·4		0·7	
4		12·1			
5		1·9			
6		0·5			
Mean mid-point diameter (cm)	3·6	11·2	3·5	3·5	5·6
SD	1·5	3·8	1·1	2·1	1·7
Durability† (years)			14·3	12·5	12·2
No. species encountered	28	14	19	15	15
Species most frequently used	*Brachystegia microphylla* Harms	*Brachystegia microphylla* Harms	*Markhamia acuminata* (Klotzsch) K.Schum	*Bridelia* spp.	*Commiphora africana* (A.Rich.) Engl
% wood comprised of most frequently used species	40·9	56·9	23·7	18·6	34·2
n	1081	372	165	138	135

* Size classes were determined in 5-cm increments, thus size class 1 = <5 cm, size class 2 = ≥ 5 cm $-$ <10 cm, etc.
† Durability depends upon the species used; the figure displayed is the average durability combined across all species encountered.

with no single species dominating. Among the 30 focal households in Chembe, 47% grew *Eucalyptus* spp. within the compound, both for home use and as a cash crop, and 30% grew *Eucalyptus* spp. within farmplots (Table 5). This species is preferred because of its rapid growth and coppicing ability. The poles of many *miombo* species [e.g. *Commiphora africana* (A. Rich) Engl. and *Lannea discolor* (Sond.) Engl.] take root and grow to form 'live' fences (Coates Palgrave 1983) explaining the high proportion of study households with *Commiphora* spp. (47%) and other *miombo* species (*Kirkia acuminata* Oliv., 23%; *Sterculia* spp., 10%) growing around the compound.

FISH SMOKING

Table 6 documents the number and ownership (by cultural group) of fish smoking stations within the five enclave villages. Data from four fish smoking stations monitored at Msaka demonstrated their preference for wood of a very large size class. On average, the logs had a mid-point diameter three times larger than the average piece of fuelwood selected for domestic purposes (Table 4). Species selection was narrow. Nearly two-thirds of the logs monitored consisted of just one species, the dominant hardwood canopy tree, *Brachystegia microphylla* (Table 4). This activity was highly species specific: in total, just 14 different species were recorded at four fish smoking stations during the 11-month monitoring period.

Large fish are conventionally smoked at open wire smoking places. This preserves the fish, increasing domestic shelf-life and allowing transportation to markets. Fish processors require fuelwood that burns for a long time without producing much smoke that would taint the fish. Hardwood species are preferred because they produce *makala* or coals that retain heat. Large logs of wood are selected that burn for prolonged periods, without the fire going out.

Fish smoking was usually carried out by men and the wood was collected by them (but they were never seen collecting domestic fuelwood). Wood of the preferred large size class was obtained from trunks, requiring the felling of the tree, or from very large branches. In contrast to women, men had the tools that are required to fell trees: of 27 men, 46% used panga knives, 42% had axes and 7% had saws. Whereas most women collected by hand, just 5% of men collected in this fashion. In addition, the men had several options for transporting their fuelwood loads: of 27 men, 45% used a bicycle, 22% a dug-out canoe and 11% a boat. Only 22% of men collected wood on foot, but this was the sole method of transporting fuelwood observed amongst domestic fuelwood collectors.

Discussion

DOMESTIC FUELWOOD

The results indicate that a moderately large quantity of wood is used per capita (10·1 kg capita^{-1} week^{-1}; cf. 6·8 kg capita^{-1} week^{-1} for Amboseli Maasai, Barnes, Ensminger & O'Keefe 1984; 687 ± 48·8 kg person^{-1}

Table 5. Exotic and *miombo* tree species grown in compounds and on farms in Chembe village (n = 30)

Species	No. (%) households growing trees for poles within their compound	No. (%) households growing trees for poles within their farmplots
Eucalyptus spp.	14 (47)	9 (30)
Kirkia acuminata Oliv.	7 (23)	0
Commiphora spp.	14 (47)	0
Sterculia spp.	3 (10)	0
Cassia spp.	0	1 (3)

Table 6. The number of fish smoking stations owned in each village and by each cultural group, together with the estimated population size of each village

Village	Northern cultural group (Tonga or Tumbuka)	Southern cultural group (Chewa, Yao or Lomwe)	Population (1994 census)
Chembe: Nsonga and Nchenga	0	6	3083
Chembe: Dwale	35	37	169
Msaka	31	16	2495
Mvunguti	86	30	2106
Zambo	42	3	464
Chidzale	19	0	123
Total	213	92	8440

year^{-1} or *c.* 13 kg capita^{-1} week^{-1}; Shackleton 1993). However, total domestic fuelwood use appears to be less than the estimated total production of fallen dead wood, and the most extreme maximum consumption estimate is of an order similar to the most conservative minimum production estimate. Group discussions emphasized that village women prefer dead wood as an energy source, because of its ease of collection and superior burning properties compared with live wood (Abbot 1996). Thus, if villagers act on their expressed preference for dead wood, this analysis suggests that the *miombo* woodland can support high levels of fuelwood harvesting: specifically, it is estimated that the fuelwood requirements of the total population of 8440 people living in the Park can be sustained by the fallen dead wood produced in just 69 ha of woodland.

There are three main caveats in this analysis. First, the availability of dead wood does not mean that women use dead wood, or use it exclusively. However, because dead wood is easier to harvest than live wood, and makes better fuel, it is not unreasonable to assume that women use this resource where it is available. Secondly, the findings do not imply that domestic fuelwood collection has no impact on the woodlands; some authors have expressed concern over nutrient stripping through removal of dead wood (Hall & Bawa 1993). Rather, this study demonstrates that patterns of wood collection and preferences are important factors that determine the sustainability of resource use. Thirdly, it should be noted that the dead wood production estimate is for the whole Park, yet women's wood collection activities are concentrated in woodland areas proximal to the village. This suggests that highly frequented woodland areas would be depleted of dead wood, with more dead wood available in less accessible areas. This was observed in the Park and has been demonstrated by Grundy *et al.* (1993) in a study of woodland use in resettlement areas of Zimbabwe.

Other research supports local preferences for dead wood as an energy source. Working in the Sudan, Whitney (1987) suggests that 'in rural areas most of the fuelwood comes from dead branches, and ... only 10% of the rural firewood used involves the destruction of entire trees'. Similarly, the World Bank Industry and Energy Department (1991) estimates that, in many rural areas, dead wood may represent over 80% of the fuelwood collected by villagers. Shackleton (1993) investigated fuelwood harvesting in a communal grazing land and a protected area in the South African Lowveld. He demonstrated that the amount and size class of dead wood at the harvested site was significantly reduced, showing people's preference for this resource.

Women use a range of species and size classes because different woods have different purposes. For example, small fast-burning woods are used to start fires, while larger slow-burning species maintain fires for cooking purposes. Furthermore, because women headload their bundles, they select a variety of fuelwood species, a trade-off between preferred hardwoods that are heavy to carry and lighter species that are less efficient fuelwoods. The dominant species used for domestic fuelwood, *Brachystegia microphylla*, accounted for over 40% of all pieces enumerated (similarly in the Amboseli Maasai, the dominant firewood species *Acacia nubica* Benth. accounted for 37% of the total; Barnes, Ensminger & O'Keefe 1984). The extent to which preferences for specific fuelwood species and size classes can be met in a wood collection trip to one area of the woodland is not known. It would seem unlikely, however, that bundles of the appropriate quality and quantity could be compiled entirely of dead wood, especially in the more frequented areas of the woodland close to the village. Thus, women are likely to cut some live wood and this is consistent with our observations that bundles comprised both dead and live wood.

The collection of a combination of dead and live wood will not necessarily have a discernible, negative impact on woodland communities. The sustainable offtake of fuelwood is much higher than just the production of dead wood. Shackleton (1993) assumes that 3% of the standing crop is a sustainable yield. The high growth rates of coppiced species (see below) imply that sustainable yields from natural woodland could be even higher. But long-term ecological research beyond the scope of this study would be needed to monitor the impact of the cutting of live wood on coppicing and woodland regrowth.

A final point on the use of domestic wood concerns the tools available for fuelwood collection, which are able only to cut small wood. This corroborates the findings in Table 4 indicating selection of fuelwood of a small mid-point diameter. Furthermore, because all domestic fuelwood is headloaded, women assert that they avoid large logs because they are heavy to carry and preclude the transport of a range of different species.

CONSTRUCTION POLES

The extended durability of construction poles used in the villages suggests that their collection is unlikely to cause the observed woodland decline. Furthermore, the use of *Eucalyptus* spp. grown within the village enclaves as a cash crop reduces village dependence on the Park's natural resources. The commonly observed habit of fencing poles taking root as live hedges reduces the need for further fence pole collection.

Few studies document the internal changes in woodland structure and woodlands in response to selective collection of woody resources, or their sustainability (Hall & Rodgers 1986; Hall & Bawa 1993; Medley 1993). However, the important role of vegetative reproduction, or 'coppicing', from the stumps and root masses of felled trees in facilitating woodland recovery is increasingly recognized (Stromgaard 1986;

Nyerges 1989; Chidumayo 1993; Medley 1993; Shackleton 1993). Based on crude estimates of wood consumption within the enclave villages, Bell (1978) predicted that a wood crisis would occur within 30 years. While his calculations were somewhat 'political' in their use to establish a National Park in the area (R. H. V. Bell, personal communication), he attributes the failure of his forecast to the underestimation of coppice regrowth in the Park woodlands.

FUELWOOD USED IN FISH SMOKING

A less obvious but major use of wood in the village is fish smoking. The large quantities of wood required to smoke fish (Table 2) supports the hypothesis that this commercial enterprise will have a major effect on the Park woodlands. Open wire fish smoking places have a high fuelwood consumption: trials around Lakes Chilwa and Chiuta, Malawi, suggest that approximately 1 kg of wood is required to smoke 1 kg of fish (Walter 1988). Moreover, the large size of the wood selected suggests that harvesting will have a direct effect on the woodland canopy (Table 4). In her study of Tana River National Primate Reserve, Kenya, Medley (1993) suggests that the removal of large trees leaves a gap in, and opens up, the forest canopy. This is consistent with the pattern of change observed in the aerial photographs suggesting the removal of mature canopy trees. In addition, the number of fish smoking stations in each village illustrates the great pressure that fish processing puts on the Park woodlands. While large quantities of dead wood are produced in the woodlands, the narrow species diversity and large size of fuelwood required by fish smokers limits their use of this resource.

HISTORICAL PATTERNS OF WOODLAND-USE

Fish smoking is an important commercial enterprise in most of the enclave villages, and may be having a profound effect on woodland cover. Several lines of evidence suggest that the scale of fish smoking has changed with:

- change in fishing gear used and hence size of fish caught;
- urban demand for preserved fish.

Early accounts suggest that traditional Chewa fisheries focused on fish small enough for sun-drying (Berry & Petty 1992) using the open-water seine nets still common in the Chembe fishery today. Gill nets, which catch much larger fish, were rare in Chembe in the 1930s (Bertram, Borley & Trewavas 1942, in Smith 1993a) but have increased, probably as a result of the recent influx of the Tonga and Tumbuka from the north of Malawi (Smith 1993b; Fig. 2). They settled in Dwale (the easternmost part of Chembe; Fig. 1), Msaka, Mvunguti and Zambo villages, where they introduced and expanded gill net fishing. Smith (1993b) reports that half of all gill net fishing at Chembe is undertaken by the few northerners who live at Dwale. The larger fish caught by gill netting may be sold fresh to tourists, eliminating the need for processing. However, most fish is preserved by smoking for sale to urban markets.

The scale of fish smoking seems to have increased along with gill netting: Bell (1978) found that 73% of 1858 people in Chembe and 82% of 520 people in Msaka used no wood for fish processing. Fish smoking is now widespread among the enclave villages but is primarily undertaken by people of northern origin; currently around two-thirds of fish smoking stations are owned by northerners, and one-third owned by Chewa and others of southern origin (Table 6). Recent, but extensive, use of wood (particularly of large logs) for fish processing is consistent with aerial photographic evidence demonstrating significant woodland decline in the late 1980s.

Immigrants may be less constrained by local management systems governing natural resource use than long-established residents (Ribot 1998), although it is often convenient to blame migrant communities for irresponsible resource use and environmental damage (Fairhead & Leach 1995). However, the present study suggests that it is the activities and technologies (i.e. gill netting and wood-dependent fish processing) initially introduced by, and still preferentially associated with, one culture more than another, that appear to affect resource use. Therefore, the present study identifies a commercial activity that appears to have a severe impact on the woodland environment, rather than a particular cultural group.

Urban demand for fish was always high (Berry & Petty 1992) and is growing, with ever increasing urban population numbers driving ever higher extraction. Preservation of the large catches enables fish to be transported and sold in inland markets; only a small proportion of fish landed is consumed in the village. This study indicates that the commercial fish enterprise depends entirely on the free extraction of substantial quantities of wood from Lake Malawi National Park.

Conclusions and recommendations for management

The present study has used ecological and anthropological methods to investigate the status of the Lake Malawi National Park woodlands in combination with the use of woodland products in the enclave villages. Woody resources are extracted for use as domestic fuelwood, for construction materials and for commercial fish smoking. Because of the large village populations, these activities appear to be detrimental to the woodland, reducing mature, closed canopy woodland to sparse woodland. Deforestation in *miombo* means a decreased capacity to protect watersheds adequately and prevent soil erosion (Sharma 1985, in Chidumayo 1997). Woodland degradation also reduces the Park's aesthetic value, an important factor in tourist attraction (cf. Emerton 1995).

This research demonstrates that not all wood collection activities have an equal impact on the woodlands of the Park. In spite of their conspicuous collection patterns, and the relatively large woody biomass consumed overall, domestic wood collectors appear to have limited impact on the woodland. Wood cutting for building materials appears to have a similarly limited impact on woodland communities. However, wood used in the commercial activity of fish processing is taken from a narrow species base and is biased towards large size classes, which requires tree felling.

The present study suggests that it is a commercial activity, with an urban demand for the fish product, that drives the decline in closed canopy woodland within the Park. This is consistent with previous studies that demonstrate that the end-use, and demand for, the product are key determinants of offtake. Specifically, several studies have made a distinction between the impact of urban and rural demands on woodland communities (Whitney 1987, fuelwood in the Sudan; Chidumayo 1987a, 1987b, 1993, charcoal production for the urban market in Zambia; Ribot 1995, 1998, charcoal in Senegal; Ravindranath *et al.* 1991, impact on tree biomass of urban fuel demand in India; Hall & Rodgers 1986, pitsawing timber for commercial rather than local use).

At Lake Malawi National Park, a complex mixture of history of technological and livelihood change, population migration, and changing regional and national markets for the Park's resources appears to underpin woodland decline. At the microlevel, gender differences in access to tools for resource harvesting and modes of transportation influence wood selection and cutting practices, and thus the impact that different harvesting activities have upon the resource base.

By disaggregating the various wood cutting practices that impact upon the woodlands of the Park, this study provides a basis for informed management policies by the Malawi Department of National Parks and Wildlife. These should focus on methods of reducing demand for, and providing alternative sources of, woody biomass within the enclave villages. In addition, law enforcement and forestry extension efforts should be shifted in emphasis to address what appears to be the most damaging form of wood use, the selection of fuelwood for fish processing.

Leach & Mearns (1996) note that 'the driving force behind much environmental policy in Africa is a set of powerful, widely perceived images of environmental change'. The conventional analysis that deforestation in Lake Malawi National Park is caused by the domestic use of fuelwood is a prime example. This study has highlighted the fallacy of routinely applying conventional assessments of the impact of harvesting practices on woodland resources. The multi-disciplinary nature of this research has enabled the causes and effects of resource use to be explored by taking a detailed historical, local level and disaggregated approach to studying patterns of woodland use.

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