Mopane Woodlands and the Mopane Worm: Enhancing rural livelihoods and resource sustainability

Final Technical Report

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Executive Summary

The mopane worm (MW), *Imbrasia belina*, and mopane woodland products are key resources to poor farmers and landless poor people across southern Africa. The project purpose was to identify the principal factors that limit MW production and to determine how MW and mopane woodland can be managed to increase production. Socioeconomic studies addressed the use of MW as a livelihood support for poor rural people. Ecological investigations will build on existing knowledge of MW biology and mopane woodland management to facilitate improved management of mopane woodland to increase mopane worm yields; and a community mopane worm farm will be established. Principal ultimate beneficiaries will be the rural poor across the mopane zone.

Background

The widespread utilization of non-timber forest products (NTFPs) by rural households in sub-Saharan Africa has been confirmed by several studies (exhaustively reviewed in Townson 1994). Forest foods, firewood use and sale, basketry and handicrafts, furniture and carpentry and other extractive products all form a portfolio of NTFPs that have an important role to play in the growth and functioning of rural households' small-scale enterprises and collectively make substantial contributions to rural households economies. Indeed, Cavendish (1999a) using household data from rural Zimbabwe, showed that environmental resources generated as much as 35 percent of average per capita incomes, with major contributions coming from wild foods, firewood, the use of woodland-derived construction materials, and the contribution of woodland areas to livestock browse and graze. Furthermore, this study revealed significant differentiation in resource use by different rural groups. Poor households, for example, derived over 40 percent of their income from environmental resources, and resource dependence declined systematically as households became richer.

Mopane worms, caterpillars of the Anomalous Emperor Moth *Imbrasia belina*, which feed almost exclusively on the mopane tree *Colophospermum mopane*, are a valuable NTFP resource that contribute substantially to rural economies and nutrition in mopane forest areas. The value of mopane worms in South Africa alone has been estimated at £2,850 ha^{-1} (Rebe 1999), and extrapolation from Styles's (1994a) estimation of mopane worm density, the annual population of mopane worms in South Africa's 20,000 km^2 of mopane veld is worth £57m, of which approximately 40% goes to producers who are primarily poor rural women. In addition to their value as an income source for poor rural women, mopane worms also provide nutritious food for rural households and urban dwellers. Traditionally, mopane worms have been harvested for subsistence use by rural households (Ashipala *et al.* 1996) and they are thought to make a significant contribution to rural diets, although there has never been a proper assessment of this. Malnutrition, particularly with pre-school and primary school rural children, is a serious problem in many areas of South Africa (Vorster *et al.* 1997). Dried mopane worms have a high protein content with 65.8 percent dry weight crude protein content and 53.3 percent dry weight digestible protein (Siame *et al.* 1996; Dreyer and Wehmeyer 1982). Rebe (1999) suggests that a daily intake of mopane worms could play an important role as a source of nutrients for pregnant women and children in rural areas, but found that adults consume mopane worms more frequently and in larger quantities than children. Increased supplies of mopane worm in both rural and urban areas therefore have the potential to address food security problems both by increasing incomes for poor mopane harvesters or producers (providing financial capital for food purchases) and by increasing the availability of a high-protein and popular food.

Harvesting of mopane worms takes place during a short period (about three to four weeks) while the caterpillars are on the tree. There is usually one main harvest per year but a smaller second harvest occurs in April or May following good rains. Harvesting is mostly done by women (Dithlogo *et al.* 1996, CAMPFIRE 1999) who hand pick the caterpillars from the branches or, on larger trees, shake the trees or cut infested branches. Most estimates suggest that an individual can harvest between 25 and 50kg of mopane worm per day (Ashipala *et al.* 1996). Following harvesting, the caterpillars are eviscerated, boiled and dried in the sun, after which they can be stored for almost a year. Thus, the consumption of mopane worms can occur over a considerably longer period than the harvest, provided processing and storage procedures are adequate to avoid spoiling.

Mopane worms form just one part of a whole set of household economic activities and therefore it is important to place mopane worms in the context of the wider rural household economy. Rural household economic activities are multifarious, usually comprising agricultural production, livestock rearing, a variety of non-farm enterprises, migration and economic connections to formal labour markets, goods trading, and the collection and use of freely-provided environmental goods, some of which come from forests and woodlands. From the perspective of rural households NTFPs form just one component of a set of livelihood activities, and mopane worms comprise a single, albeit important forest product. An important goal of socioeconomic research on mopane worms is therefore to place (i) the value of mopane worm use in the context of the broader household economy and (ii) to identify the opportunities and constraints arising from interactions between mopane worm based activities and other household activities.

According to Rebe (1999) commercialisation of the mopane worm trade in southern Africa has led to over-harvesting with rural women now collecting substantially more than a single person would have traditionally harvested for family consumption alone. Apparent over-harvesting in South Africa has led to strong demands for imported mopane worms from Botswana (Moruakgomo 1996; Letsie, 1996). Coupled with reports of over-harvesting there is also a severe lack in basic knowledge needed to manage mopane woodlands in the face of increasing and multiple resource demands. The need for the broader management of mopane woodland stems from the use of woodlands as sources of building material, firewood, charcoal production, rope and medicine. Mopane woodland studies are therefore needed to meet the demands of multiple resource management.

The value of the mopane worm trade is substantial. The commercial value of mopane worm harvests can reach $3,000 per ha (DeFoliart 1995) amounting to annual sales of 1.6m kgs in South Africa alone. In Botswana, the mopane worm harvest in a good year is estimated to be worth $3.3m, providing employment to 10,000 people (Styles 1995a). It is unlikely that these values are achieved year on year as the mopane worm trade is known to fluctuate. The basis for this is not economic, as demand for mopane worms appears to be constant, but rather ecological in that mopane worm outbreaks are temporally and spatially erratic. The irregular and largely unpredictable nature of mopane worm outbreaks results in price fluctuations and uncertainty of supply, both undesirable outcomes for poor, risk-averse farmers. Variability in the geographic occurrence of outbreaks may also lead to conflicts between community groups. One of the main objectives of this programme is therefore to mitigate this “feast-or-famine” harvest problem by means of community-based mopane worm farming, so as to stabilize the mopane worm industry and provide rural people throughout the southern SADC region with more stable and sustainable seasonal incomes as well as an important source of protein.

Previous studies indicate that trading networks are complex (Ashipala *et al.* 1996) involving several different marketing channels drawing on several producer groups, middlemen, wholesalers, retailers and consumers, although in general the structure of the mopane worm market chain is poorly known. Given that the main market constraint is the intermittent supply rather than demand it seems likely that mopane worm commercialisation will not face the demand constraints that have often undermined other NTFP commercialisation projects. Yet in meeting poverty alleviation objectives it is essential that steps along the market chain at which value is added are identified and quantified to ensure that the benefits of commercialisation are realised by the poor producers and urban retailers as well as the wholesalers and consumers.

Mopane worms are generally harvested from communal woodlands. As a consequence of the good returns associated with mopane worm trading, and the fact that outbreaks occur in different areas from year to year, it is now common to find people using motorised transport to harvest mopane worms for commercial purposes and far from their local communities (Ashipala *et al.* 1996). This increased harvesting pressure may be causing social and ecological problems. Outsiders are less likely to ask for permission to collect and more likely to strip the resource. In return, local communities are attempting to impose rules on worm collection, but in the context of a management system where these have never existed before, and where little is known about scientific management of mopane generally (Timberlake 1996). Problems of resource access, resource supply and community conflict appear to be emerging in response to mopane worm commercialisation (Ashipala *et al.* 1996, Cunningham 1996, CAMPFIRE 1999). Underlying the economic considerations of the mopane worm trade are the ecological constraints to mopane worm supply. Despite the recent growth of the economic importance of mopane worms there are no empirical data on the population dynamics of *I. belina*, although considerable anecdotal evidence indicates that it displays outbreak dynamics as noted above. A study of the population dynamics of mopane worm lay outside the scope of this project, and so remains a major researchable constraint that underlies the long term sustainability of harvesting from wild mopane worm populations.

The socioeconomics of mopane worm reveals several weaknesses and research gaps that are relevant to the commercialisation of mopane worm and the realisation of benefits from increased trade to poor producer communities. These gaps include:

- the contribution of mopane woodland products generally and mopane worm in particular to rural households’ consumption and income.
- differentiation in mopane woodland and mopane worm resource use across rural households.
- the access and harvest rules that surround mopane woodlands and mopane worm utilisation.
- the supply chain for mopane worm harvesting, distribution, wholesale and retail, particularly who is involved, and where value added in the supply chain is generated

An additional constraint on the continued contribution of mopane worms to rural livelihoods and the wider economy is the persistence of the resource base upon which mopane worm s depend. *Imbrasia belina* caterpillars feed almost exclusively on mopane trees *Colophospermum mopane* which forms almost monospecific stands over large tracts of clay-rich soils in southern Africa. *Colophospermum mopane* is a xeric species of the savanna woodland zone of south central Africa and occurs within an altitudinal range of 300-1000m (Timberlake 1995, 1996). Mopane woodland is very variable in character ranging from stands of trees up to 18m high, though is more usually about 10m (Palgrave 1977), to low scrub attaining 1-2 m only. Mopane woodland is unusual in that it generally occurs in monospecific stands that supports a relatively poor shrub layer. It provides woodland cover where few other tree species occur (Timberlake 1995, 1996). Stands are often even-aged indicating episodic or cohort recruitment.

There is little information on growth rates of mopane under various conditions, which is a major limitation in the ability to manage and utilise mopane worms and the mopane trees on which they depend. Herbivory by mopane worms is likely to affect growth rates (Ditlhogo *et al.* 1997) and possibly the capacity and quality of new leaf growth following defoliation. Mopane leaves are generally not favoured by vertebrate browsers and are used only in drought years. It therefore seems likely that they contain plant defence compounds such as phenolics and tannins. As herbivory and defoliation can induce the production of plant defence compounds, natural defoliation or tree management may affect the quantity and quality of subsequent leaf growth and therefore the quality and availability of mopane leaf fodder for mopane worms, livestock and game alike. It was not possible to conduct long term growth rate studies on mopane trees over the duration of this project but an objective included assessing plant growth responses to various management strategies to increase leaf production and decrease defoliation stresses.

Previous studies of the growth of mopane trees, as well as the effects of coppicing and pollarding (Tietema *et al.* 1988; Tietema 1989; Tietema *et al.* 1991; Erkkila and Siiskonen 1992; Mushove 1992; Mushove and Makoni 1993; Mushove 1999) have shown that *C. mopane* readily produces coppice shoots (20 to 80% of stumps had coppice shoots 3 months after cutting; Mushove 1999) and that pole production from seedlings takes twice as long as from coppice. In Namibia, the best growth could be achieved by restricting coppice growth at 1 to 2 stems per rootstock and basal diameters of 50 - 250mm are achievable within 5-10 years. Trees coppiced at a height of 1m produced more, and more vigorous, coppice shoots than trees coppiced at 10cm, and smaller trees coppice more effectively than larger trees. Coppicing has been found to be most productive just before the onset of the summer rains.

Despite the literature mentioned above there is little information available on the establishment, growth rate and mortality of *C. mopane*. Notwithstanding the economic importance of mopane woodlands, little basic ecological research has been done on this tree species, with a resulting paucity of information on the management of mopane woodlands, as reviewed in Flower *et al.* (1999). There is particularly little known about the nutritional value of *C. mopane* leaves at different times of the year.

The life cycle of the *I. belina* on mopane under field conditions is well known (Oberprieler 1995; Ditlhogo 1996a). Peaks in abundance of both species are between November–January (major) and March–May (minor), though population numbers vary from year to year at any single locality. Consequently the areas from which the caterpillars are harvested vary from one year to the next. Individual trees or sizeable patches of trees can be almost totally denuded by these larvae, but usually only one brood per year is found on any individual tree (Voorthuizen 1976). The defoliation pressure exerted by the caterpillar has been found to affect the fecundity of trees, with the largest trees being least affected (Ditlhogo *et al.* 1997). Moths appear to favour the largest trees for oviposition (Ditlhogo *et al.* 1997).

The abundance of the mopane worms is, apparently, declining (Roberts 1998) as a result of increasing exploitation of mopane trees (Hobane 1995) and a general increase in pressure on mopane woodlands. Bartlett (1996) also reports of the disappearance of the mopane moths from parts of Botswana after heavy harvesting. Suggested threats to mopane worm abundance, in addition to over-harvesting, include deforestation of mopane woodland, and increased frequency of drought. However, the absence of mopane worms from certain regions of mopane woodland has not been satisfactorily explained. Areas where caterpillars occur yearly have been noted to have low ant predation and high browse quality in contrast to regions where caterpillar are rare and sporadic in their occurrence (Styles and Skinner 1996). Other possible factors include soil type, rainfall or a combination of these (Styles and Skinner 1996). An assessment of the current status of mopane worms across southern Africa and studies of its population biology are imperative to provide the baseline data that are essential to reliably determine sustainable levels of use and to inform natural resource management programmes such as CAMPFIRE in Zimbabwe (Child 1996). While the precise influence on larval populations has yet to be clarified, increased harvesting pressure may have wider effects on the mopane ecosystem itself. Mopane trees may be felled or branches lopped to facilitate harvest of the worm. The tallest mopane trees may be most at risk as they are the most heavily laden with caterpillars which are beyond the reach of harvesters. Although mopane trees are in no danger of becoming scarce, selective destruction of the tallest individuals may have profound consequences for the abundance of mopane worm and other mopane herbivores such as elephant and various host-specific insects. Research into the extent of tree felling for gathering mopane worms and the effects of this practice on mopane worm populations and other resources provided in mopane woodland is needed to ensure continued supply of these resources.

Perhaps the greatest impediment to the further commercialisation of mopane worms is their temporally restricted abundance. If it is possible to raise mopane worms artificially through simple domestication programs then the seasonal dependence on the market and the degree of exploitation on the natural occurrence of the worms would be reduced. Development of such as system is one of the main objectives of this project.

Project Purpose

The overall aim of the project was to develop strategies for improving livelihoods of mopane worm collector communities through improved production and marketing of mopane worms. This purpose was approached from four main perspectives:

1) management of mopane trees to support higher densities of mopane worms at local (household and village) scales,
2) domestication of mopane worms using new techniques and incorporating new knowledge from the integral research on mopane tree management,
3) improving the quality of mopane worm processing by promoting more hygienic processing methods and developing and piloting new processing technologies,
4) understanding the market chain to identify the opportunities for securing better returns to collector communities.

Research on management of mopane trees aims to address the main constraint of domesticating mopane worms, that is the provision of good quality and abundant fodder year round. Development of domestication strategies would, if successful, remove the dependency of rural communities of erratic and spatially unpredictable mopane worm outbreaks, and enable the production of higher quality mopane worms throughout the season. A key constraint of marketing mopane worms is the quality of the product which is often unhygeinically prepared and not sufficiently dried or rendered pest free for long term storage. An improvement in processing methods would address the constraints of sanitation and product quality, and also provide opportunities to investigate value addition such as by flavouring or salting. As the price secured by the producer is a small fraction of the market price in large urban centres, a constrain on sustainable production of mopane worms, and on the success of comparatively expensive domestication strategies is the ability to secure a good value for the product by the collectors.

Research Activities

Section 1. Mopane tree ecology and management

Relevant Activities

2.3 Quantify the effect of defoliation by *I. belina* on leaf growth and quality, both within and between seasons, by means of a manipulative field experiment

2.4 Quantify the effect of various management regimes on growth and leaf quality of *C. mopane* by means of a field experiment

The objective of these activities is to improve management of mopane woodland for the purpose of increasing mopane worm yields. To this end the following ecological studies were undertaken:

- The effect of tree management regimes (coppicing, pollarding and pruning) on growth and leaf quality of *C. mopane* were quantified by means of a field experiment.
- The effect of defoliation by mopane worms on the growth and quality of *C. mopane* leaves was assessed by manipulative field experiments.

The study site
Experiments on mopane management and quality were conducted on the Musina Experimental Farm (previously known as the Messina Experimental Farm) (MEF) which is presently owned and managed by the Department of Agriculture, Limpopo Province (previously known as the Northern Province). The MEF is situated *ca.* 20 km west of the town of Musina in Limpopo Province of South Africa. The Limpopo River forms the northern border of the MEF which lies between 22E 12' and 22E 17' S and 29E 50' and 29E 57' E (Dekker 1996).

Additional research on mopane woodland management and mopane worm population biology was conducted in the Plumtree District, Matabeleland South, Zimbabwe. The locations in South Africa and Zimbabwe were chosen as they are in the core of the mopane veld of the two regions and by and large associated with mopane worm outbreaks.

Vegetation of the MEF
According to the classification of Acocks (1988) the MEF falls within the mopane veld, but in the *Colophospermum-Combretum-Commiphora* vegetation community (Louw 1970). In the region of the study plots the woody layer was composed of *C. mopane*, *Grewia* spp. and *Terminalia prunioides*. *Colophospermum mopane* was the dominant species, with an estimated density of 1,344 trees ha^{-1}. The herbaceous layer was composed of various forb species.

Materials and Methods

Manipulating leaf production
Studies in this section were performed to determine the following null hypotheses:

- *Coppicing, pollarding or pruning regimes have no impact on subsequent leaf productivity.*
- *Coppicing, pollarding or pruning regimes have no impact on leaf quality as a food source for mopane worms.*

Tree manipulation studies were initiated during February 2002:

i. Coppicing – Forty randomly selected trees were coppiced at a mean height of 71cm within a plot 29.0 x 13.7 m in a relatively homogenous stand of *C. mopane*. The height at which the trees were coppiced represents the usual height at which rural inhabitants cut *C. mopane* for fuel and other uses. The sawn off parts of the trees were left in the plot to act as rainwash barriers, obstacles for seed accumulation and subsequent germination and organic matter recycling.

ii. Pollarding – Forty randomly selected trees were pollarded at a mean height of 2m within a plot 26.6 x 11.3 m in a relatively homogenous stand of *C. mopane*. The sawn off parts of the trees were also left in the plot. Four healthy branches on each tree were permanently marked after noting the total number of leaves they bear.

iii. Pruning – Seven healthy branches from each of 40 trees were randomly selected and, after recording leaf production in terms of quantity and size, pruned back and permanently marked.

iv. Control trees – Forty trees were randomly selected and permanently marked. Seven healthy branches on each tree were randomly selected and permanently marked.

The treatment and control trees were regularly inspected every 55 days and leaf material collected for further analyses and measurement.

Leaf size

Seven leaves were randomly collected from branches of the 40 treatment and control trees. Leaves were transported in sealed plastic bags to the laboratory in a cooler box. The length, width (at the widest point) and surface area of on of the two leaflets were measured using SigmaScan (Version 5.1, SPSS Inc.).

Leaf quality
Leaf quality is likely to be determined by the nitrogen content of the leaves and the concentration of anti-herbivore defence compounds, principally phenolics and tannins. Phenolic compounds have important roles as plant defence compounds by making leaves less palatable to herbivores (Cooper and Owen-Smith 1985; Herms and Mattson 1992). Tannins also impact animal nutrition by forming complexes with carbohydrates, proteins, polysaccharides, bacterial cell membranes and enzymes involved in protein and carbohydrate digestion (Cannes 2001). Tannins can cause direct toxic effects on the gut (Kreber and Einhellig 1977), impacting larval growth and development (Feeny 1968, 1970; Waiss *et al.* 1981; Al-Izzi and Al-Maliky 1996). Two groups of tannins are widely recognised: hydrolysable tannins, assumed to be insect deterrents due to their ability to precipitate proteins (Salminen and Lempa 2002); and condensed tannins that are located in plant cell walls and protect the living leaf against microbial attack and deter mammalian browsers (Scholes and Walker 1993).

The nutritional quality of *C. mopane* leaves from treatment and control trees were assessed in all growing seasons with samples taken in the wet warm season (December) that is usually associated with the first leaf flush, the cool dry season (June) and the hot dry season (October) which, depending on rainfall patterns, is usually associated with leaf fall.

Seven leaves were collected from the treatment and control trees, transported in plastic bags to the laboratory in a cooler box and dried in plant presses in the shade (Hagerman 2002). Dried leaves were sent to accredited (SANAS) analytical laboratories for the following analyses:

- Protein and Acid Detergent Fibre – ARC-Irene Analytical Services, Irene, Pretoria
- Tannin concentrations – University of Cape Town, Cape Town
- Total nitrogen, polyphenols and various macro- and micronutrients – Institute for Soil Climate and Water, Arcadia, Pretoria

Leaf phenology and shoot growth
The same marked treatment and control trees were also used to record different leaf phenological stages on a 55 day basis. The different phenological stages were defined as follows:

- Buds — Newly formed leaf buds - red in colour
- Young — Young, pliable leaflets still reddish in colour
- MG1 — Mature green leaflets, leaflets still pliable
- MG2 — Mature green leaflets, leaflets rigid
- Senescent — Leaflets yellow with brown dead spots to various degrees
- Dead — Leaflets dead, brown to dark brown and brittle

The number of leaves on all marked branches was recorded every 55 days and vegetative growth recorded at the end of the growing season, following the protocol of Smit (1994).

Results

Characteristics of treatment and control trees
Trees in the treatment and control plots were similar in height and structure. The majority of trees were multi-stemmed with usually two or three stems (Table 1.1).

Table 1.1 Mean height, stem circumference and number of stems of treatment and control trees at the experimental site

	Coppiced	Pollarded	Pruned	Control
Mean tree height (m)	4.14	4.41	4.68	4.42
Mean stem circumference (mm)	167.61	170.92	184.1	161.1
Number of stems	3	2	3	2
Multi-stemmed trees (%)	90	65	73	70

Leaf phenology

The mean number of leaves per marked twig during the successive growing seasons are shown in Fig. 1.1. During the December 2001 to October 2002 growth season, marked twigs on pollarded trees lost leaves between February and April. By contrast leaves on control trees increased between February and April (Fig. 1.1A). Leaves on both pollarded and control trees remained constant between April and June 2002 after which they declined (Fig. 1.1). Pruned branches remained leafless until October 2002 when the first buds appeared. Shoots of coppiced trees were heavily pruned and defoliated by game and cattle. Consequently, the first leaves on intact coppice shoots were only recorded in August 2002. Heavy browsing on mopane appears largely due to the lack of leaf material from other more palatable deciduous tree species which were mostly leafless owing to below average rain at this time.

Changes in the number of leaves (through the retention and/or loss of older, and the formation of new leaves) did not follow any consistent pattern among treatments or across any of the growing seasons. Leaf fall also occurs during the growing season, which results in varying numbers of leaves present on twigs during a particular growing season and between successive growing seasons.

The mean difference between leaf production and retention of control and coppiced trees was significant at the 0.05 level (t-test), with coppiced trees having consistently fewer leaves than control trees. There were no significant differences between the other treatments and the control.

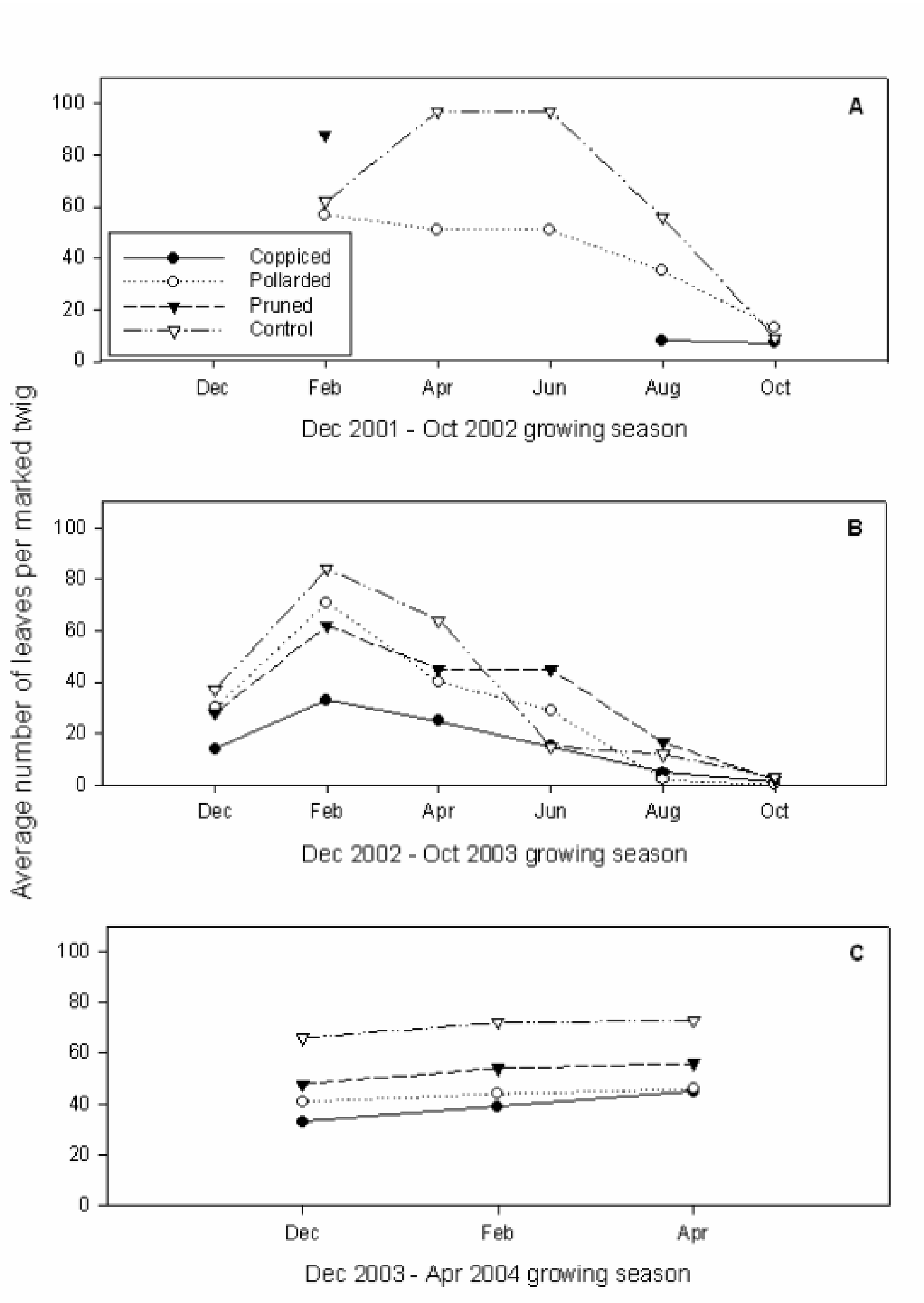


Figure 1.1 Average numbers of leaves per marked branch on treatment and control *C. mopane*.

Changes in leaf sizes

Leaf sizes varied both through the year and between years, though there was no statistically significant difference among treatments (Figure 1.2, Table 1.2). Leaf size was greatest in the third season presumably due to the increased availability of soil water following improved rainfall. No leaves formed on the pruned branches during the 2001 - 2002 growing season (Figs 1.2A & B). Coppice shoots were heavily browsed by game between February and July 2002. Different game species, which included Kudu and Eland, and livestock (Nguni cattle) browsed the shoots to an extent that the first representative leaf counts and measurements could only be made during August/October 2002. Browsing of coppice shoots declined during the subsequent growth seasons presumably due to the abundance of leaf material on other tree species resulting from improved rainfall. During periods of good rainfall it seems that leaf number and leaf size increase while browser pressure declines resulting in conditions that are highly favourable to mopane worm outbreaks.

Figure 1.2. Changes in mean leaflet sizes on treatment and control *C. mopane* trees.

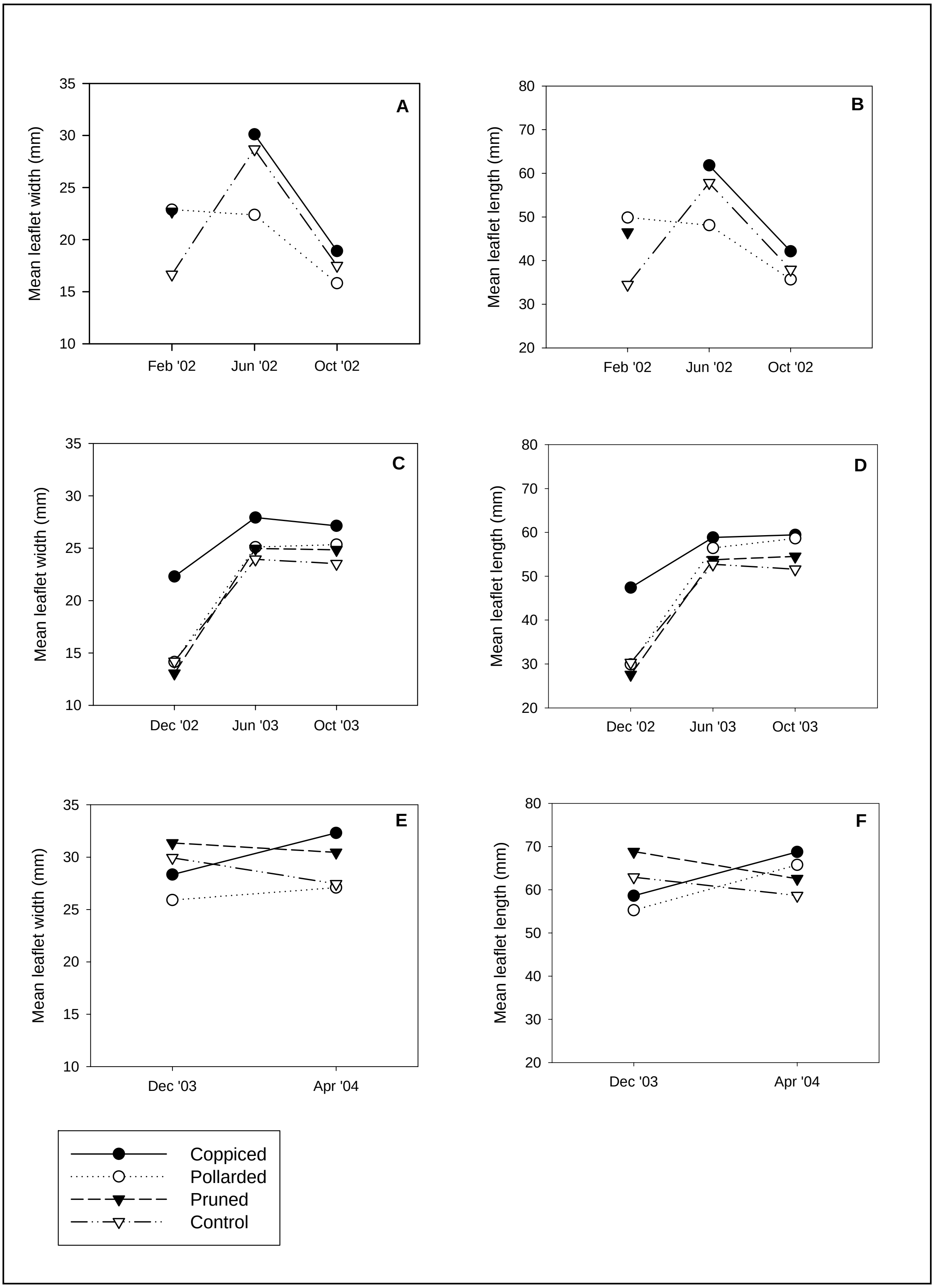


Table 1.2 Leaf surface areas on treatment and control *C. mopane* trees during the period of study.

	Coppiced	**Pollarded**	**Pruned**	**Control**
Leaflet area (mm^2)	**2002 leaf set**			
Mean	1988	1494		1507
STD	1014	507		911
Min	1270	910		918
Max	2705	1814		2558
	2003 leaf set			
Mean	2427	2005	1695	1613
STD	1369	964	796	589
Min	1410	664	566	693
Max	5035	3051	2718	2390
	2004 leaf set			
Mean	3314	2692	3202	2778
STD	753	422	180	196
Min	2519	2260	3020	2581
Max	4017	3104	3380	2973

Leaf phenology

Phenological changes in leaves: 2001 - 2002 growing season
During February 2002, when the study was initiated, all the trees bore MG1 and MG2 leaves, resulting from rains that fell in the area during the onset of the rainy season during 2001 and January 2002. After pruning, the pruned branches remained leafless for the entire 2001 – 2002 growing season. Bud initiation was observed during October 2002 and the first leaves on these branches appeared during the December 2002 leaf flush. This contrasts with coppiced, pollarded and control trees which responded by new bud initiation and leaf growth immediately after rainfall. Thereafter coppiced trees initiated new leaves and coppice shoots throughout the year in response to initial rainfall and heavy browsing. Due to these successive growth spurts there is no clear leaf phenological pattern among coppiced trees. Leaves on coppice shoots primarily remained in MG1 and MG2 stages, even towards the end of the growing season (October 2002) and only coppiced trees responded to the limited rain that fell during July 2002. By the end of the normal growing season in October 2002 pollarded, pruned and control trees were leafless all their leaves having senesced and died. Coppiced trees on the other hand still supported comparatively luxuriant growth and continued to produce new leaf and bud tissue.

Phenological changes in leaves: 2002 - 2003 growing season
Rains during November and December 2002 (albeit below average) and January and February 2003 resulted in a range of leaf development stages present on control and treatment trees during the December 2002 and February 2003 surveys. The above average rainfall during March 2003 resulted in continued leaf production by coppiced, pruned and pollarded trees during April which was dry. No new growth occurred on control trees during April 2003 which, with pruned trees, were the first to show senescent leaves. Despite rains during June 2003 there was no further leaf production among treatment and control trees. Pruned and control trees had more dead leaves than coppiced and pollarded trees in August 2003. By October 2003 all treatment and control trees were largely leafless.

Phenological changes in leaves: 2003 - 2004 growing season
Rain showers during October, November and December 2003 resulted in a range of leaf development stages being present on control and treatment trees by December 2003. Further rainfall during January and February resulted in continued leaf production by control and treatment trees through February. No newly formed leaves were present on control or treatment trees during April. All except coppiced trees had some senescent leaves in April 2004.

It seems that pollarded and particularly coppiced trees respond better to rainfall in producing secondary leaf flushes. Furthermore, coppiced trees have a capacity to produce new leaves throughout the year and even in the dry season, and are able to retain their leaves for longer. Thus although coppicing appears to offer no advantage in leaf number or size, an advantage is conferred by virtue of tree vigour and continued productivity.

Leaf quality

Tannin, fibre and protein content of leaves
Although leaf material of *C. mopane* was assayed for the presence of hydrolysable tannins on several occasions, no detectable amounts could be found.

Low concentrations of condensed tannins and polyphenols were present in the leaves of treatment and control *C. mopane* trees from the onset of the 2001 – 2002 growing season (February 2002) to the cool dry season (June 2002). Thereafter the concentration of condensed tannins and polyphenols in the leaves of treatment and control *C. mopane* trees increased dramatically to October 2002. Compared to the other treatment and control trees, leaves on coppiced *C. mopane* trees contained the largest amounts of condensed tannins and polyphenols during October 2002.

There was a steady decline in condensed tannins and total polyphenols in maturing and mature leaves of treatment and control *C. mopane* trees during the 2002 – 2003 growing season (Figs 1.3A & B) with the highest tannin levels found in the youngest leaves.

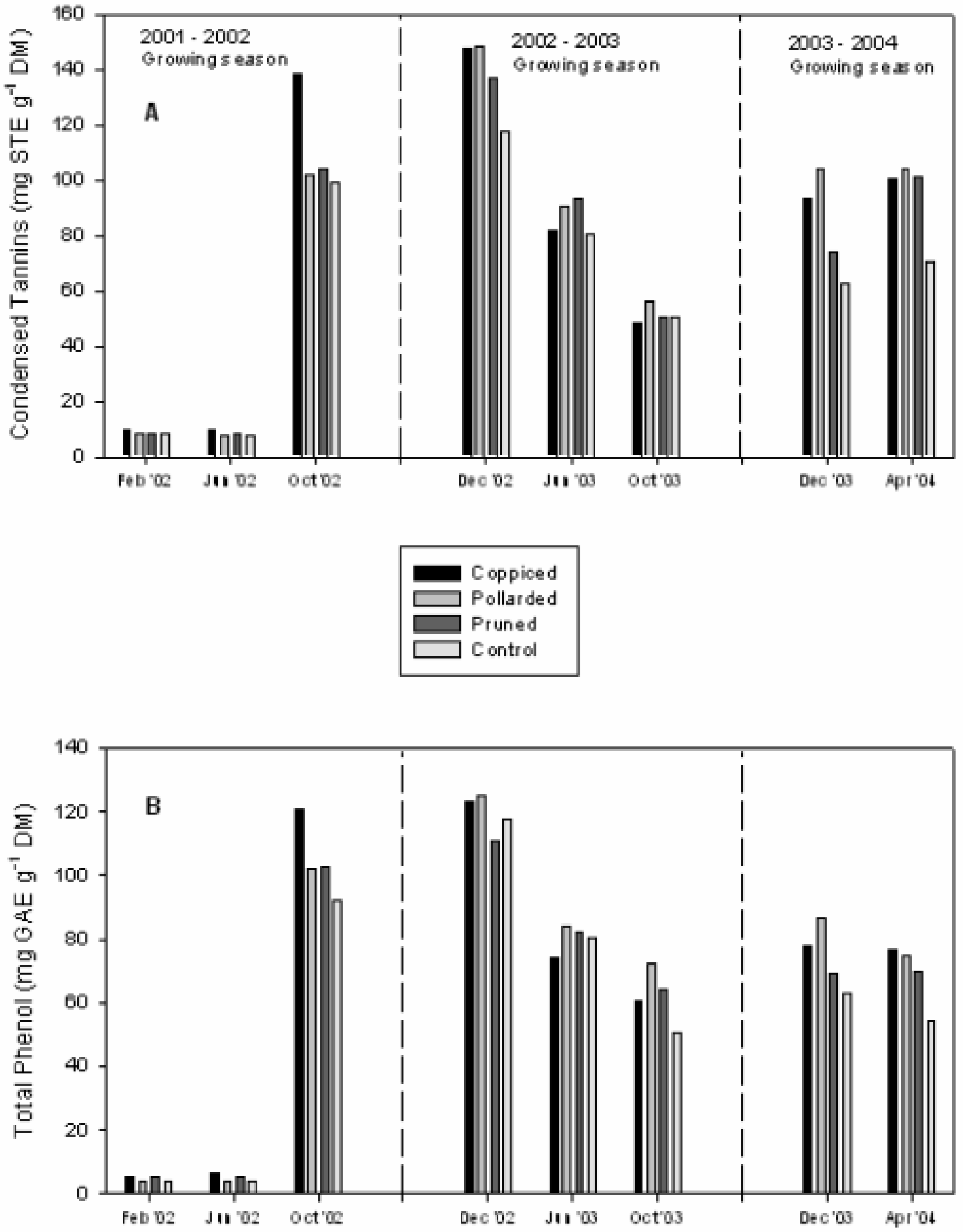


Figure 1.3 Condensed tannin and total phenol content of the leaves from treatment and control *C. mopane* trees (GAE = gallic acid equivalents; ST = sorghum tannin equivalents)

Condensed tannins and total polyphenolic concentrations in the leaves of treatment and control *C. mopane* trees changed independently during the growing season and between growing seasons. These changes could be attributed to differences in climatic conditions between the different growing seasons and characteristics unique to the treatment and control trees, similar to the findings of Ernst *et al.* (1991). There was no significant difference among treatment and control groups in the concentration of condensed tannin or total polyphenol content of leaves indicating that different treatments did not affect leaf quality in this respect.

Protein and fibre content
The leaf protein content of treatment and control trees was higher in February and June than in October in the 2001/2002 and 2002/2003 growing seasons (Fig. 1.4A). During the 2003/2004 growing season the protein content of leaves from treatment and control trees was substantially higher (Fig. 1.4) and closer to that reported by Bonsma (1942). The decline in protein content of October leaves has implications for browsers that depend on *C. mopane* during the dry season when most other tree species are leafless.

Highly variable results for leaf fibre content from treatment and control trees emerged from the different growing seasons (Fig. 1.4B). During the 2001 - 2002 growing season there was an exponential increase in leaf fibre content, while the 2002 - 2003 growing season was marked by an initial fall in fibre content from December 2002 to June 2003 followed by an increase in fibre content to October (Fig. 1.4B). The December 2003 – April 2004 growing season revealed negligible difference in the fibre content of leaves. No differences across treatments in fibre content were recorded.

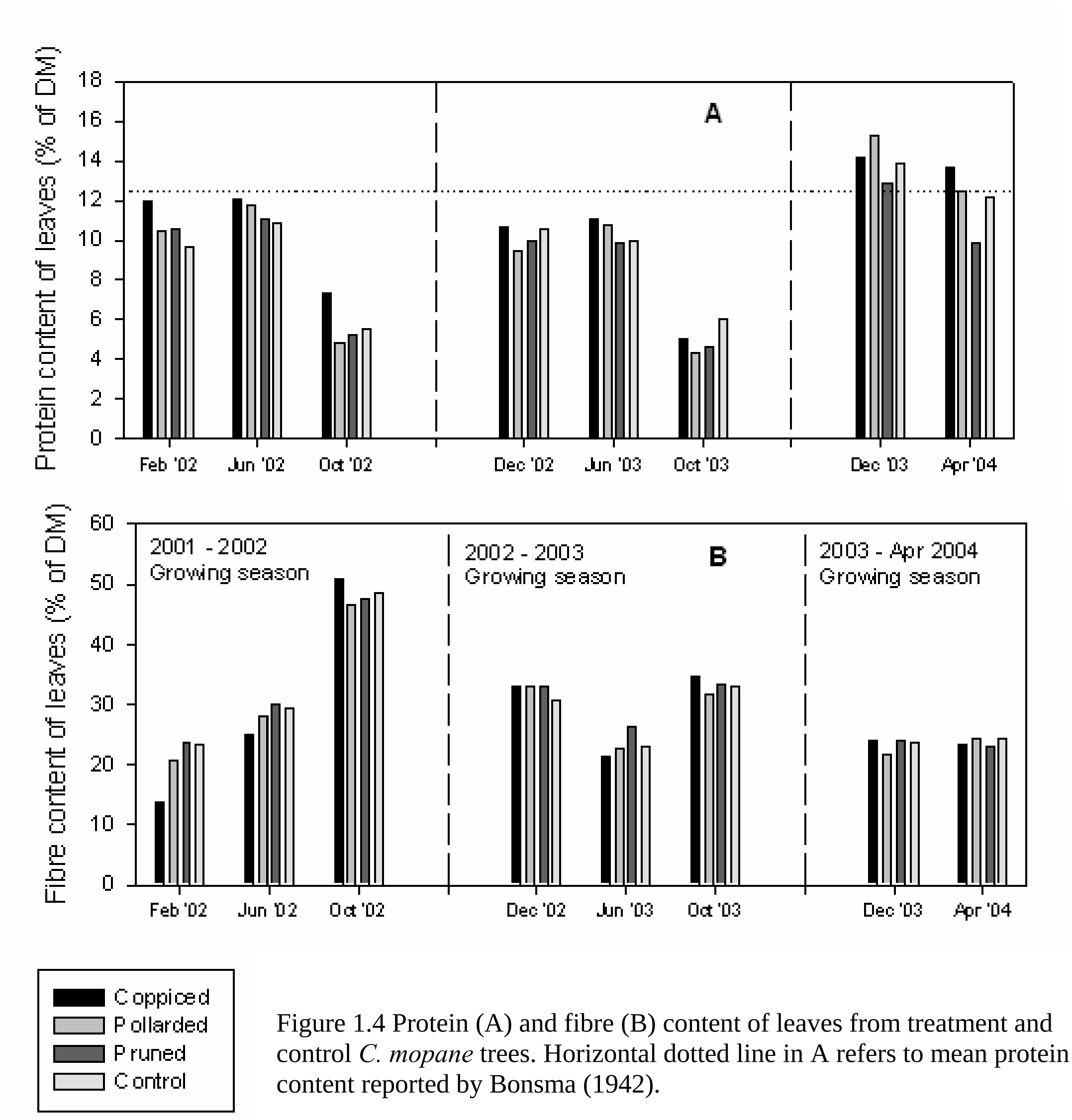


Figure 1.4 Protein (A) and fibre (B) content of leaves from treatment and control *C. mopane* trees. Horizontal dotted line in A refers to mean protein content reported by Bonsma (1942).

There is a decline in leaf protein content that is associated with an increase in fibre content as the growing season progresses (Figures 1.5). In terms of these two variables, mopane worm outbreaks (November/December and March/April) occur when leaf quality appears to be at its best. Differences among groups for leaf protein and fibre content were not significant at the 0.05 level, indicating that leaf quality in terms of protein and fibre content was not influenced by the different treatments.

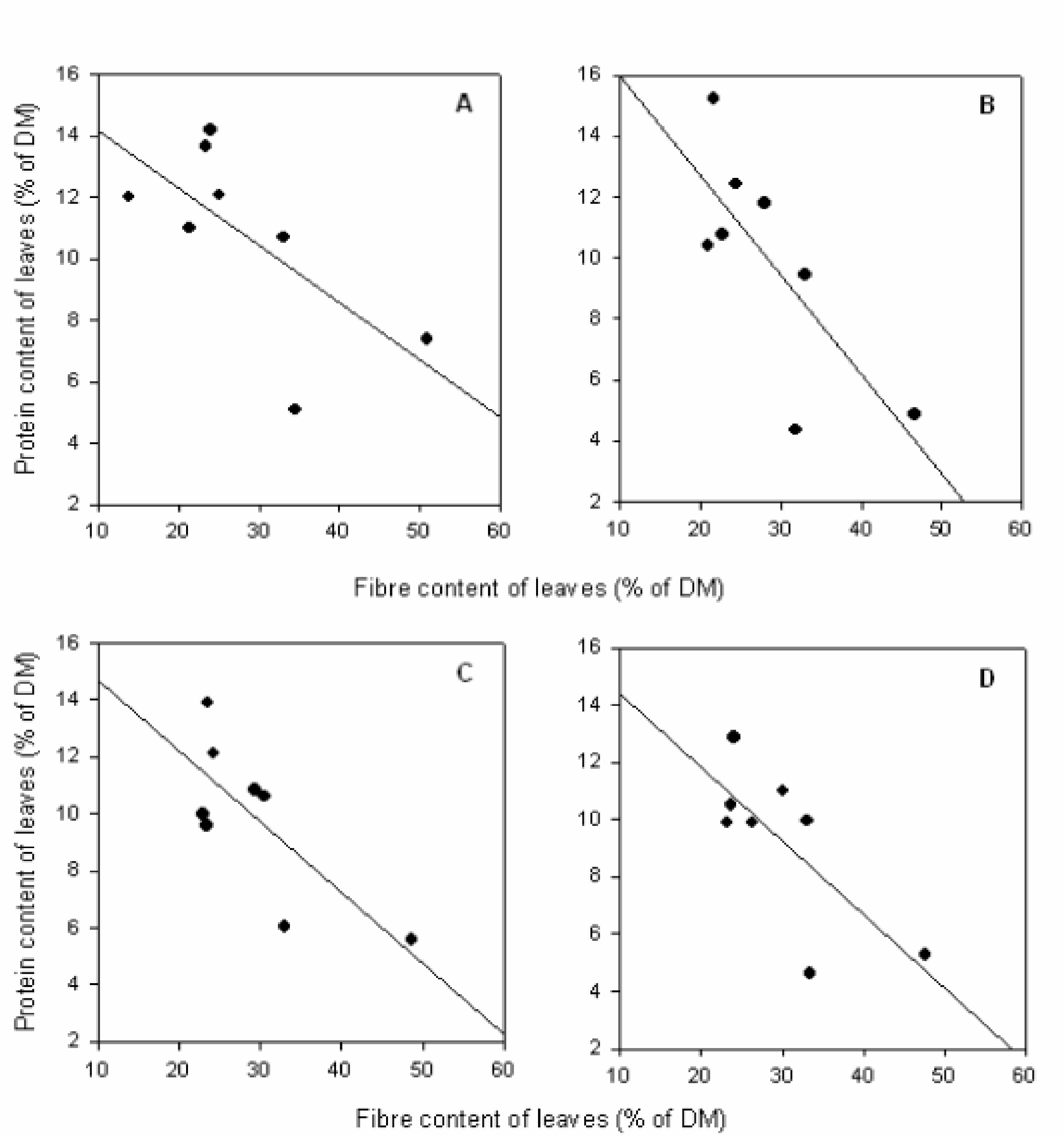
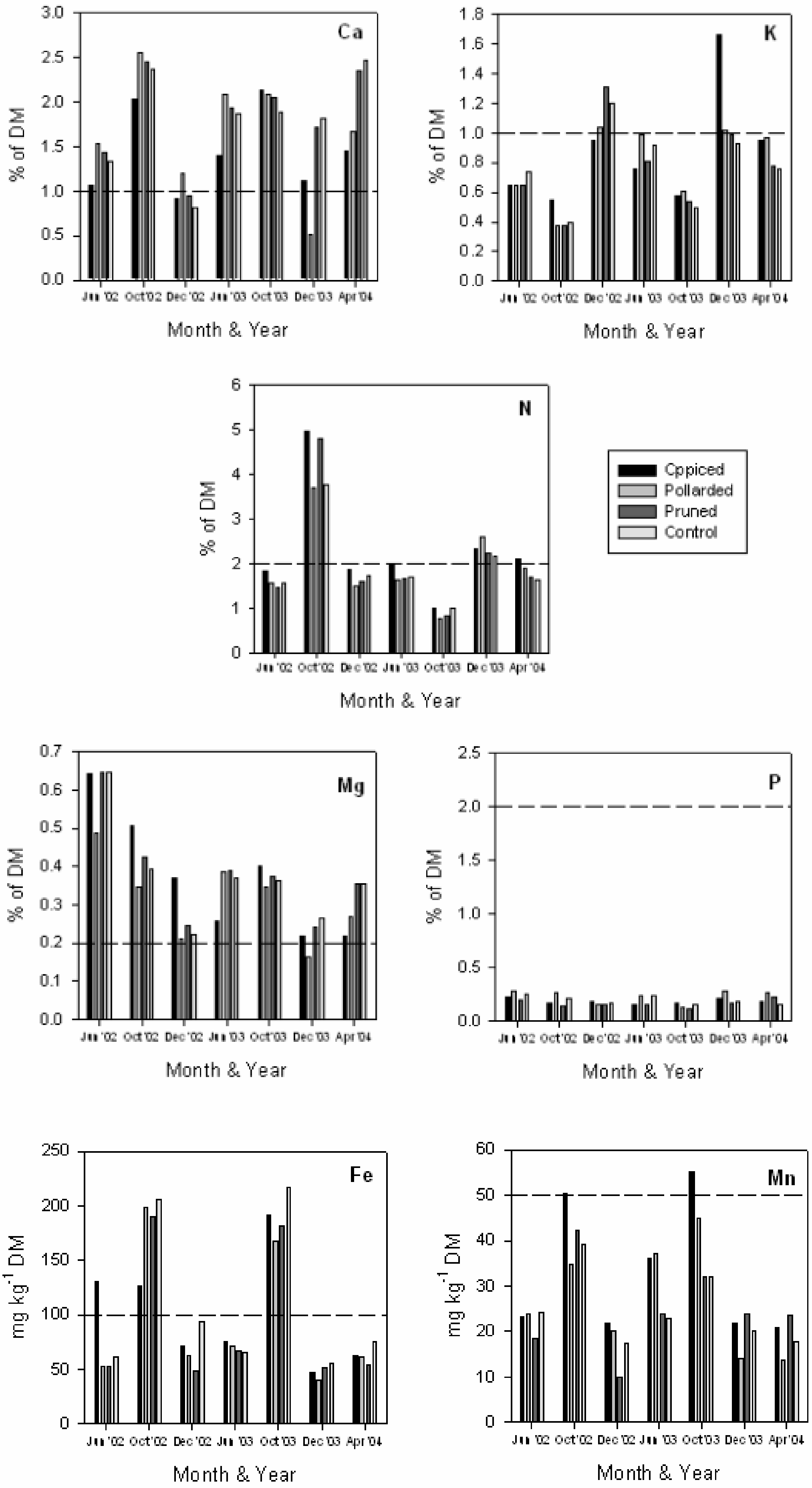


Figure 1.5 The relationship between fibre and protein content in the leaves of *C. mopane* under different treatments: Coppiced (A); Pollarded (B); Control (C); and Pruned (D).

Leaf mineral content

Macronutrients
Compared to the mean mineral content of land plants listed by Larcher (1991) it is evident that *C. mopane* leaves contain less phosphorous (P) throughout the growing seasons (Fig. 1.6 P). The more mobile elements nitrogen (N) and above all potassium (K) were most concentrated in young leaves (Figs 1.6 K & N), with concentrations declining as the leaves matured and aged. However, there was a sharp increase in the N content of leaves during October 2002, which could be ascribed to a leaf flush resulting from rains during September and October 2002. Calcium (Ca) content of leaves increased as they matured and aged (Fig. 1.6 Ca) resulting in an increase of the Ca:K ratio in the leaves during the course of a year. One-way ANOVA showed no statistically significant differences in mineral content across treatments.

Micronutrients
The less mobile elements, iron (Fe) and manganese (Mn) in particular, accumulated in the leaves with increasing age (Figs 1.6 Fe & Mn). The Fe and Mn content of *C. mopane* leaves were lower than mean values reported for other plants by Larcher (1991). Copper (Cu) and zinc (Zn) showed highly variable concentrations through the growing season and no consistent pattern (Figs 1.6 Cu & Zn). One-way ANOVA revealed no significant difference among treatment and control groups for andy of the micronutrients recorded, probably due to large between tree variability.


Ca
% of DM
Month & Year
K
N
Cppiced
Pollarded
Pruned
Control
Mg
P
Fe
mg kg^{-1} DM
Mn
Jun '02
Oct'02
Dec'02
Jun '03
Oct'03
Dec'03
Apr'04

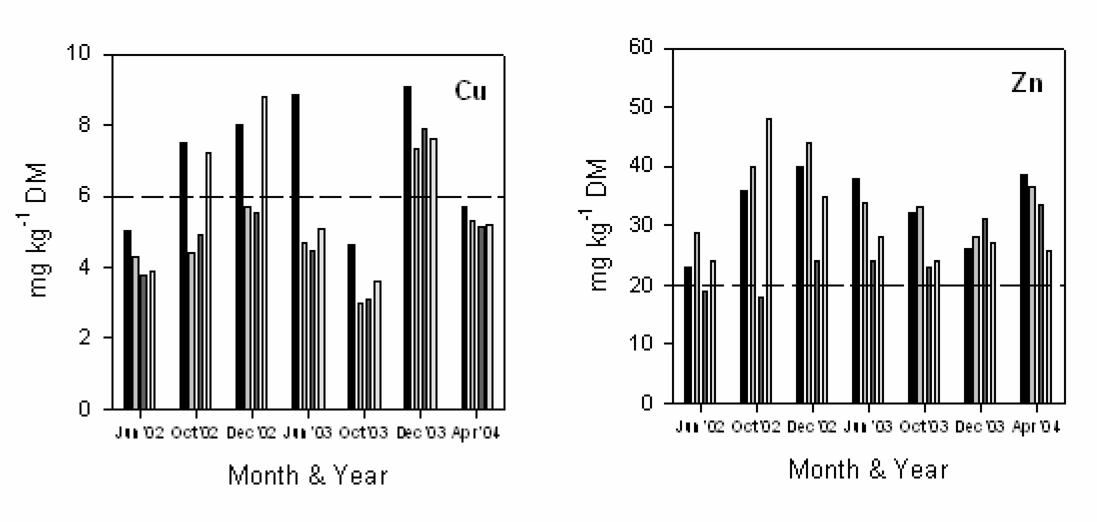


Figure 1.6 Mineral nutrient content of *C. mopane* leaves from treatment and control trees. Dashed line indicates mean mineral content of land plants (Larcher 1991)

Vegetative growth following tree manipulation

Figure 1.7A depicts vegetative growth of marked twigs on treatment and control trees between April 2002 and April 2003. During this period, shoots of coppiced trees showed the largest increase in mean shoot length and pruned trees the least. The largest amount of vegetative growth during the period April 2003 and April 2004 occurred on shoots of pollarded trees (Fig. 1.7B). The least amount of vegetative growth again occurred on trees with pruned branches, followed by shoot growth on coppiced trees.

Shoots of coppiced and pollarded trees showed more growth during the period April 2002 and April 2003 than during the period April 2003 and April 2004 (Fig. 1.7C). The largest mean increase in shoot length occurred among pollarded trees (Fig. 1.7C). Coppicing and pollarding *C. mopane* appears to stimulate vigorous regrowth, although there was some inter-annual variability. Pruned *C. mopane* branches had retarded growth even though these branches represented only a small proportion of the branches of the whole tree.

Despite apparent differences in rates of growth on treatment and control trees, the results are not significantly different. It is likely that this is an artefact of the high variability and sample size resulting in low statistical power, particularly given the repeated demonstration of vigorous regrowth following coppicing and pollarding in other similar studies.

Conclusions

Based on the findings discussed above, the following conclusions can be drawn:

- Except for leaf production and retention on coppiced trees, there are no quantitative differences in leaf production among trees subjected to pollarding or pruning regimes compared to control trees.

- There are no differences in leaf quality as a food source for mopane worms among trees subjected to coppicing, pollarding or pruning regimes compared to control trees.

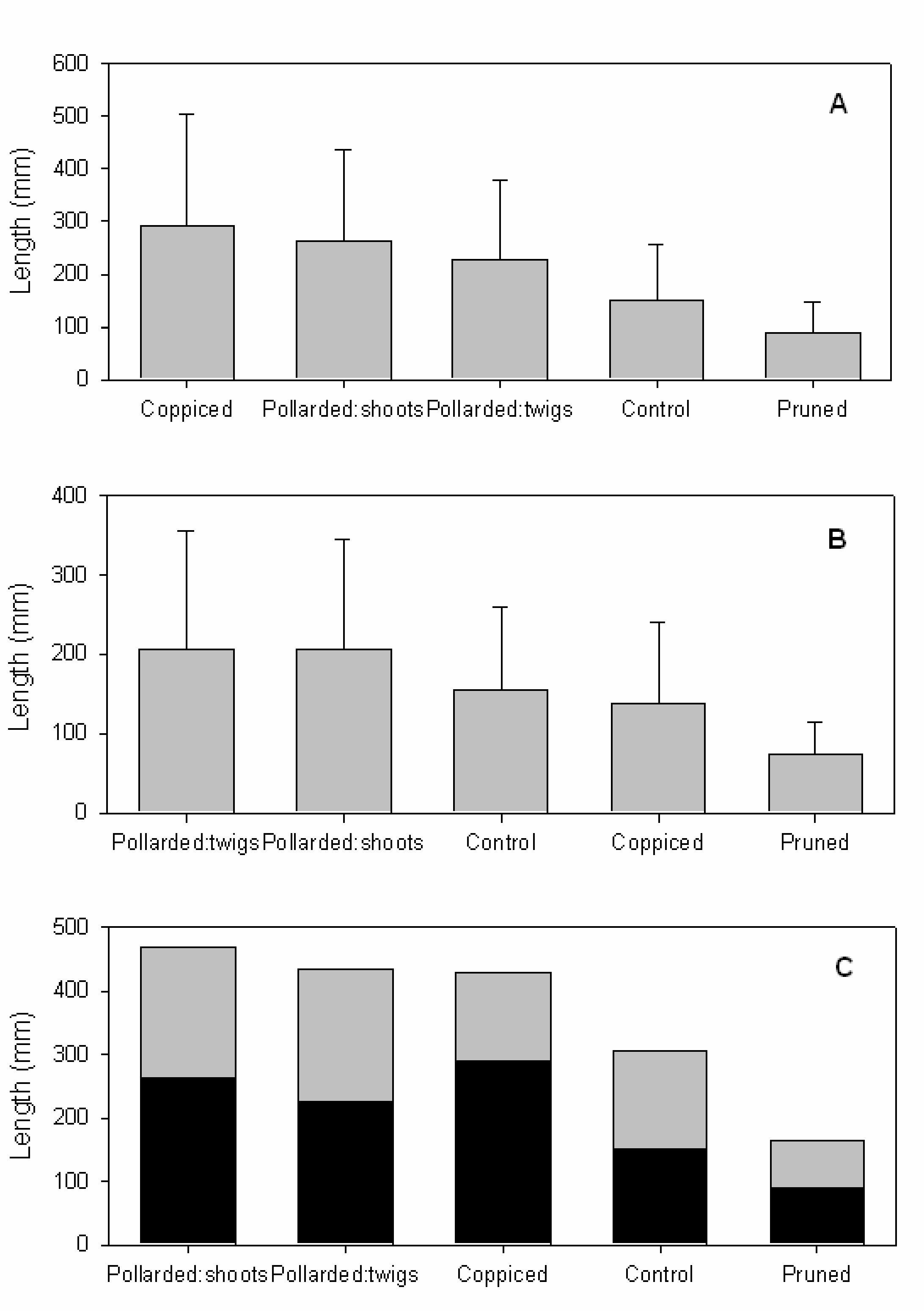


Figure 1.7 Increase in length of marked twigs on treatment and control trees of C. mopane. **A**: April 2002-April 2003 growing season. **B**. April 2003-April 2004 growing season. **C**. Combined results for both growing season.

Section 2.1 Mopane worm productivity and domestication

Relevant Activities

2.2 Quantify age-specific mortality for *I. belina* populations under low-density and outbreak conditions
2.5 Build an *I. belina* breeding facility and establish and maintain a captive breeding population of *I. belina*
2.6 Quantify the relationship between *I. belina* larval density, growth and mortality under controlled field rearing conditions to determine the range of larval stocking densities that maximise yield.
2.7 Develop techniques for increasing the yield of mopane worms using information acquired from activities 2.1-2.4 and 2.6
2.8 Develop techniques for increasing the yield of the second generation of *I. belina* larvae within each season
2.9 Establish in collaboration with KyT producer groups a pilot project to test, modify and improve techniques to increase the yield of *I. belina* larvae (linked to 2.7 and 2.8)

Collectively these activities were developed to meet the objective of establishing a low-technology mopane worm domestication unit where production of mopane worms could be undertaken independently of their availability in the wild. This necessitated research on the growth and survival of mopane worms at different ages and densities in both wild and captive conditions (Activity 2.2 and 2.6), and the development and establishment of new technologies and management options for captive breeding and maintenance of mopane worms (Activities 2.5, 2.7 and 2.9).

In establishing the domestication unit or 'mopane worm farm' it was necessary to address a number of specific challenges for developing appropriate pupation, breeding and rearing facilities including determining the most appropriate substrate conditions for pupal viability, the best stocking density for larval growth and survival, and the most appropriate age at which the larvae can be released onto managed mopane trees

Research to address these issues was conducted in Botswana in collaboration with Kgetsie ya Tsie Women's Community Group (KyT).

Study site
A breeding facility was established near Maunatlala in east central Botswana. Maunatlala ($22^0$36'S $27^0$38'E) is situated near the north east base of the Tswapong Hills. An office and laboratory was located in the village approximately 5 km from the farm. Maunatlala has a population of approximately 2000 people and is close (30 km) to the Headquarters of KyT at Lerala. The Tswapong hills are covered in mixed woodland including *C. mopane*, *Terminalia sericea, Croton spp*., *Combretum spp*. and *Albizia anthelmintica* (Wild & Fernandes 1967 vegetation type 47, deciduous tree savanna [medium and low altitude] for more details). The hills are surrounded by large areas of *C. mopane* dominated vegetation (Wild & Fernandes 1967 vegetation type 50, dry deciduous tree savanna [*C. mopane*]). The site for the farm was chosen for its relatively dense stands of medium to low *C. mopane*.

Mopane Worm farm
The total area available for the farm was approximately five acres, a portion of which was fenced to prevent disturbance by goats and cattle. The site was previously used as a small holding and many of the trees had been previously coppiced to promote grass for grazing by cattle. The small holding had been abandoned for at least six years prior to the establishment of the mopane worm farm. Throughout the plot the *C. mopane* trees were between 1-3 m tall. The site included a hut (made of pole and dagga with a grass roof) used for equipment and livestock, two tents for staff, a 'cooking shed', a long drop toilet (of bricks and cement), a weather station (with the ability to record: rainfall, min and max temperature, evaporation, humidity and soil temperatures), and an experimental 40m x 10m wooded plot.

Two "shadehouses" enclosed mopane trees within a 10m x 20m x 2.5m volume with 40% shade cloth (Block A, Figure 2.1) and 70% shade cloth (Block B). Shadehouses were constructed using gum poles and wire to support the shade cloth, the gum poles being planted in the ground and held in position by straining wires attached to buried tyres. Access into the house was restricted to a single wooden door in an attempt to minimise the introduction and spread of disease. All plants other than *C. mopane* were removed from the shadehouses. During the experiment the floor of the shadehouses was swept clean of other vegetation. Tall mopane trees or ones that contacted the sides of the shadehouse were trimmed so that they were contained within the structure. Each shadehouse was divided into 10 plots, each measuring 5m x 4m, and delineated with a ridge of soil.

Two further open experimental areas, Blocks C and D, measuring 10m x 20m x 2.5m were de,marcated within a fenced area protected from large vertebrates. Due to restriction on the availability of space these blocks had to be located next to each other. The size of the grids within these blocks were identical to those in the shadehouse and were treated in the same way (see below for details). In the third year half of block C was covered with shadecloth (Figure 2.2).

Block E (10m x 20m) was established near to Block B but lacked shade cloth and lay outside the protected fenced area. Random trees within the farm were also used for sleeving experiments.

Fig. 2.1. A shadehouse (Block A) entirely enclosing a patch of mopane woodland within shade cloth

Fig. 2.2. Block C partially covered with shadecloth.

Egghouse
A smaller structure (4.2m x 4.2m x 2.5m) was constructed for the hatching and mating of moths (Figure 2.3). A wooden frame was built over several small *C. mopane* trees and was covered with bionet. The entrance consisted of an isolation chamber, 1.3 m x 1 m, with one door to the outside and another into the egghouse. The double door entry was devised to minimize the introduction of predators and parasites.

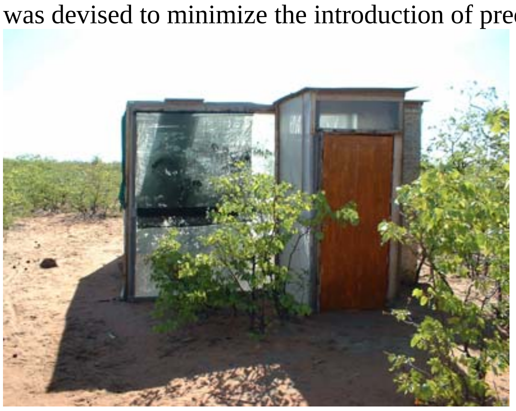


Figure 2.3. Egghouse used for mating moths and hatching of eggs.

Collecting moths
Several methods were tested to collect moths of breeding and these are outlined below.

Mercury vapour lamp
Collecting wild female moths by light trapping was tested and assessed in October/November of 2001 and 2002. All moths collected by this method had already laid their eggs.

Digging for pupae
In outbreak areas stock can be successful obtained by digging for pupae, although at low density the amount of digging effort per pupa obtained is too high for it to be of practical use. Pupae can be located near the base of trees and shrubs. Most pupae were found at between 10- 15 cm depth in the soil. There is, however, a risk of introducing chalcid parasitoids from wild dug pupae. Chalcids (Figure 2.4) have a high reproductive output (73 pupae dug up from the study site area in the second year hatched on average 353 chalcids per pupa with a maximum of 618 and a minimum of 115). These parasitoids can move easily from one pupa to the next, and pupae need to be kept separately in plastic containers to avoid transmission (Figure 2.5).

Fig. 2.4. Chalcid parasitoids tightly packed within a pupae.

Fig. 2.5. Plastic containers were used to isolate pupae to minimise spread of parasitoids. In the container on the left one infested pupa resulted in the parasitism of the rest.

Searching for eggs and larvae
Egg masses can be easily found by standing approximately one meter away and visually scanning the leaves and twigs as the white egg masses stand out from the darker vegetation on which they rest. In areas of large outbreaks the eggs can even be seen from the road while travelling in a car (Figure 2.6). Eggs were placed in plastic containers (26x14x4cm) and transported back to the farm. Young larvae were found by scanning trees for signs of defoliation which proved a very effective technique.

Figure 2.6. Egg masses on a *C. mopane* tree at the beginning of the season. Two of the egg masses are indicated by arrows.

Involving local children
In 2002 children at the local Junior Schools were engaged to search for eggs, larvae and pupae, in return for a small reward. This proved to be a very successful way of obtaining livestock. Plastic containers were left with the school head to whom the children brought the eggs and young larvae they had collected. The biggest drawback of this method was the sporadic nature of the pupils' enthusiasm for collection.

Larval rearing and survival
The following rearing methods and a combination of them were compared for their suitability as techniques for rearing mopane moth larvae.
1) rearing on open exposed trees
2) rearing under covered mopane shrubs
3) protecting larvae within chiffon sleeves
4) protecting larvae within large shadecloth bags
5) rearing within the shadehouses

Sleeves (70cm x 110cm) around branches were used to enclose eggs and first to third instar larvae (Figure 2.7) to protect them from predation and parasitism. Two types of material were used, chiffon and organza. These were mostly white but some of the chiffon bags were also made of other colours. Each sleeve was numbered. Sleeves were used in blocks C & D, on random trees and on occasions inside the shadehouses. The sleeves were tied onto branches of the trees using string. The larvae within the sleeves were counted initially and again each time the sleeves needed changing (this meant the larvae underwent minimal disturbance caused by the removal and replacement of the sleeves, which was necessary to count them).

Large bags measuring 2 metres in three dimensions were made from 40% shadecloth. The bag was placed over a mopane bush or small tree (Figure 2.8) and the larvae introduced as appropriate.

Figure 2.7. Chiffon sleeves covering branches to protect eggs against parasites in shadehouse.

Figure 2.8. Shadecloth covering a small *C. mopane* tree.

Larvae were also introduced into the shadehouse with no further protection. The number of surviving larvae within all treatments were counted every second day. Larvae on exposed trees were counted every day. In all experiments the cause of larval death was recorded when possible. When the larvae reached pre-pupation stage they were collected, counted and placed in the pupation boxes, drums or pits (see below).

Development of appropriate pupating, breeding and rearing facilities

Pupation techniques and pupal mortality

Boxes

Plywood boxes with hinged lids were constructed with dimensions of 26 x 52 x 32cm (Figure 2.9). Soil was placed in the boxes until they were half to three-quarters full. Several soil types were used to investigate substrate suitability. Different numbers of larvae were placed in the boxes to assess whether larval density within boxes affected survival. The larvae were placed in the boxes at the end of the final (5^{th}) instar (pre-pupation stage). Some mopane leaves were included in case some larvae were still feeding. Boxes were stored indoors and away from direct sunlight. Rats are able to chew through the boxes and therefore rat poison was placed in the vicinity. After approximately one month the boxes were emptied and the contents examined. The number of live, deformed, dead and parasitised pupae were counted. Once emptied the boxes were cleaned with a sodium hypochlorite solution.

Figure 2.9. Plywood pupating boxes

Figure 2.10. Removal of pupae from the pits. Live pupae lie beside the lady on the right.

Drums

200 litre capacity oil drums were cut in half and 5mm holes drilled in the bottom. The drums were half filled with soil and pre-pupation stage larvae introduced on the top of the soil with a few leaves. These larvae were allowed to pupate within the soil and about one month later were dug up and categorised as live, deformed, dead or parasitized. Drums remained outside at all times.

Pits

Pits were constructed, in the open, by digging an area of 2.5 x 1.0m to a depth of 20 cm (Figure 2.10). Plywood sheets were placed along the sides of the pit which was then covered with shadecloth. The pit was filled with soil to a depth of approximately 20cm thereby securing the plywood sheets in place which protruded about 25 cm above the soil level. Shadecloth was used to cover the structure. Pre-pupation larvae were placed on the surface of the pit with a few fresh leaves. Pits were reused on subsequent occasions the only treatment being a light application of water.

Length of time pupae remain viable and substrate type

Both wild pupae and pupae from the farm were kept in the lab in pupation boxes, using a variety of substrate types, as well as in the shadehouse and hut until the adults emerged. The time of hatching was recorded for all pupae within boxes. The substrate within boxes was varied to assess whether soil type affected pupal mortality. The softness and sand content of the soil were examined crudely and qualitatively by assessing how easy it was to crumble the soil between the fingers and by wetting a sample and feeling its texture. The soil was categorised into four groups shown in Table 2.1. This simple and crude scale was adopted over other more quantitative measures to ensure that the methods could easily meet local needs and capacities.

Table 2.1. Soil categories

Category	**Description**
1	Sandy and crumbling on its own
2	Sandy and requiring a small amount of pressure to crumble
3	Sandy-clayey, giving some resistance to crumbling
4	Clayey and difficult to break up

Obtaining a second generation

Egg production

To obtain a second generation from a fully independent captive breeding system a second generation has to be raised for which mating and egg production (Figure 2.11) is an essential step. Several techniques were developed and assessed for mopane moth breeding.

Figure 2.11. Egg mass laid on a twig, typical of the Oct-Nov brood when leaves, the preferred oviposition sites, were not available.

Figure 2.12. Shelving for pupal hatching within the shadehouse. Pupae were placed on the protected lower shelf for hatching.

Hand mating

Applying slight pressure to the abdomen of many male butterflies opens the claspers which are then placed over the end of the female abdomen to cause mating. In *Imbrasia belina* neither the male or female were responsive in this manner and it seems that a pheromonal stimulation may be required before mating can take place.

Females in boxes

The evening after the moths had hatched females were placed in 26 x 52 x 32cm plywood boxes used for pupation (as described above). Various numbers of males were then added to the boxes for a period of 24 hours.

Females in sleeves

Sleeves measuring 70 x 110 cm were placed on branches of trees in the open. A female and one or a few males were introduced and the free ends sealed.

Females in large shadecloth bags

A few female and male moths were introduced onto small trees enclosed within shadecloth bags as described above.

Females in egghouse and shadehouse

Adults were introduced into both the egghouse and the shadehouse by placing pupae on shelves, covered to protect them from the sun (Figure 2.12), and located within the egghouse or shadehouse. These pupae were left to hatch. A second method was to allow pupae to hatch within the pupation boxes with the adults being released into the egghouse or shadehouse the next day.

Vulnerability of eggs to parasitoids and their protection

Egg batches proved susceptible to parasitoids such that it proved necessary to develop methods to protect eggs. Egg batches were observed for five 15-minute periods (hourly from 1100hrs until 1500hrs) from 15th October 2002 to 20th November 2002 and thereafter at intervals when time allowed. Parasitoid visits to egg masses were noted during these observation periods.

Egg masses from the egghouse and shadehouse were placed in small plastic containers until they hatched. On hatching a fresh leaf was placed in the container for the young larvae to crawl onto. Within a day the larvae could be transferred to trees for feeding.

Leaves bearing newly laid eggs could be easily transferred by pruning then pinning or stapling them to leaves in the desired location (the first instar larvae feed on fresh leaves as soon as they hatch). Branches to which newly hatched larvae were transferred were then covered with a chiffon bag to protect them from parasitoids. In the case of eggs being laid in the shadehouses or experimental plots some of the egg masses were left on their natal branches and covered with a chiffon bag.

Manipulating pupal diapause time

Research was conducted on the artificial control of pupal diapause to escape the natural seasonality of the mopane worm harvest and thereby allow for production of fresh larvae throughout the year. Using a refrigerator and oven pupae were maintained at ten different temperature treatments as well as at ambient temperature used as a control (Table 1). Pupae were initially kept cool within a refrigerator at 11^{o}C (average fridge temperature 11.2^{0}C) for a period of days (see Table 1) followed by 5, 10 or 14 days in an oven at 32^{o}C (average oven temperature 32.7^{0}C). Ten pupae were used for each treatment making a total of 110 pupae. Pupae were then placed in plastic containers at ambient temperature.

Table 1. Treatments applied to pupae to determine control of pupal diapause.

Number of pupae	days at 11^{0}C	days at 32^{0}C
10	2	5
10	2	10
10	4	5
10	4	10
10	8	5
10	8	10
10	16	5
10	16	10
10	32	5
10	28	14
10	control	control

Stocking density for rearing larvae

Eggs obtained from the farm and kept in plastic containers were used for experiments to determine the appropriate stocking densities. Mortality of larvae kept at different densities within the shadehouses was monitored at least once in every instar. The density treatments were constrained somewhat by the availability of stock, but varied from just a few mopane worms to about 1000 larvae per block. Survival data are presented as the proportion of the first instar larvae that remained alive at the end of the final instar.

Age at which larvae can be released onto trees

Larvae cannot be kept in large numbers in the shadehouse as the leaf material will eventually be consumed. Additionally, if all stock is retained within the shade house there is a risk that the entire stock may be lost through the introduction and spread of disease. It is therefore necessary to determine an appropriate age at which larvae can be transported out of the shadehouse and to nearby mopane trees.

Groups of 100 larvae from each instar were placed on exposed trees outside the shadehouse and their survival was monitored at least once during each successive instar. This was conducted in three years (2001-2003), with each group of larvae being placed on separate trees.

Results

Patterns of pupal survival

There was a significant negative correlation between the date of *I. belina* pupation and survival (Figure 2.13, r = 0.652, df = 30, p < 0.01) indicating that pupation early in the season contributed to increased likelihood of survival. Pupae in soil category 1 had better survival than in other substrate types.

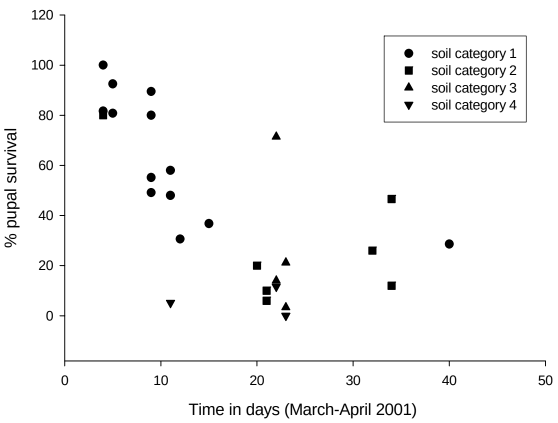


Figure 2.12. The number of pupa surviving and date of pupation (time in days from March 1st).

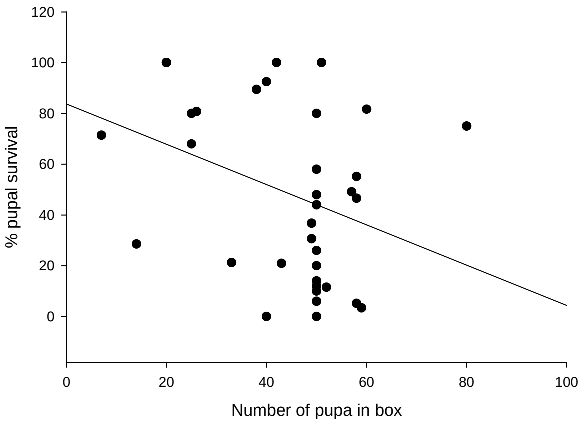


Figure 2.14. The number of pupa in a pupating box and the percent of these pupa surviving.

There considerable variability in survival of pupae at different densities within pupation boxes with a suggestion of lower survival at high densities (Figure 2.14, r = 0.352, df = 35, 0.05 > p > 0.01), but there is considerable uncertainty at the extremes of the data set owing to insufficient data.

Pupation in drums had the lowest chance of survival while boxes and pits proved successful in delivering healthy pupae (Table 2.2). Because of the large numbers placed in the pits only three could be tested.

Table 2.2. Survival of pupae from larvae placed in boxes and drums in year two (yr2) and boxes and pits in year three (yr3). Figures in brackets refer to the number of drums, boxes and pits used.

	Total mopane worms	No. alive	No. dead	Survival (%)
Boxes yr2 (61)	2945	1465	1480	49.7
Drums yr2 (5)	1050	381	669	36.3
Boxes yr3 (13)	624	446	178	71.5
Pits yr3 (3)	1890	1350	540	71.4

One per cent of the pupae within boxes were parasitised by parasitoid wasps (Figures 2.15 & 2.16). These wasps lay their eggs in the 4^{th} & 5^{th} instar mopane larvae, pupated simultaneously with the host and emerged at various stages of the next brood.

Figure 2.15. Fully grown larval parasitoid wasps removed from the prepupal stage of the mopane larvae.

Figure 2.16. Pupa and adult of the parasitoid.

Chalcid parasitoids from wild pupae dug up in year 2 were inadvertently introduced into the captive mopane worm stock. Enclosing pupae in material bags was not sufficient to exclude the parasites and resulted in 100% parasitism of the pupae in the bags. The chalcid outbreak was controlled by keeping pupae in small plastic containers (Figure 2.17), although if one pupae within the container was parasitized then all became parasitized.

Figure 2.17. First instar larvae crawling from eggs onto a fresh leaf, the leaf can then be placed on a branch of a mopane tree.

Disease was a major cause of mortality among pupae (56.3% of the pupating larvae died of disease in year one, 52% in year two and 38% in year three). We have been unable to identify the diseases but as many of the infected and dead pupae smelt strongly and had extensive fungal growth, it seems that viral and possibly fungal diseases were the main causes. It was not possible to determine whether fungal infection was the primary cause of death or a secondary infection following the death of the pupating larvae.

Conclusion

The drums were found to be unsuccessful for pupation. Most larvae burrowed to the bottom resulting in severe competition for space and, owing to poor drainage, high mortality through fungal attack.

Despite the slight negative correlation between density and survival, a density of 50 pupae per box seems to be a good practical number for the size of box used. This density should not significantly influence survival and has a suitable size for easy box management.

The soil pits proved a useful method for pupation and is the most cost efficient method of producing pupae.

Three reasons are proposed to explain the increased mortality among pupae as the season progressed, although no data are available to support any of these possibilities: 1) bacteria and fungi increase in numbers as the season progresses; 2) the climatic conditions are more suitable later in the season; and 3) in the first year the introduction of infected larvae may have increased towards the end of the season.

High pupal mortality is principally due to viral infection and parasitoid attack. Larvae need to be protected from parasitoids to prevent the spread of attack as the parasitoids emerge from infected pupae and pupae need to be isolated in small groups for the same reason.

Larval rearing and survival

Year 1

Sleeving provided the greatest amount of protection with more modest protection provided by the shadehouse (Table 2.3). The combination of sleeving within the shadehouse provided the greatest degree of protection with over 90% survival of larvae within this treatment. This contrasts with less than 1% survival of unprotected larvae on exposed trees.

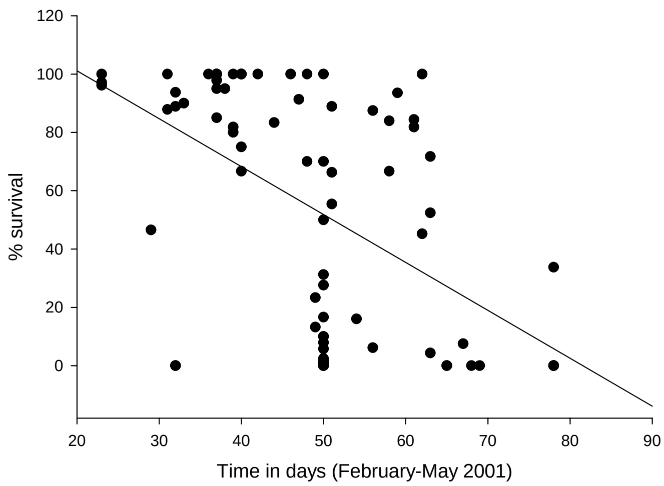
Table 2.3. A comparison of the effectiveness of different levels of larval protection by comparing pairs of treatments from the 2001 season.

Treatment	N	Mean (% survival)	Treatment	N	Mean (% survival)	t-value	df	p-value
Sleeved, Shadehouse	13	92.4	Exposed, Shadehouse	7	14.5	8.90	18	< 0.01
Sleeved Outside	10	46.6	Exposed Outside	5	1.1	5.21	12	< 0.01
Sleeved Outside	36	37.2	Exposed Outside	7	0.6	-4.16	35	< 0.01
Sleeved, Shadehouse	24	92.4	Sleeved Outside	36	37.2	4.40	51	< 0.01
Sleeved Outside	36	37.2	Exposed, Shadehouse	14	14.5	-2.92	42	< 0.01

Exposed, Shadehouse	14	14.5	Exposed Outside	7	0.6	2.24	19	0.037

There was a significant negative correlation between time of season and number of mopane worms surviving to pupation (r = 0.519, df = 76, p<0.01). Mortality increased dramatically after March 22nd (Figure 2.18) perhaps due to the larvae being brought in from Bobonong on March 16th which may have introduced viral diseases to the captive population. Infected caterpillars had reduced feeding and later dispersed and were found dead hanging from branches by their prolegs, a characteristic of a nuclear polyhedrosis virus (NPV). Some caterpillars turned bluish purple on death (indicating an iridovirus, the iridescent blue/purple colouration caused by crystalline arrays of virus particles in the insect's cells, R. Knell *pers.comm.*).

Figure 2.18. For each treatment (sample) the % survival at the end of the final instar against time in days.



Year 2

The two broods differed significantly in survival with the first brood having a higher survival (Chi-square = 54.089, df = 1, p<0.001). For this reason the treatments were compared with separate broods. The differences between treatments were less marked than in the first year (Table 2.4) reflecting the reduced protection provided by shadecloth bags covering single trees compared with the protection afforded to larvae by individually sleeved branches.

Table 2.4. A comparison of the effectiveness of different levels of larval protection by comparing pairs of treatments from the 2002 season.

Brood	Treatment	N	Mean	Treatment	N	Mean	Chi-sq	df	p-value
1	Exposed, shadehouse	21	47. 7	Bag, outside	60	46.9	0.01	1	n.s.
2	Exposed, shadehouse	34	6. 7	Bag, outside	15	0	4.70	1	0.03
1	Exposed, outside	31	37.9	Bag, outside	60	46.9	1.95	1	n.s.
1	Exposed, outside	31	37.9	Bag, shadehouse	21	47.7	1.97	1	n.s.

Year 3

In year 3 experiments were conducted only with the first brood. Larvae without protection outside the shadehouse had a significantly lower survival compared to sleeved outside, roofed only and shadehouse larvae (Table 2.5). The sleeved outside treatment had a significantly higher mortality than the larvae in the shadehouse (Table 2.5). There was no difference between the shadehouse and roofed only blocks (Table 2.5).

Table 2.5. A comparison of the effectiveness of different levels of larval protection by comparing pairs of treatments from the 2003 season.

Treatment	N	Mean	Treatment	N	Mean	Chi-sq	P value
Outside covered	7	48.7	Exposed, outside	97	6.3	22.83	< 0.001
Outside covered	7	48.7	Exposed, shadehouse	21	58.1	0.21	n.s.
Exposed, outside	104	9.2	Bag, outside	29	25.0	25.88	< 0.001
Exposed, outside	104	9.2	Exposed, shadehouse	18	51.1	37.99	< 0.001
Exposed, shadehouse	18	51.1	Bag, outside	29	25.0	8.88	0.003

When outbreaks were small and the surrounding mopane veld had low larval densities, exposed 3rd and 4th instar larvae were rapidly found by birds (particularly Jacobins Cuckoo, *Clamator jacobinus*) and predated. This often led to complete mortality of larvae on trees. The large shadecloth bags were used primarily for 4th and 5th instar larvae and resulted in higher survival, which is likely an underestimate of true survival as larvae sometimes escaped from the bags which could not be closed at the base.

Discussion

In year one the sleeving method resulted in the highest survival of larvae, particularly if the sleeves were kept within the shadehouse. Sleeving will probably prove to be a useful method of producing 3rd and 4th instar larvae. The sleeves prevented easy access of major invertebrate (spiders, reduvid bugs and praying mantids) and vertebrate (birds and lizards) predators.

Temperatures in 2002 were less extreme than in 2003 which had periods of unusually high maximum temperatures. Higher rainfall was also experienced in 2002 although almost all the rain fell in the first half of the season (October to January). Under these conditions it larvae within shade cloth bags survived slightly better than within the shadehouse. This is most likely attributable to the incidence and transmission of disease in the shadehouse under moist conditions.

In 2003 it was hot and dry at the beginning of the season, with no or few leaves on the trees. Consequently, mortality was high at early stages of the life cycle (Figure 2.19). Under these conditions survival was better in the shadehouses. The larvae in the open and in shade cloth bags probably died because of the high temperatures and poor food quality.

Figure 2.19. First instar larvae on a bare *C. mopane* tree. Owing to the dry and hot conditions of 2003 leaves had not yet developed on the branches and the larvae died probably due to lack of nutrition and heat stress.

The main impact on the mopane worm population at the farm was disease. The introduction of diseased caterpillars on March 16th of the first year almost totally wiped out the farm population (from March 22nd to April 1st). The control of disease is a major constraint in the development of a successful and sustainable mopane worm farm. Diseases caused mortality in all treatments regardless of the degree of protection. Attempts to control disease by spraying with a general anti-virus solution, Virkon S, it appears that dormant viruses and bacteria were always present. Captive populations appear to be particularly susceptible to disease late in the season and/or under humid conditions.

Length of pupal viability and substrate conditions

Length of time pupae remained viable

A small proportion of pupae remained viable from when the farm was initiated through to the end of the project almost three years later (Table 2.6). Contrary to earlier reports only about 50% of pupae would emerge as adults with the next brood six month later (Table 2.7).

Table 2.6. The number of seasons over which pupae remained viable. The number in brackets at the beginning of each row is the original number of pupae. Other figures represent percentages of original sample that hatched at different seasons and the percentage recorded as dead, alive or parasitised at the end of the experiment. Parasitised pupae were the result of chalcids inadvertently introduced from wild pupae.

Season One		**Season Two**		**Season Three**	
First brood Oct-Dec2000	Second brood Jan-Mar 2001	First brood Oct-Dec 2001	Second brood Jan-Mar 2002	First brood Oct-Dec 2002	Second brood Jan-Mar 2003
Wild pupae (129)	Hatching 53%	Hatching 12%	Hatching 2%	Hatching 2%	Parasitised 4% Dead 25% Alive 2%

Own pupae (666)	Hatching 55%	Hatching 0.6%	Hatching 6.5%	Hatching 0.5%
	Own pupae (1518)	Hatching 46%	Hatching 37%	Hatching 0.5% Dead 12% Alive 4%
		Wild pupae (295)	Hatching 66%	Hatching 9% Dead 13% Alive 12%
			Own pupae (1632)	Hatching 42% Dead 28% Alive 30%

Table 2.7. The proportion of pupae from the original number hatching during successive mopane seasons through the course of the project. Seasons are at roughly 6-monthly intervals.

1st Season	2nd Season	3rd Season	4th Season	Alive at end of exp.
53	12	2.3	1.6	1.6% after 2.5yrs
55	0.6	6.5	0.5	no data after 2 yrs
46	37	0.6		4% after 1.5yrs
66	9			12% after 1yr
42				30% after 0.5yrs

A small proportion of pupae were still dormant and viable two and a half years after pupation, considerably longer than the 6-8 months previously assumed as the maximum duration of the pupal stage. It is possible that these pupae may remain dormant for even longer periods as the experiment had to be concluded owing to the end of the project. Around 10% of pupae remain dormant and viable after one year indicating that adults from two or more broods contribute to mopane worm outbreaks. About 50% of the pupae hatched at the next brood at around 6 months, though there was considerable variation in this proportion. It is not clear whether there is a genetic basis to the pupal duration, but this seems likely given the variability among pupae within identical settings. Assuming the pupation period is a heritable characteristic there is much scope for selection of stock for different dormancy periods.

Substrate type

Pupal survival in sandy crumbly substrate (Category 1) was significantly better than in all other substrate categories (Table 2.9). Survival was not significantly different among other soil types.

Table 2.9. Paired comparisons of pupal survival among different soil categories.

Soil category	Soil category	*t* value	df	*p*
1	2	2.975	18	0.008
1	3	2.460	15	0.027
1	4	4.907	16	0.000
2	3	0.067	9	n.s.
2	4	1.703	10	n.s.
3	4	1.430	7	n.s.

Soil type appears to influence the number of larvae that pupate successfully. Studies on other emperor moth species, for example the pine beauty moth *Panolis flammea*, have also demonstrated an influence of pupation substrate, temperature and waterlogging on pupal survival (Leather 1984). Higher survival in the sandy soils may be related to the water retention capacity of the substrate, with high water content producing a microclimate that is more suitable for bacterial, fungal and viral growth. Drier conditions may also provide better conditions for molting into the pupa stage by allowing the cocoon to harden more quickly.

Obtaining a second generation

Egg production

Mating was only occasionally recorded within the boxes and sleeves and it appeared that the moths were too disturbed within the small spaces afforded them in these enclosures. Mating occurred regularly within the shadecloth bags that covered single small trees, which had the further advantage, compared to the shadehouse, of being easy to locate egg masses. This set-up was also very easy to relocate when necessary. The most successful method of mating and producing eggs is by introducing the adult moths into the shadehouse or egghouse. However, the size of the egg house and shadehouse made it very difficult to score and even find the total number of egg masses, particularly as oviposition occurs as the trees begin to flush new leaves (early in the season this is not usually a problem as the trees are without leaves, but leaf flush occurs soon after the first egg batches are laid).

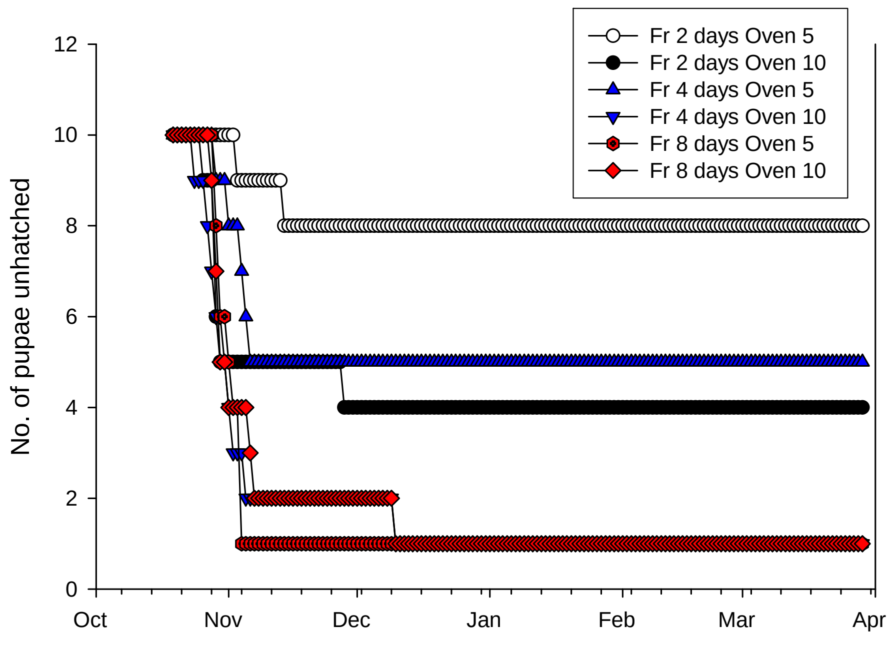
Vulnerability of eggs to parasitoids and their protection

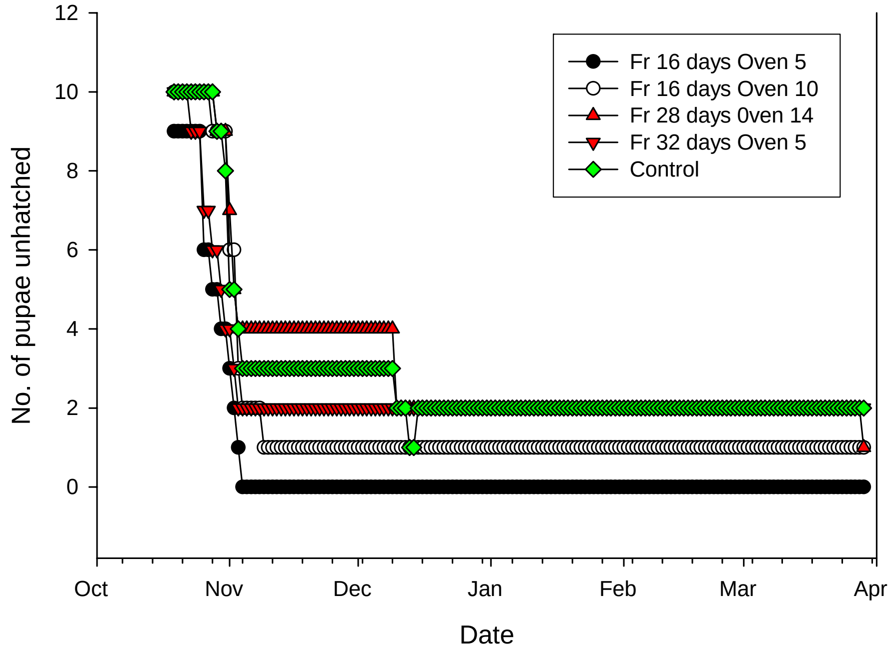
Egg parasitoids were only observed from November 7th after which they were observed on every occasion. Base on these results which are, however, based on a single location and single year, protection needs to be applied from early November onwards.
For experimental purposes it was useful to have the eggs in containers, as the larvae, when hatching, were then easy to count. For farming the method of transferring the eggs to a branch that could be protected with chiffon bags is a more appropriate practical method that proved successful in totally preventing egg parasitism. When a very large number of eggs were laid on trees (that is tens of egg masses on a single 3m tall tree) protection is less necessary as owing to the size of the outbreak final larval productivity will be limited more by available leaf material than parasitism or predation of eggs.

Manipulating pupal diapause time

Generally, pupae with the most delayed hatching (or fewest hatched by the end of the experiment) spent the shortest period of time in the refrigerator. The first pupae to hatch were those that were kept for 16 days in the refrigerator (Figure 2.20). The control had a similar hatching time to those that had been placed for 8 days or more in the refrigerator. The experiment had to be terminated after 1 year as chalcids introduced from wild pupae killed the remaining pupae.

Figure 2.20. Effects of different temperature treatments on pupal hatching times. Treatments are successive periods in cool (Fr) and warm (Oven) conditions.





Stocking density for rearing larvae

There was no correlation between density and percent of larvae surviving to the final instar (Figure 2.21) indicating that within shadehouse conditions food does not limit productivity. The implication of this is that mopane worms may be stocked at very high densities provided they can be protected from parasites and disease.

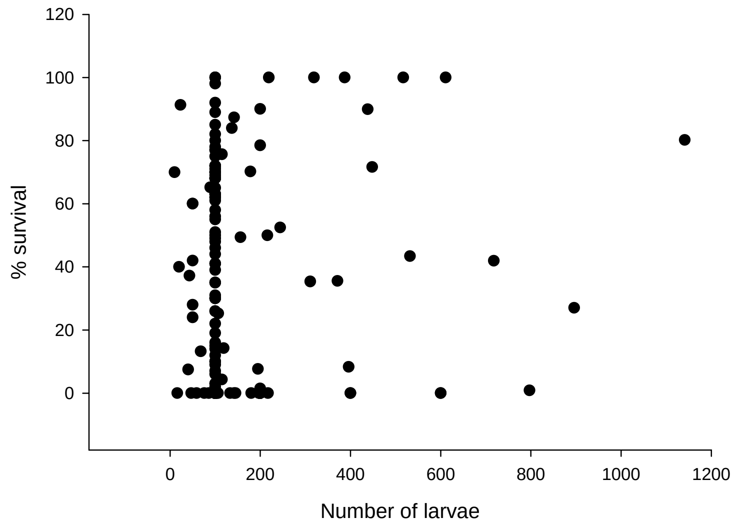


Figure 2.21. The percent survival of larvae at different stocking densities.

Age at which larvae can be released onto trees

Data combined across all three years for larval mortality with age showed a clear positive relationship between age and proportion surviving (Chi-square=80.66, df=4, p<0.001) (Table 2.10).

Table 2.10. Mean survival of larvae transferred to unprotected trees out at different ages. N Groups refers to the number of groups of 100 larvae placed out at the corresponding instar.

Instar	N Groups	Mean Survival (%)
1	243	18.2

2	29	35.5
3	23	44.1
4	25	50.4
5	26	79.0

Although the greatest survival was among the final instar larvae it would not be economically efficient to transfer larvae at this stage. It is more appropriate to transport 3rd instar larvae from the shadehouse, where leaf material will eventually become limiting, to exposed nearby trees.

Conclusions and Recommendations

This project has demonstrated that it is possible to establish and maintain a captive breeding population of *Imbrasia belina* over three years. The advantages of such a system is that fresh mopane worms can be produced at almost any time of year and at much higher quality than before. There remain, of course, several problems in the long term viability of such a venture, and these lie primarily with the control of viral and bacterial diseases. It may be impossible to entirely eliminate this risk from a captive population that is maintained throughout the year. Outbreak dynamics may confer some protection through unpredictability forcing disease and parasitoids to 'catch up' with the mopane outbreaks. A farm that has as its central purpose the continuous production of fresh mopane worms may become highly susceptible to a build up of diseases or parasitoids that are not checked by long periods when mopane worm are unavailable.

High mortality results in natural unprotected conditions owing to disease, parasitoids attack, predation and heat and drought. Many of these causes of larval mortality can be controlled and alleviated through the use of the simple techniques developed here, notably through the use of protective sleeves around branches, and the construction of shadehouses. Larvae can be successfully bred in shadecloth bags draped over small trees, especially up to the end of the second or third instar. Under normal environmental conditions the larvae can be efficiently released from bags at end of second instar (or from shade house during 3rd instar) onto exposed trees bearing fresh leaves. Mortality thereafter is relatively low and mopane worm production can therefore be raised in this manner without necessitating investment of effort in the protection of the large 4th of 5th instar larvae. However, under persistent hot dry conditions larvae under shadecloth bags overheat and desiccate. Instead, larvae can be successfully bred in the more expansive shadehouses under drought conditions, although there remains the risk of disease which seems to build up during the season. Similarly, keeping larvae in the same area, year after year, is likely to increase the viral load. Very high larval mortality under all conditions results from viral infection which is seen as the major limiting factor for mopane worm production.

Two successful methods of pupation were boxes and pits. Either method can be used, though the pit method requires less labour but is less conducive to experimentation and monitoring. Pupae can remain viable for at least two and a half years, and artificial cooling prolongs adult eclosion. If mopane worm farming is to be pursued it would be worth investigating the conditions by which dormancy could be prolonged or adult emergence artificially induced.

One central village-based mopane worm breeding facility was established to secure predictable and stable mopane worm populations. However, the results of this trial over three years indicate that domestication of mopane worms is more likely to be more successfully managed at a household level with several satellite operations across the village. At the household level this would limit the spread of disease by limiting opportunities for viral transfer. At the village level it would provide insurance among mopane worm breeders such that a failed household farm could be easily restocked from a neighbouring one. Such a network of household domestication units would also motivate individual innovation, while allowing for exchange of information and pooling of resources when appropriate.

The overall success of multi-household domestication units depends to some extent on collaboration among farming units, particularly in the exchange of information and pooling of resources, as well as in providing support in the event of failure of an individual farming unit. It should be noted that the farm system developed by this project was completed collaboratively with KyT, a cooperative women's group representing a strong mutually supportive network. This may not be the case in other situations.

Further basic research is required particularly on the ecology and population biology of wild populations. What controls the timing and location of population outbreaks remains unknown. If this becomes better understood the management of wild populations could be undertaken, which is likely to require much less in the way of investment of time and resources, and with less risk. Understanding what limits population size, particularly with regard to the role of diseases and parasitoids, remains a crucial gap in knowledge that is relevant to the productivity of wild populations as well as domestically managed stocks.

Section 2.2 Mini-livestock: Rural Mopane Worm Farming at the Household Level

Activities:

4.9a Preliminary production of text (in English, Shona and Indebele) and drawings for the mopane worm farming manual.

7.1 Identify parasites and diseases affecting mopane worms in community farm systems.

7.2 Identify sources of contamination by disease and vectors for dispersal and maintenance of infectious agents and parasitoids.

7.3 Develop procedures to reduce risk, and minimise spread, of infection and parasitism.

8.1 Build four household breeding facilities in two villages and establish a captive breeding population of MW at each.

8.2 Develop larval rearing and growth techniques, and cost-effective bulk pupation methods.

8.3 Establish materials needed and quantify financial and time requirements.

8.4 Systems to support household enterprise coordination explored by participating community members and facilitated by project researchers.

8.5 Production of updated MW farming manual relevant to household scale operations, including information on construction, breeding and rearing and prevention of disease and parasitism.

9.1 Evaluate performance and acceptability of alternative handling, processing, drying and storage techniques.

INTRODUCTION

The caterpillar of the emperor moth *Imbrasia belina* (Westwood) is a source of income for the poorest people of rural society who collect and sell caterpillars as food under the name Amacimbi (Indebele), Madora (Shona) and Mopane Worm (English). An attempt was made in an earlier part of the "Mopane Woodlands and the Mopane Worm" project ZF 0142 to establish one central village-based Mopane Worm (MW) breeding facility in order to secure predictable and stable MW populations (Gardiner 2003). The single central-base system proved problematic owing to the rapid spread of infections among the MWs. Results from the pilot study indicated that MWs are likely to be more successfully managed at the household level.

The principal aim of the latter part of the project was to implement and test the feasibility of a household scale semi-domestication system for breeding and rearing MWs. It was done with the prospect of meeting the subsistence needs and to enhance household income through the marketing of surplus production. The study utilized and built upon the earlier research results and attempted to establish farming systems at three independent households.

It is also expected that such a network of household domestication units would motivate individual innovation, while allowing for exchange of information and pooling of resources when appropriate. In the implementation of the farming methods the farmers were allowed to make their own choices; if they wanted to reject a method or change it, this was their prerogative. Methods, which were considered to be of help with farming, information and the required material, were provided. A further component of the work investigated and developed improved processing and storage methods. The farming and improved post harvesting was done in order to increase the households' output and decrease levels of contamination.

Biological and ecological information obtained at the same time builds on the existing knowledge of MW biology and ecology both from the first part of the project and previous studies (Frears *et al.*, 1997; Wiggins, 1997; Styles & Skinner, 1996).

A HOUSEHOLD GUIDE TO FARMING MOPANE WORMS

The "Farming Mopane Worms" guide, an output resulting from the findings in the first part of the project, was printed in 3 languages (Figure 1) and distributed in July 2005 to the villagers and government officials for the areas concerned. The draft MW guide was used as an introduction to the concept of farming MWs. Draft copies were distributed to interested members of the rural communities, local organizations (Rural District Councils, Forestry Commission Offices) officials (village headmen and councilors) and schools (see Appendix 1). Feedback on the draft version was gathered through workshops and meetings and then used to produce the final version of the guide. Field days in each area were carried out to make sure there were no unanswered queries concerning the contents of the guide (Appendix 1). The guide and the idea of farming MWs were well received and much interest was shown in improving drying and storage methods. The guide was produced in a story format, with a conservation theme, so that it could also be used as a teaching aid at the local schools. The schools showed a great interest in the guide and asked for further copies.

Figure 1. The Mopane Worm guide colour coded for the three languages (English, Ndebele & Shona).

STUDY SITES

The three sites in Zimbabwe chosen to implement the farming were ones where economic and biological work on MWs had already been carried out. The University of Zimbabwe, Institute of Environmental studies (IES), had carried out most of their economic work in the Matobo District (Gondo 2001, Frost 2003). For this reason the specific villages chosen were Ndiweni (part of the Madwaleni Ward in Tshatshani Communal area) 5 km south of the town Kezi and Kapeni (part of the Beula Ward in Mambali Communal Area) approximately 40 km south of the town Maphisa (Figure 2). Work carried out by the Zimbabwe Forestry Commission (Mushongahande 2003) on the biology of the MW took place at Village 27, Dombodema, 18 km NW of the town Plumtree in the Bulilimamangwe District, this village was chosen as the third site (Figure 2).

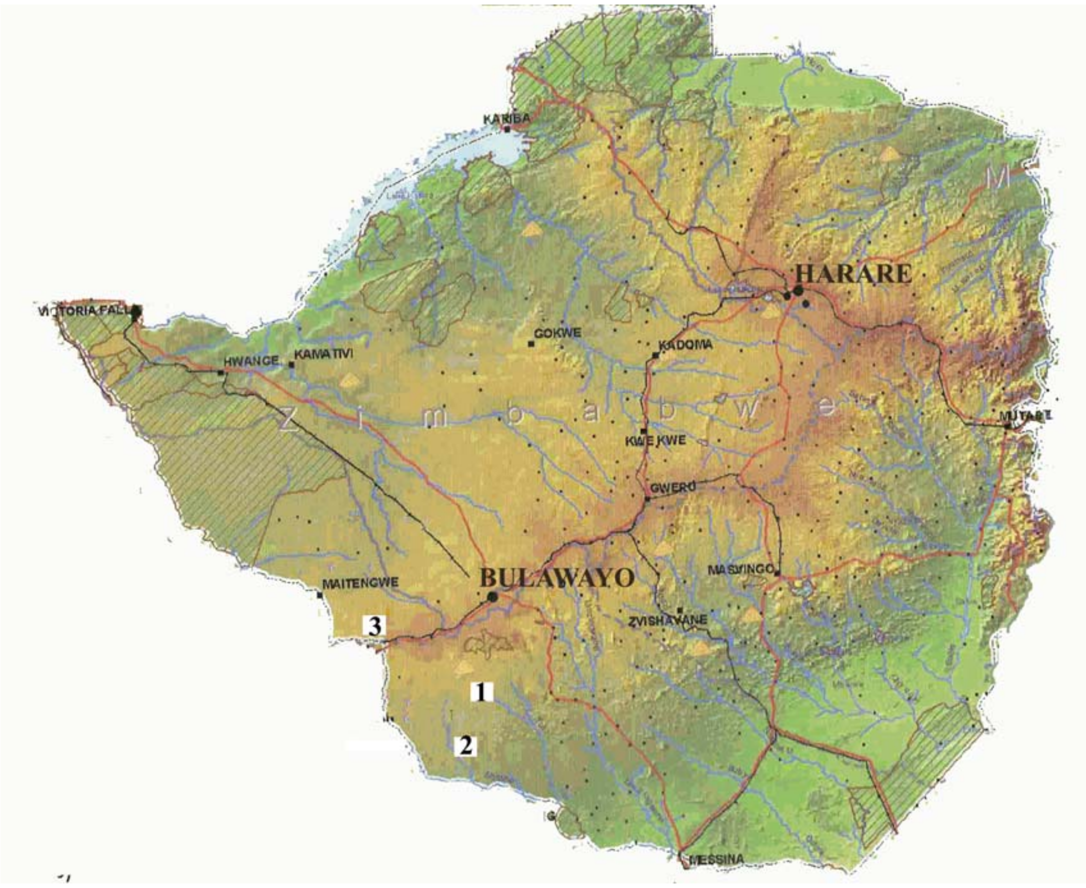


Figure 2. Map of Zimbabwe illustrating the location of the three study sites in the south west of the country: 1-Ndiweni, 2-Kapeni and 3-Dombodema.

From our visits to the study sites the following households were identified for the farming and processing:

1. At Ndiweni Mr. Moyo carried out the farming in conjunction with the Kraal head Mr. Ngwenya. This site is characterized by the presence of only a few large Mopane trees scattered amongst the households (Figure 3).
2. At Kapeni it was decided the village would farm MWs co-operatively. Although the person in charge was Mr. Dube (the councilor for Kapeni) it was mostly women from the neighbouring households who were involved in the farming. In this area there are medium to dense stands of low to medium sized Mopane trees close to the households (Figure 4).
3. At Dombodema (Village 27) near Plumtree, Mr. Ndebele and his wife, Senzeni Ndlovu carried out the farming. The village has their households close together and no Mopane trees are present within their household area (Figure 5a). Due to outsiders coming and harvesting MWs from the general area, the family utilized the Mopane trees within their enclosed field area (Figure 5b). Most of the Mopane trees were of a low to medium size.

Figure 3. A large Mopane tree in Mr. Ngwenya’s yard; the tree was used for Mopane worm production.

Figure 4. The low-medium Mopane trees surrounding the households in Kapeni.

(a)  (b) 

Figure 5. (a) Mr Ndebele and Mrs Ndlovu's household area. (b) Mrs. Ndlovu and Mr. Nyoni within the families enclosed field area, note the Mopane branch fence (arrows) behind Mrs. Ndlovu.

FARMING MOPANE WORMS

From Mopane Worm Egg to Adult Moth

<u>Egg collection, storage, placement and protection</u>

While eggs were being located, egg parasites (Figure 6) were collected and sent to the South African National Collection for identification. Two egg parasites were identified as *Mesochomys pulchriceps* and *Pediobius* sp. *Mesochomys pulchriceps* is a common and widespread egg parasite of *I. belina* and total egg parasitism is not uncommon (Ditlhogo 1996).

Figure 6. An egg parasite (arrow) investigating a Mopane Worm egg mass

Materials & Methods

This was the first brood of the season and the households collected and took care of the eggs in slightly different ways.

1. Ndiweni

At Ndiweni eggs were collected from Mopane woodland approximately 4km from the households. Young boys who were tending to their cattle and goats brought the egg masses (attached to twigs or leaves) back to the household. The twigs with the eggs were tied to the Mopane tree around Mr. Ngwenya's homestead (Figure 7). Mr. Moyo said he did not want to store the eggs in the tin cans or put a bag around them, he preferred to attach them straight to the trees. (Approximately 14 egg batches were placed on a large tree next to the homestead, but the exact number cannot be given as, after the first field visit, Mr. Moyo added a few more batches-he did not keep a record of exact numbers).

Figure 7. Mr. Moyo with an egg batch (upper arrow) attached by string (lower arrow) to the lower branch of a large mopane tree.

2. Kapeni

Mr. Dube's daughters collected eggs from Mopane woodland within a radius of 2 km of the household. The local moth population also laid eggs on some of the trees surrounding the households. At Kapeni the eggs were treated in three ways.

i) Eggs were placed in used tins and kept in the house to protect them from parasites. The cans were checked daily for hatching activity. (Figure 8a).

ii) Eggs were tied to branches of trees (2-3 batches per tree) and left to hatch.

iii) Eggs were tied to branches of trees as in (ii) but they were also covered with chiffon sleeves (70cm x 110cm) to protect them from egg parasites (Figure 8b). When the eggs hatched the chiffon bag was removed.

(a) 

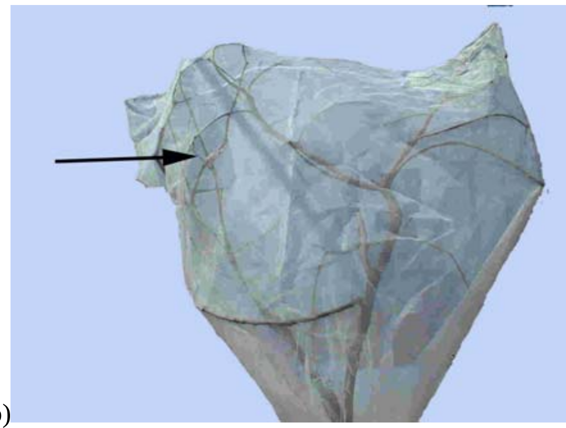
(b) 

Figure 8. (a) Mr. Dube's daughter with eggs in a used tin can, the eggs were stored on the top of the cupboard to the left of the picture, (b) eggs (arrow) enclosed in a chiffon bag.

3. Dombodema (Plumtree)

Eggs were brought into Dombodema from the Maphisa area, approximately 100 km south east of Plumtree. At Dombodema the eggs were treated in a similar way to Kapeni (Figure 9a-c) but in addition some eggs that were tied to branches were covered with a 20% shade cloth bag (Figure 9d). This meant that when the eggs hatched the young larvae were already protected from large predators.

(a)  (b) 

(c)  (d) 

Figure 9(a & b) Egg batches being placed in used tin cans and covered with small pieces of chiffon, (c) Mrs. Ndlovu tying an egg batch to a branch of a small Mopane tree and (d) eggs tied to a branch of a tree enclosed in a $2m^3$ shade cloth bag.

Results

Few egg parasites were present, possibly because it was the first brood of the season and parasitism by *M. pulchriceps* is far greater during the second generation than during the first (Styles 1996). At all three sites tying the eggs straight onto the branches was successful. Successful hatchings were also achieved by the other methods (eggs in cans, the eggs in chiffon bags and those in the shade cloth bags). The introduction of eggs into Mr. Ndebele's lands was very successful as no other eggs were in the area and as a result he was the only household with significant numbers of larvae. Ease of egg introduction close to the house varied and depended on the natural MW situation. Both at Ndiweni and Kapeni eggs were brought in from walking distance to the households. In contrast the eggs at Dombodema had to be brought from a distance that required transportation.

Discussion and Recommendations

At Dombodema the closest source of abundant eggs was approximately 50 km and the cost of the transport to get eggs would have to be taken into account (by bus approx £ 1.75 for the trip). When the eggs are attached directly to the tree the only material required is string. It is hoped that from the next moth hatching the Ndebele family will be able to produce MW eggs from their own stock.

In the second brood the egg parasitism level is likely to increase (Ditlhogo 1996 & Style 1996), and placing the eggs in tins or covering them with chiffon bags could be more successful than tying them straight onto the branches. This could not be checked in the present study, as the eggs for the next brood will only be laid after the conclusion of the project. Parasite levels and how these affect the second brood need to be investigated further. Tying the eggs straight onto the branch does save time, the eggs do not need to be checked as regularly as with the other methods and on hatching the larvae can start feeding immediately. If parasitism is high the farmer can decide on one of the other methods. The cost of a chiffon bag is approx £2.9 (see Table 1 for costing of material for 10 MW seasons). The farmer could keep 3 or 4 egg masses in a chiffon bag and then move the clusters of 1st instar larvae once they have hatched (this has the potential of producing about 1000 larvae). If tin cans are used, apart from the tins, a piece of chiffon and string is required (£ 1.06). Households are likely to be able to source and store a supply of used tins from the previous year. The disadvantage is that cans need to be checked daily for hatching activity.

Larval protection and movement

During this period of the farming diseased larva were sought in order to get a sample for disease identification. A few that showed some symptoms of being diseased were obtained approximately 7 km north of Kezi. Portions of these specimens were dissected and samples preserved in both 70 % alcohol and a 60% sucrose solution. The samples have been sent to the Universidad Publica de Navarra in Spain for virus identification.

Materials and Methods

Disease control

At Kapeni & Dombodema the density of larvae was kept fairly low, approx 600-900 per 2-4 m high tree. This was done to decrease the chances of disease outbreaks. At Ndiweni the trees are very isolated and this in itself should limit the spread of disease.

Protection from birds

The methods used to protect the larvae from bird predation were:

i) Physical deterrent in the form of shade cloth bags of two different sizes, one for trees from 1-2m in height ($2m^3$ bags in both green and white, the latter due to green shade cloth becoming unavailable, for costing see option no. 3 Table 1) and the other for trees 3-4m in height ($4m^3$ bags, for costing see option no. 4 Table 1).

ii) Visual bird deterrents, hawk silhouettes and scary eyes. The hawk silhouettes were cut out of galvanized steel sheeting and painted black (for costing see option no. 5 Table 1). Scary eye masks were made from paper maché. A balloon was covered with paper maché and left to dry. The outside was then painted with white enamel. A number of large eyespots were then painted to create a mask effect (Figure 10). As an added deterrent some streamers were attached to the base of the mask (for costing see option no. 6 Table 1).

1. Ndiweni

The trees at Ndiweni are too large for the use of shade cloth bags. As Mr. Ngwenya's tree is very close to the homestead and the children play outside, near and around the tree, acting as a bird deterrent, Mr. Moyo & Mr. Ngwenya declined the use of the hawk silhouettes and scary eyes. Their larvae were left within the protection of the household activities.

2. Kapeni

At Kapeni larvae that hatched from eggs placed in the tin cans were transferred to trees covered with the 2 m^3 bags. A small Mopane tree twig with leaves was placed into the tin (see Figure 8a), which allowed the young larvae to crawl onto the twig. The twig was then tied to the branch of the covered tree. The shade cloth protection was only kept for the first three instars. From the fourth instar the bags were removed and the larvae allowed to move from one tree to the next of their own accord. This was also done because the wild population around the households was quite high and the people felt they no longer needed to protect the larvae to ensure a good harvest. For the young larvae that hatched from the eggs attached to the tree both hawk silhouettes and scary eyes were used independently (Figure 10).

Figure 10. Mr. Dube with a hawk silhouette and a scary eye, they were attached to the trees by a piece of string.

3. Dombodema

Some eggs, which were attached directly to the trees, were allowed to hatch within the 2 m^3 shade cloth bags (Figure 11a & c). In addition 4 m^3 bags were placed over larger trees and upon reaching the 4th instar some of the larvae from the small bags were moved into these (Figure 11b & d). As there were no wild larvae at this site the Ndebele family were keen to maintain the use of shade cloth bags for maximum protection of the larvae. If the larval density was too high some larvae were removed and placed on another tree (Figure 12). Similarly, when the leaves from a tree had been depleted, the bags were moved and the larvae placed on the new tree. Trees that did not have bags had hawk silhouettes or scary eyes to deter the birds (Figure 13). Once the larvae reached the fourth and fifth instar the farmer no longer used these two visual deterrents.

(a) (b) (c) (d)

Figure 11. (a) Mrs. Ndlovu placing a 2 m^3 and (b) a 4 m^3 shade cloth bag over Mopane trees. (c) 2nd and 3rd instar larvae (arrows) and (d) final instar larvae in shade cloth bags.

Figure 12. Moving late second instar larvae from one tree to another. These small branches are placed amongst the leaves of the new tree.

Figure 13. Mrs. Ndlovu and Mr. Nyoni with a scary eye, in the background just behind and to the left of Mr. Nyoni is a shade cloth bag covering a small tree.

Results

Larvae often disperse once reaching the fourth instar. It is therefore difficult to compare the results for the different methods as the larvae on trees without shade cloth bags tended to move more readily to neighbouring trees. However the farmers at both Kapeni and Dombodema felt the larvae in the shade cloth bags developed faster and had a better survival than those in the open. This may be a result of the temperatures in the bags being more favorable for growth. Styles (1996) found MWs would not feed under high temperatures and mortality in the early instars was high under adverse climatic conditions. The farmers also thought the green shade cloth bags were better than the white ones. The farmers at Kapeni did not worry too much about their stock, as there was a good number of MWs in the wild. In contrast Mr. & Mrs. Ndebele were very keen on the use of the shade cloth bags and to a lesser extent the other methods to protect their stock. At Ndiweni the physical presence of Mr. Ngwenya's household close to the tree appeared to offer enough protection to the larvae. No diseases were recorded at any of the households.

Discussion and Recommendations

Each farmer assessed his situation concerning the MW season and decided on what he would like to do. The results follow the suggestions in the MW guide, in good seasons the farmers can pack away their larvae protection equipment and keep it for the next. A greater need for larval protection is realized when the wild populations are low or climatic conditions are harsh. This season was favorable for MW growth and under adverse conditions the shade cloth bags may have greater importance. The bags would have to be tested under unfavorable climatic conditions.

It does appear that the household system reduces the disease risk associated with one large MW concern. It is recommended that the farmers keep their larval density at 600-900 per 2-3 m high tree. In years when there are low numbers of MW and the households are isolated the risk of disease spread is low. Disease outbreaks still need to be monitored and investigated during the second brood.

Pupation and pupal storage

Materials & Methods

The pupation pits, which were successful at Maunatlala (Gardiner 2003), were modified so as to decrease the cost of material required (Figure 14, for costing see option no. 10 Table 1).

(a)  (b) 

(c) 

(d)  (e) 

Figure 14. The construction of a pupal pit: (a) a pit is dug measuring 2 m x 1 m and 30 cm deep, (b) a 3m x 3m piece of 40% shade cloth is placed over the pit and positioned so that most of it overhangs on one side, (c) sandy

soil is placed back into the pit, (d) a frame is made from six small poles pushed into the soil supporting two pieces along the length of the pit and three pieces across the width; the poles are tied together with string for stability, (e) the shade cloth is folded back over the frame covering the pit and the sides are then sown together with string. A small part of the seam is left open through which the larvae can be introduced.

The materials are shade cloth, string and poles. Approximately one thousand larvae can be placed in each pit for pupation. Once the larvae have been introduced into the pit, they are left for about three to four weeks before being removed.

In the first season, once the pupae have been dug up, they are placed in cardboard boxes. As an additional safety precaution the box can be placed in a chiffon bag to prevent an attack by Chalcid parasites. The cardboard boxes must be kept in a place that is safe from rats. Some of these pupae hatch after a very short diapause and storage in boxes allows the moths to hatch, in February, without the risk of wing deformation. Second season pupae, and those not hatching from the first brood, are stored in jars or similar containers for better protection over the long dry winter. Shortly before hatching with the first rain of the summer season in November the pupae are placed in the boxes.

Results

Ndiweni, Kapeni and Plumtree

Farmers are keen to have their own MW stock. At all three sites the participants were enthusiastic about the pits (Figure 15). At Kapeni and Dombodema neighbours stopped and asked about the pit. At the moment the pupating larvae are in the pits and will be dug up in February. The farmers have been instructed about pupal storage.

(a) 

(b) 

(c) 

Figure 15. a) Mr Ngwenya discussing the pit with passers-by, b) Mr Dube’s children having just introduced larvae into the pupal pits c) the last segments of the larvae as it burrows into the sandy soil.

<u>Moth hatching</u>

During the field days it became apparent that many of the households were unaware of some aspects of the MW life cycle, for instance that moths were of different sexes or that the moths were even associated with the MWs. The farmers were shown how to sex the adult moths (Figure 16a). They then wanted to know if it was possible to sex the pupae, and were taught how to differentiate between male and female pupae (Figures 16b&17). At some stage they may want to keep a certain number of male and female pupae together, for instance if they want to transport them to another area.

(a)  (b) 

Figure 16. a) Sexing of the adult MW moth and b) sexing of the pupae

(a)  (b) 

Figure 17. The difference between male and female MW pupae, (a) in the male the last segment, when seen ventrally, forms a straight line, indicated by the arrow head parallel with the previous segment, (b) in the female the last segment forms a line that curves in towards the previous segment and then out again forming a shallow V shape.

When the moths hatch the shade cloth bags will be set up over small trees. The day after the moths hatch the male and female moths will be removed from the cardboard boxes and introduced into the bags. The moths can also be released by placing the boxes at the base of a tree under a shade cloth net and opening the lid. The moths will be allowed to lay eggs on the tree and these eggs can then be moved and treated as indicated above. Experiments on moth release and mating was done in Maunatlala (Gardiner 2003) but has yet to be tested at the household level.

Mopane Worm Processing

Harvesting & degutting

The MW has a tough skin and is protected along the length of the dorsal surface by six parallel rows of black or dark reddish brown spines (the two rows of large central spines are clearly visible on the first picture of the frontispiece). The spines can be painful and cause lacerations and the spines and associated hairs seem to have a slight urticating effect. In addition, when the larvae are handled, they often exude a slimy green fluid from the mouth (some fluid can be seen around the mouth of the frontispiece larva). This fluid irritates any scratches on the hand. Hand protection therefore helps with harvesting and degutting. In an attempt to prevent excessive damage to their hands, some collectors' tie bark fibres around their fingers (Kozanayi & Frost 2002). As it has been noticed that harvesters in Botswana often wear gloves this aspect was investigated. The rollers, developed during the initial stages of the MW project (Taylor 2003) were not successful as the traditional method of degutting by hand is faster.

Materials, Methods & Results

Different glove types were assessed for their harvesting and degutting (squeezing) suitability, PVC gloves, commercial leather gloves and household kitchen gloves. It was found that leather gloves and PVC gloves were the preferred choice for harvesting (for costing see option no's 8, 9 & 10 Table 1).

For squeezing, the household kitchen gloves were preferred (Figure 18). The household kitchen gloves allow the hands to be more sensitive to the touch. They however do not last very long and wear out completely after approximately three 20 litre buckets of MWs are squeezed. Although PVC gloves are more robust, they make squeezing slow and cumbersome.

Figure 18. The use of kitchen gloves for squeezing MWs (the yellow and black pairs). The yellow pair is showing signs of wear, there is a hole in the top of the right index finger, caused by the spines of the larvae penetrating the glove as the larvae is concertinaed into the glove. The orange pair of gloves is made from PVC.

Discussion & Recommendations

Squeezing and drying are the two main bottlenecks in the processing of MWs. The hand method is a very fast way of removing the gut contents and it will be difficult to find a mechanical method to replace this system. If an efficient mechanical system could be developed it would greatly help and it is worthy of further consideration.

Leather gloves are effective and the cheapest for harvesting. Some harvesters squeeze as they pick and for this method they either have to have kitchen gloves or bare hands. A harvester from Bulawayo, who was visiting relatives and was harvesting approximately 20 km N of Kezi, had developed an interesting method of protecting her hands. The harvester had cut bands from the inner tube of a car tire and had wound these around her forefingers and thumbs, she squeezed the larvae while harvesting. The protected digits shown in Figure 19 are the ones most used for squeezing. This could be investigated further and a thimble-like structure produced which is durable and protects the thumb and forefingers of both hands.

Figure 19. The use of rubber bands to protect the hands while harvesting and squeezing.

A preferred time for collecting the larvae is when they are coming down off the tree for pupation. If they are collected at this time, no squeezing is required as the larvae empty their guts naturally before going underground. However the collecting window where there are enough on the ground to make it worthwhile is relatively brief and hence people collect prior to this. There may also be a certain amount of "we had better get there first" involved and this aspect of

MW collection needs to be investigated. If collection during large outbreaks could be restricted to the period when the larvae leave the trees processing would be a lot easier. It would be of interest to find out how much can be harvested during this time compared to normal harvesting. Harvesting at this time could be a problem in areas were outsiders come in, or where there is little control on harvesting, as outsiders may not aim solely for the larvae coming down off the trees but instead take what they can. Although not as many may be harvested, as they are fully mature, their final dried size should be larger than the immature ones and it is possible that the same volume could be harvested. In areas where the MWs are not farmed it is likely that leaving them until this time would also allow a number to pupate and more likely to lead to sustainable utilization.

Cooking

Traditional cooking is done on a fire. The MWs are placed in a container with some water and salt (see Taylor 2003 & Figure 20). This system relies on the use of wood and regular stirring, in order to allow even cooking and prevent the MWs at the bottom of the pot burning. Solar cooking was tested as an alternative as it decreases the amount of wood used and the physical labour/time spent on cooking. Solar cooking allows the items to be evenly cooked without stirring.

Figure 20. A villager in the Kapeni area cooking MWs in a large three-legged potjie pot.

Materials & Methods

Three solar cookers were tested.

1) The solar box, painted mat black on the inside with a lid of Perspex and insulated with polystyrene (Figure 21a)
2) A solar cooker made available and developed by the University of Zimbabwe (UZ) Technology Development Centre (in Depart. Soil Science and Agr. Eng.). (Figure 21b)
3) An adaptation of the UZ cooker: A cooker made of shiny sheet metal in a wooden frame and backed with polystyrene with a glass cover (Figure 21c).

(a) (b) (c)

Figure 21. The various types of solar cookers a) the black box with a reflector b) a cardboard cooker coated with a silver film on the inside and c) a sheet metal cooker being demonstrated to the women from surrounding households at Kapeni.

Results, Discussion and Recommendations

The solar box was not as efficient as the cardboard cooker or the sheet metal cooker and was rejected. Modifications to this system may improve its efficiency. The cardboard and sheet metal cookers were found to be efficient and a 1 litre pot of MWs cooks in three hours.

The most desirable of the cookers was the sheet metal with glass cover. Although this cooker had the same cooking time as the cardboard version it was the people's first choice because of its durability. If there is rain it can stay out in the rain only being brought in during the night. The people at Kapeni would like to see this solar cooker made available commercially. The affordability of this type of cooker to farmers needs to be investigated. Even though the cooker has a glass cover it proved to withstand transportation in a trailer to Kapeni, approximately 40km along a corrugated dirt road. The lid could also be made from Perspex, which would decrease the chances of breakage.

Solar cooking may have a significant place in farming MWs. Solar cooking has not faired well in family meal cooking (pers. comm. Mrs. Shangwa Technology Development Centre, UZ) this may be due to meal preparation being very traditional and not an income generating process. On the other hand MW processing is seen as a means of income and hence people may be more willing to try the method to increase their output. It is unlikely to completely replace fire cooking as at least 50% sunshine is required but can be used as a significant supplementary method for cooking. Effort needs to be made to disseminate solar cooking information and make commercial cookers available.

Drying

Drying is one of the major problems in processing. It can take many days and during this time of the year (in particular the December/January harvest) the humidity is often high, making drying difficult. If the MWs are not dried properly they spoil rapidly. Traditionally, after cooking the MWs, they are laid for drying on a swept piece of ground. The piece of ground varies depending on the harvesting situation (Figures 22-24) and hence the amount of contamination is likely to vary. In Botswana the MWs are also sometimes placed on hessian bags (pers. obs. & Taylor 2003). The traditional ground drying method takes 2-4 days depending on weather conditions, about 3 days with cloud cover of 30-40%. It also allows easy access for other insects. Insects such as dermestids and flies can cause significant levels of contamination (Allotey et al. 1996 & Nyakudya 2004).

Figure 22. Drying at the harvesting site away from the household. An open area is found, swept, and the MWs spread out on the ground.

Figure 23. Traditional drying at Mr. Dube's household; MWs are spread outside the house on a swept area. These MWs are open to the movements of animals (dogs & chickens) and wind can easily blow material onto them. Debris and other matter can be seen around the MWs in the right-hand photograph. This is probably a major source of contamination and samples have been taken under such conditions for bacterial and fungal analysis.

Figure 24. Another household in the Kapeni area used a cemented foundation for drying, this is slightly raised off the ground and is likely to be more hygienic than the previous situation.

The methods and systems given below were tested to try speeding up the drying time and improve the hygiene of the traditional system. The driers were developed with the idea that other household commodities, such as vegetables, grain and meat can also be dried when no MWs are available. An attempt was also made to make them cost effective.

Materials & Methods

Drying frames

Drying frames were constructed as these were found to be a useful aid in the drying system (Taylor 2003). They can be used with all the drying systems developed. The frames were constructed in a similar way to Taylor (2003) but were made smaller so they could be inserted into the drying tower (56 X 60cm with 6mm round bar and covered with 20% shade cloth).

1) Drying tower with heating tunnel (Figure 25).

It was found in the earlier part of the project that a number of frames suspended above one another did not work (Taylor 2003). This was due to the shading of the lower frames from those above. A solar drying tower was developed in an attempt to overcome this problem.

The tower was modified from a large drying tower developed at the University of Zimbabwe. The UZ tower had an extractor fan mounted on the side of the drying chamber. As a fan would not be practical or affordable in a rural area an attempt was made to make the drier without the fan and rely on the heating of the chamber by a long plastic tunnel. The tunnel was sloped up towards the drying chamber allowing the movement of hot air by convection. The bottom of the tunnel was made from foam covered with black cloth; the tunnel was then covered with clear plastic. The chamber was insulated on the inside to prevent the escape of heat. The chamber was made to take seven shelves that could be slid in and out.

Figure 25. Drying tower with heating funnel

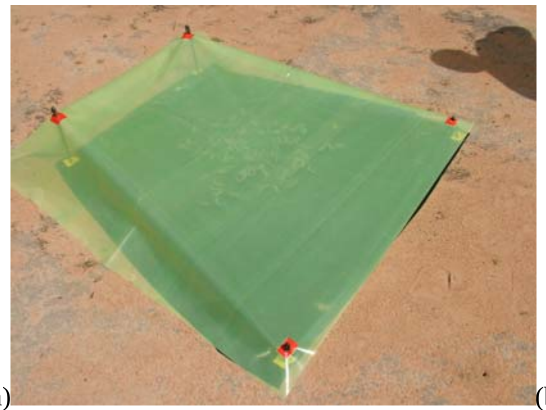
2) Modified tower (Figure 26)

Figure 26. Modified drying tower, the chamber heats up drawing air in at the back and out through the turret at the top.

The tunnel, which had proved to be ineffective, was removed from the tower and the heating chamber modified so as to absorb heat from the three sides facing the sun. The back, shade side, was kept insulated. On the front of the tower clear plastic was used while the sides were made of sheet metal painted black. The air inlet, where the tunnel previously would be attached, was covered with a piece of gauze. This prevented the entry of flies and other insects. This entrance could be covered with different sizes of plastic depending on how much airflow was required.

3) Black plastic base with a clear plastic cover (Figure 27)

The MWs are placed on black plastic sheeting under a cover of clear plastic. At Ndiweni this method was used to dry the MWs without cooking. This was done in two ways: firstly by soaking the MWs overnight in brine and secondly just sprinkling salt over the MWs and allowing the salt to draw water out overnight.

(a)  (b) 

(c) 

Figure 27. Plastic drying systems: (a) with heavy duty UV resistant plastic cover held by four metal pegs. It can be opened to various extents and the tray slopes towards the back allowing movement of hot air. This system can also be used with (b) a shade cloth frame, or (c) a lighter plastic cover, which was effective but less durable.

4) Black steel trays with and without clear plastic covers (Figure 28)

The above system was modified slightly by the use of a metal tray in place of the black plastic.

Figure 28. Instead of the black plastic a sheet metal tray was used to dry the MWs, the tray slides under the plastic shown on the left of the picture. The metal trays can be used with or without the shade cloth frame, the MWs grouped at the top are cooked in the traditional way while the bottom group are salted but not cooked.

Results & Recommendations

1) Drying tower with heating tunnel

Unfortunately the movement of air along the tunnel was slow and relied more on the presence of a breeze than convection. The chamber did not heat up sufficiently for the MWs to dry rapidly. For this reason the drying tower was modified.

2) Modified drying tower

Mr. Ndebele preferred the tower for drying even though it was slower than the next method (plastic sheeting). He liked the idea of the larvae being stacked and not having to take them in when it rains. He also liked the idea of using it for other household products. The Mopane worms took 1.5-2 days to dry under sunny (30% cloud cover) conditions. At Ndiweni and Kapeni the people preferred the plastic sheeting methods.

The tower system should not be abandoned as it could be modified further to improve its ability to absorb heat. For instance side reflectors could be attached to the base of the chamber.

3) Black Plastic with a clear plastic cover

The use of plastic produced an efficient drying system and reduced the drying time to one day (7 hrs under sunny conditions). The method is cheap (for costing see option no's 15, 16&17 Table 1) and locally cut wooden pegs could replace the metal pegs. It was also found that few insects stayed within the drying area, this was likely to be due to the high temperatures (47^0C after 10 minutes of full sunshine) produced by the plastic. The uncooked MWs took a few hours longer to dry than the cooked ones but it has the time saving advantage of no cooking. No difference could be found in using brine or just sprinkling the uncooked MWs with salt. However the storage ability of these “uncooked” MWs would have to be tested. Mr. Dube & Mr. Moyo liked the taste of them. A disadvantage of the plastic was dirt could still be blown onto the plastic.

4) Black steel trays with and without clear plastic covers

The drying time was similar to that of the plastic but it has the advantage that dirt does not get blown or kicked into the tray. It would also be the cheapest drying method over 10 MW seasons (Option No. 17, Table 1). Even though the MWs dried without the clear plastic cover, having it prevented flies from coming and settling on the MWs.

In this and the previous system the decrease in drying time and the decrease in number of insects entering the MWs is likely to help with the storage and hygiene of the MWs. Some people liked to use the shade cloth frames in conjunction with the tray but this made little difference in drying time.

The method adopted would depend on the financial ability of the farmers. Many surrounding households at Kapeni wanted to purchase the black plastic. These relatively small improvements and the availability of information could significantly increase the drying hygiene.

4.2.4 Cooking and Drying Combined (Roasting)

At Kapeni we were shown a traditional charcoal method where the larvae are squeezed and then mixed with hot coals (Figure 29). The pile is then turned continuously until the MWs are dried, this may take up to 5 hours. The MWs are not cooked in salt water prior to charcoaling. Although this method is said to be the easiest, the product is not of high quality and does not fetch the best price as the MWs do not keep well under wet conditions. Their spoiling may be due to the lack of salt to preserve the MWs.

Figure 29. The traditional charcoal method of cooking & drying, the MWs are mixed with the charcoal from a fire and stirred continuously, after a number of hours the MWs are picked out of the charcoal.

Materials and Method

A modification of the charcoal method was tested. The MWs were roasted over a fire on a grid (Figure 30, see Option No. 18 & 19 for the costing of two grid types). The grid must have small holes to prevent the MWs falling through. The roasting method was tried with uncooked MWs (soaked with salt over night as a preservative) and cooked MWs. The MWs must also be moved (stirred) to prevent them burning, the amount of stirring depends on the heat of the fire.

Figure 30. Roasting MWs over an open fire, this method both cooked and dried the MWs.

Results & Recommendations

With a hot fire this method only takes about an hour for the MWs to dry. This could be particularly useful for periods when it is cloudy or of high humidity. It still uses wood but the amount of wood used compared to when the MWs are cooked in water needs to be investigated. The big advantage is the MWs are cooked and dried at the same time. The pre-cooked MWs dried in a similar time to those not pre-cooked. The storage and acceptability to the market of this method needs to be investigated. When one considers that the traditional charcoal method is accepted in Zimbabwe it is very likely the grid-roasted system will be too, as it produces a superior product. This simple modification could dramatically help decrease contamination and processing time.

<u>Storage</u>

As indicated in an earlier part of the project (Taylor 2003), there are problems associated with the storage of MWs (Nyakudya 2004). Traditionally they are kept in woven polypropylene bags in which maize or a similar product has been stored, plastic or metal buckets and clay pots. In all these items they are subject to contamination and spoilage (Allotey et al. 1996). In many cases the MWs are sold as soon as possible in order to prevent losses due to spoilage. In order to decrease the deterioration both from micro-organisms and insects the mopane worms are taken out of the bags and spread on the floor in the sun. In Botswana some people have started a sterilization system by placing a black plastic sheet over the MWs while they are in the sun, in an attempt to kill the unwanted insects. This does help, as after treatment the MWs get infested to a lesser extent (pers. comm. Pearce, KYT Botswana).

Better prices are obtained later in the year and for this reason traders who store the MWs fumigate them with Phostoxin gas (Taylor 2003). However, Phostoxin gas is dangerous and only registered pest control operators are allowed to fumigate with it. An attempt has been made to improve the solar radiation method so that households can store their MWs for longer and have a more hygienic product.

Materials and Methods

Sterilization bag

For the sterilization of stored mopane worms, large envelopes (lm x 1m) were made from black, high-density polythene sheeting on one side and clear sheeting on the other (Figure 31, Option No. 20, Table 1).

Figure 31. A large sterilization bag, folded at one corner to show the black plastic under surface, the upper surface was made of heavy duty UV resistant clear plastic.

The edges were stuck together to prevent heat (or MW) loss from inside. The envelopes are placed on the ground, if possible facing the sun with the clear plastic uppermost. Under windy conditions the edges of the envelope can be weighed down with bricks, stones or pieces of wood. The envelopes are left in the sun for 15-25 minutes. The MWs are then removed and placed back in their bags where they can again be stored for 2-3 weeks before the process is repeated. The high temperatures in the bag should kill fungi, bacteria, moulds and insects. It is not recommended that they be left for longer as sustained high temperatures, 60°C and above, are likely to have little added benefit and may decrease the food value of the MWs.

Results

The results for this method are still to be obtained, as it will take further months to check the efficiency of the system. The contamination by microorganisms and insects of the MW products are being tested. This could not be done before as the MW products have only just become available for testing.

4.3 **Mopane Worm farming costing summary**

An estimate of the investment required for equipment over 10 MW seasons (5year period) is provided in Table 1. The farmer does not need to purchase all the equipment but can purchase the items he feels are most necessary to increase his output sufficiently to obtain a return.

Table 1. The cost of Mopane Worm farming equipment. The cost has been calculated to cover 10 MW seasons. The number in brackets in the "Option description" is the number of that particular item used over the ten MW seasons, if no figure is given then it is one item. * The figure for household gloves assumes that between 2 –3 pairs of gloves are used per season.

Stage	Option	Option description	Cost £ for 10 MW seasons	Use in 10 MW seasons
Eggs	1	Tin, string & cloth	2.2	Protects 3000-12000 eggs/tin
	2	Chiffon bag (2)	5.8	Protects 3000-12000 eggs/bag
Larvae	3	Shade cloth bag 2 m^3	15.2	6000-9000/bag
	4	Shade cloth bag 4 m^3	28.6	6000-9000/bag
	5	Hawk silhouette	6.4	1/tree
	6	Scary eye balloon (3)	20.4	1/tree
Pupae	7	Shade cloth (2), poles & string	23.5	1pit 5000-10000 pupae
Harvesting	8	*Household gloves (25)	*70	

Stage	Option	Option description	Cost £ for 10 MW seasons	Use in 10 MW seasons
	9	PVC gloves (2)	7.4	
	10	Leather gloves	3.2	
Cooking	11	Cardboard cooker (5) & plastic	23	
	13	Metal cooker	66.7	
Drying	14	Shade cloth frame	2.8	
	15	Modified drying tower, 7 frames	93	
	16a	3 plastic bases & cover, 1 frame, 4 pegs	23.1	
	16b	3 plastic bases & cover, 4 pegs	20.3	
	16c	Plastic base (3) & cover	15.9	
	17a	Black metal tray + Plastic (3) + frame + pegs	18	
	17b	Black metal tray + Plastic (3) + pegs	15.2	
	17c	Black metal tray + Plastic (3)	10.8	
	17d	Black metal tray	2.7	
Cooking & Drying	18	Chick mesh grid (2) on round bar frame	20.5	
	19	Expanded metal grid	37.0	
Sterilization	20	Plastic envelopes (2)	15.6	

HAND BOOK PRODUCTION

A handbook on Mopane Worm farming has been planned. It will be in a different format to the guide, both in terms of its content and layout. The manual will provide guidelines for farming, taking into account the new developments. The manual will provide information on the following: life cycle and biology; egg collection, storage, placement and protection; larval protection and movement; pupation and pupal storage; moth hatching; processing (picking, degutting, cooking, drying, storage). It will also include the materials required and people to contact for assistance. It will be A4 size and illustrated with numerous pictures. Workshops will be held when the manuals are disseminated.

DISCUSSION AND CONCLUSIONS

The rural people can achieve benefits with the use of MW farming and by improving their processing and storage systems. Positive outcomes were achieved in nearly all the aspects investigated. The benefits may be slight in some cases and hopefully major in others. Even the movement of eggs closer to the household was seen as a benefit: people do not have to walk so far to harvest; they have control of the MWs near their household; they can leave them to mature without fear of losing part of their crop to other collectors. Similarly the simple modification of placing a grid over the fire and combining cooking & drying has major benefits in reducing processing time. The marketability of this product needs to be investigated but indications suggest that it will be acceptable.

The three sites were different in their attitudes and ways they took to the farming, in particular that of Dombodema. In Dombodema, where the last good MW harvest occurred in 1999, they were very keen and enthusiastic about most of the farming methods. Here the use of shade cloth bags was seen as a good protection measure. It is during these poor years that farming would be of most benefit. This study indicates that MW harvesting could become more reliable when farming methods are introduced. In years with harsher climatic conditions shade cloth bags may be of greater benefit. It is still too early in the farming process for financial benefits to be assessed and this requires further study.

There are many possible interventions and modifications to the farming. The study tried to provide the farmer with a number of options. The farmer can then choose those best suited to him both logistically & financially. For instance the farmer has a choice between the use of tins or chiffon bags when storing and protecting eggs. The tins are a cheaper method but require more attention than placing the larvae in bags outside. Similarly, when drying, a decrease in drying time and better hygiene can be achieved with either the use of the plastic drier or the sheet metal and plastic combination (the farmers' choice will depend on their situation). At Dombodema they were keen on the drying tower even though it was not as efficient as the plastic driers. They saw advantages in the form of less movement of the drying MWs and the possibility of using the drier for other products. The farmer can also investigate other possibilities for materials; for instance the farmer could use woven citrus bags as an alternative to shade cloth.

This livestock system is in its infancy and people will still require guidance. The household farming should be investigated over a longer time period so other situations can be investigated and the farming monitored for a few years. At some stage one could envisage a system to be put in place, by government departments that allows extension workers to be trained and provide farmers with advice. This may still be a long way off as there are still many directions to be researched, such as information networks and pathways. There are also a number of other aspects that require further study. For instance how the food value changes depending on the cooking treatment. When should MWs be harvested? Can the harvesting be left until the larvae are coming down from the trees? This aspect may be important for the sustainable use of MWs, as it may allow a higher proportion of the larvae to enter the pupal stage. These questions have only become available because of the work that has been done in this project.

This livestock system has potential and certain aspects can be taken up more rapidly. It is hoped the handbook will fulfill some of the immediate needs. The people were keen on information on all aspects of the MW for instance on parasites, predators and sexing of the adult moths. It may be possible to also disseminate this type of information as posters (for instance in a similar style to the Save the Mopane Worm poster produced in another part of the ‘Mopane Woodlands and the Mopane Worm project”). Similarly posters, possibly with information sheets, could be done on processing methods. It is hoped this study has gone some way to illustrate the improvements that can be made at the household level to MW farming. It also shows this livestock system is worthy of further consideration and development.

Appendix 1: Community Workshops & Guide Distribution

A field trip to distribute the Mopane Worm Guide was carried out by Alan Gardiner, Member Mushogahande (Forestry Commission), Tendayi Gondo and Eva Gardiner. Prior to the trip Member and Tendayi organized for us to meet household members and important people in the Maphisa and Plumtree areas of Matabeleland. Equipped with the new booklets and some refreshments we visited these areas during the week of the 25th July. We first went to the Rural District Councils for the areas concerned, introduced ourselves, met the key people for the area and explained and presented the booklet to them. We then had meetings with the village heads and household members. The meetings were attended by a varying number of people, depending on the number of households concerned (Figure 32). With the aid of an interpreter the booklets were explained and examples of the materials used shown, the people were then asked for comments and questions. The people were very enthusiastic about the testing of the methods with the households. In addition we visited Whitewater high school (near Natisa) on the way to Maphisa, and Mathambo primary school near Village 27 Dombodema. Whitewater school was very pleased to receive the booklet. We will revisit the school and find out how the pupils are enjoying the booklet and get a better idea of the demand for it. We emphasized the conservation aspects of the booklet and the mopane worm farming. The heads of the schools were keen to receive more booklets. The trip was successful and well received by all we met.

(a)  (b) 

Figure 32. (a) A group of people from Ndiweni and (b) Dombodema, with Mathambo Primary school in the background, listening and asking questions about the MW guide.

Of interest was the enthusiasm of obtaining a booklet both in the local language and in English (people were very keen to obtain an English version). A definite beneficial spin off will be its use as a teaching aid in rural schools.

Groups and contacts made

Schools visited

Whitewater High School approximately 40kms before Maphisa
Mr. Charms Ncube
The Acting Headmaster
Whitewater High School
Bag 5134
Bulawayo

Joseph Moyo D/Head
08 324 404 P39
Mathambo Primary School
P.O. box 207
Plumtree
3560

Rural District Council Maphisa

Mr. Tapson Ncube
(082) 354, 584 fax 362
cell 011 789451

Forestry Commision Maphisa
Mr. B. Tshuma
(082) 217

Important members of the community Maphisa

Chief Malaba 011 778693 (Matobo District Beula Ward Kapeni Village)

Mr. Reggie Mpofu 082 382 (Headman Ndiweni Village)

Mr. Kiwa Ngwenya (Headman Ndiweni Village)

Mr. Pharoah Moyo (082 436) (respected elder)

Alphias Ncube (Madwaleni Village Councillor)

Rural District Council and Forestry office Plumtree

Mrs. Sifiso Dube (CEO)
091 851 393

Mr. Ben Faba Moyo (Bulilima RDC Chairperson)
084 411 88556

Mrs. Pauline Sibanda (Bulilima Rural District Council Training Office)
P. Bag 5908
Plumtree
Phone No: 019 2513
Fax No: 019 2385
Mobile No. 091 851 392

Mr. Bekithemba Ngwenya (Plumtree Forestry)
Box 271
Plumtree
(019) 2761 (W)
(019) 3032 (H)
011 615 382

Important members of the community Nyambi & Makwa Villages 27 & 29 Bulilimamangwe District Plumtree

Mr. Dennis Mathonsi Ngwenya (Headman Nyambi Village (Village 27))
08 274390B56
Mathambo Primary School
P.O. box 207
Plumtree
3560

Mr. Dearly Nleya Makwa (Headman Makwa Village (Village 29)) 08 355350B56
Mathambo Primary School
P.O. box 207
Plumtree
3560

Mrs. Elizabeth Moyo
Head H/School Dombodema Mission
Joseph Moyo
Deputy Head Mathambo School
P.O. Box 207
Plumtree

Mr. Morgan P. Ndebele (Councillor Village 27)
23205 3506
Mathambo Primary School
P.O. box 207
Plumtree
3560

Appendix 2: Booklets and Presentations

Gardiner A.J. & Gardiner E.M. 2005 Farming Mopane Worms: a household guide. Action publishers, Harare, Zimbabwe.

Mopane Worm Handbook: a manual for farming Mopane worms. (Planned but still to be produced)

Gardiner A.J. 2005. “Mopane Worm Farming”. Lepidopterists’ Society of Africa Conference Pretoria, South Africa 6-7th August 2005.

Section 3. A case study of the Kgetsie ya Tsie community enterprise model for managing and trading mopane worms

Relevant Activity

3.3 Assess the wider applicability of the KyT model for improved financing, management, processing, storage and marketing of mopane worms

Kgetsi ya Tsie (KyT) is a Women's Community Trust, seeking to sustain and develop the economic and social empowerment of KyT members in the Tswapong Hills by:

1) Continuously developing the skills of members to run the Trust for themselves;
2) Ensuring the long term financial sustainability of the Trust;
3) Continuously improving the income generating potential for KyT members;
4) Continuously enhancing the ability of members to play an active role in their own communities;
5) Managing the local natural resources in such a way as to sustain and conserve those resources.

The Tswapong Hills loosely defines a rural area of approximately eighty kilometres square, encompassing some 35 villages. Those villages have typical populations of between 500 and 1,500 although a few are in the 2,000 to 6,000 range. The adult resident population of these villages is largely female, with the majority of the men either working away in the cities or at their cattle posts. There exists very little employment (in the traditional sense) within the villages. A large number of households are female-headed.

1. The Development of KyT

Origins and growth of the Trust

The origins of KyT can be traced back to efforts by the Kalahari Conservation Society (KCS) to establish a game reserve or wildlife management area in the Tswapong Hills. Through consultation with other organizations and the local communities, the focus of the initiative was re-shaped and the harvesting and processing of the mopane worm became the more dominant focus.

In March 1996, the Natural Resource Management Project (NRMP - Department of Wildlife and National Parks) carried out a rapid rural assessment in the area, with a particular emphasis on the economic situation and opportunities for women. The study found four major constraints among women:

- Lack of money to finance mopane processing;
- Lack of alternative markets for the products;
- Lack of effective storage;
- A necessity for an effective organization for group strengthening.

NRMP subsequently developed a project proposal to support the establishment of an appropriate organization and funding was provided through NRMP's sister organization, Institutional Reinforcement and Community Empowerment (IRCE). Women's Finance House Botswana (WFHB) was contracted to help establish a microlending scheme and provide initial facilities to the fledgling organization.

Kgetsi ya Tsie was thus born in March 1997 as a programme to help rural women in the Tswapong Hills to realize the full economic potential of their natural resources through microenterprises based on sustainable resource management. The name *Kgetsi ya Tsie* comes from a well known Setswana proverb meaning "let us join hands so that all will benefit".

The underlying philosophy of the new organization was three fold:

1) That natural resources would be carefully husbanded and used only when they could accrue significant value to users;

2) That Botswana's rural areas, while often marginal for agriculture, could be sustainably conserved and support livelihoods in ways that would significantly alleviate rural poverty;

3) That gender relations could change towards greater equality between men and women only when women were able to empower themselves and their families, economically.

The underlying intent was thus to empower women resource users – not with enhanced incomes – but with the knowledge, organization and scale they needed in order to determine their own livelihoods.

The original concept of eventually attaining financial self sustainability was based on the income to be generated making micro-loans to members. Original pre-project assessments by Deloitte Touche concluded that the organization needed to grow to 2,000 members and to provide loans with an interest rate of 20%, repayable over four months. This level of membership was considered a reasonable target by the end of the 30 month launching period, prior to registration as a Community Trust in 1999.

Participants organized themselves into resource user groups with a carefully defined structure based on the model of the Grameen Bank. These groups each consisted of five members of similar age and business interests. Their members had social ties to each other but were not to be from the same family. At the outset in March 1997, these groups were formed in 9 villages and soon, the groups in each village went on to federate themselves into local village Centres.

In 1999, as planned, the Centres formed an Association, registering as a Women's Community Trust. By this stage, 17 Centres had been formed, covering 14 villages. Membership remained around this level until early 2001 when the Trust launched a membership drive into the area of Tswapong South.

A financial crisis in late 2000 precipitated ambitious plans to both cut costs at the same time as finally realising the Trust's plans for growth. At the same time as almost halving its operational expenses, it set out to open Centres in Tswapong South. Over the next three years, KyT's membership more than doubled to 1,170 (Table 3.1).

Table 3.1 : The growth in membership

Year	No. of groups	No of local village centres	Total number of members
1997	40	9	200
1998	88	17	417
1999	97	17	460
2000	115	17	547
2001	125	20	595
2002	172	27	820
2003	246	32	1170

Main Components of KyT Programme

From the outset, there were two major elements to KyT's operation – microenterprise and microlending. The Trust was established to train its members as microentrepreneurs and to establish a loan fund that would enable them to access the capital necessary for their enterprises. It was envisaged that these enterprises would be largely natural resource based but not exclusively so. The sustainable use of natural resources was thus a fundamental plank of the programme.

Training programme overview

Every new Centre receives a 96 hour initial training programme covering group methodology, participatory techniques, microlending operations and sustainable use of natural resources. After this initial training, product training has been given, particularly in the quality processing of mopane and in making marula jelly and lerotse jam. In 2000/01, all Centres received three one-day business training modules, covering:

- Finance and book-keeping
- Planning and organisation
- Meetings and communication

On-going training has also covered food safety and quality issues.

Microlending overview

At least 98% of KyT members would not qualify for a bank account, let alone qualify for a bank loan. It was essential, therefore, that if KyT was to train its members as microentrepreneurs, it would also need to enable them to access capital to start small businesses.

While a bank requires its customers to put up collateral for a loan, KyT members did not have any possessions that would traditionally qualify as collateral. KyT has relied instead on the strong social bonds within the villages where it operates to provide a form of social collateral. The Trust does not loan to individuals but rather to Groups (as outlined above) and it is the Groups that repay the Trust.

Over the six years of its operation, the Trust has often had problems getting its repayments in on time, particularly during periods of drought, but has maintained an overall repayment rate of around 95%.

Central Marketing

It has always been the declared intention of the Trust to assist members to market their products and indeed, the Trust has always done this. Until October 2001, however, this was an ad hoc process focused chiefly around Annual Trade Fairs and annual efforts to find bulk buyers for the mopane harvest.

In June 2001, the Trust had started manufacturing marula oil and soap and was faced with the need to find a home market for the product. It made little sense to approach retailers and sales agents with just two products when there was potentially a large range of natural products that could be sold at the same time. The Trust proceeded to set up a

P10,000 float to purchase products from Centres to go into a Central 'warehouse' in order to have a stock of products on hand for direct sale to customers.

The major benefit of Central Marketing is that it provides a means for members' products to be sold through 40 (and increasing) outlets in Botswana. The Trust keeps an average 25% of revenues to cover the costs of packaging, marketing and distribution and is thus able to pay a fair price to members for their natural resource products. Another major benefit is that it has focused members' attention on quality assurance.

The Trust is unable to purchase all that the members can supply of every stock item. It has been able to do so for dicheru (marula kernels) and morogo, where demand exceeds supply but this is not the case for other products. Marketing efforts by the Trust appear, however, to have stimulated members to take their products directly to the market. Members are under no obligation to sell their products to the Trust – it is a free market arrangement – but in reality they are unlikely to get better prices elsewhere (and certainly not from a customer who will collect their products from their village).

Other activities

In early 2001, KyT found itself urgently seeking ways to generate income. Two ways in which it did this were in the selling of its microlending expertise as consultancy to other CBOs and in the printing of funeral programmes. Printing services has remained as an income generator, albeit at a low level.

During 2002 and 2003, KyT has become a popular destination for visitors from other CBOs and embryonic income generating projects. The Board has always welcomed these and has maintained a position of giving freely of the Trust's experience to those who want to learn from it (subject to not giving away trade secrets).

Given the prevalence of HIV/Aids infection in Botswana, the Trust wishes to play its role in fighting it and plans to do so by providing ready made audience groups to Aids educators in villages that would otherwise be difficult to organise.

2. KyT structure and management

The original governing body of KyT was the Executive Council, consisting of one representative from each Centre. When members formed themselves into a Community Trust in 1999 this proved to be inadequate for legal purposes, thus the Executive Council appointed a 10 member Board of Trustees which reported to it. A period of uncertain governance followed, with neither body certain of its role in relation to the other. The Board had greater experience, through its ability to co-opt outside members, and met more frequently, yet reported to the larger, policy making Executive Council. In practice, the Executive Council invariably deferred to and looked for guidance to the Board on policy issues.

As the number of Centres grew rapidly in 2002, the size of the Executive Council was also becoming a problem, both in terms of meeting size and the logistics of getting individuals from 24 different villages to the same meeting. A solution was found to both problems in the form of a constitutional change, abolishing the Executive Council and replacing it by three Regional Councils, each directly appointing three members to a new Board of Trustees, with the latter becoming the policy making body of the Trust.

The roles of each level of governance can thus be summarised below:

Group

The five member group operates as a local unit with its own office holders. Members should have strong social ties but should not be closely related.

Centre

Groups within the same village form a Centre. Centre meetings are held every two weeks with all members able to attend. They co-ordinate groups and deal with issues at a village level. They appoint one member to their Regional Council and receive reports back from that member.

Regional Councils

KyT has three Regional Councils as follows:

- Northern Regional Council covering the Centres from Moremi to Seolwane;
- Central Regional Council covering the Centres from Malaka to Lerala;
- Southern Regional Council covering the Centres in Tswapong South.

The Regional Councils comprise one member from each Centre and meet every two months to:

- Appoint members to the Board of Trustees, brief those members as necessary and receive reports from those appointed representatives;
- Discuss issues pertinent to the Centres within the Regional Council;

- Identify issues that need to be referred to the Board of Trustees, and notify the Project Co-ordinator of such issues in order that they can be placed on the agenda of the next Board meeting.

Board of Trustees

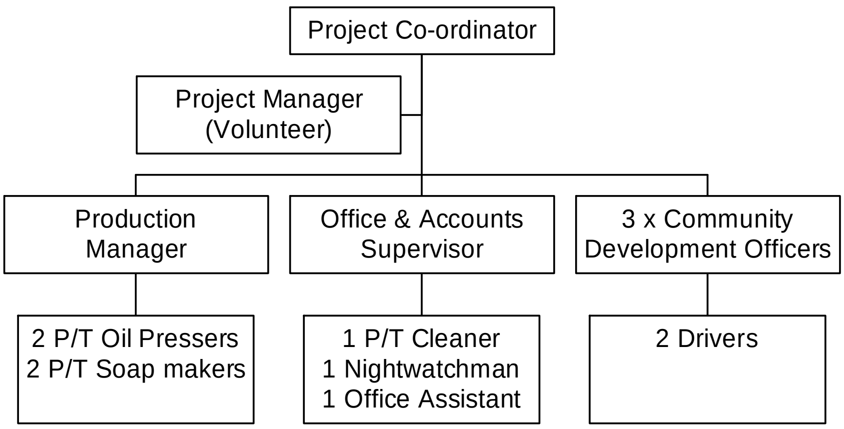
The Board is empowered to decide policy for the Trust and to manage the implementation of that policy on a month to month basis. It appoints a Project Co-ordinator to advise on strategies and plans to implement that policy and manage the affairs of the Trust in line with that policy.

It is required to ensure that proper accounts are kept and that an annual report and financial statement is prepared and audited. The Board is accountable to the AGM.

Staffing

The staffing structure of KyT has evolved throughout the six years of its existence to its present form as shown below

KyT Staff Structure - December 2003



The current structure looks radically different from that of 2000. Despite inflation, organisational growth and taking on the function of a factory and marketing operation, the monthly wage bill is actually lower than it was in 2000. For instance, the Trust has moved from 5 Community Development Officers (CDOs) servicing 17 Centres to three CDOs servicing 32 Centres. However, the Trust has from 2004 employed the services of a paid Project Co-ordinator which presents the biggest current challenge to the Trust in its drive for financial self sufficiency.

In most respects, the structure above is well suited to meeting KyT's expansion plans for the foreseeable future. The other addition required, however, will be that of a Sales & Marketing Manager.

3. Extension Training Programme and Member Education

Training is provided for KyT members in four key areas – initial training for new groups, production training, business training and governance training.

Initial training for new groups

Members of new groups receive a 96 hour training programme, spread over the first six months of their membership. Until this is completed, they are not permitted to take loans from the Trust. In the case of new Centres, representation in the Trust's governance structures follows completion of this training period. Training for new groups comprises an introduction to KyT and why it was formed and how it works, the role of the groups and their strength and solidarity, and programmes on conducting meetings, basic business skills, microlending and insurance schemes.

Production training

Production training is provided for making specific products, and more generally to cover issues such as quality assurance and food hygiene. Much of this training was initially provided in the early years of KyT. Members joining in later years received this training from Community Development Officers within a six month induction training period.

Production process training

- All members have been trained in making marula jelly and lerotse jam. Occasionally, retraining is provided when a Centre starts meeting quality problems or when a Centre discovers a process improvement;

- Members have been trained in the processes required to produce top quality mopane. Initial training was provided in all Centres. Subsequent process improvements, emanating from the DFID funded Mopane Worm Research Project have been passed on by means of two members from each Centre being trained. These members have then passed on the learning to others in their Centres;
- Quality standards for the supply of dicheru have been especially important, given the Trust's position in the market as a high quality producer of unrefined oil. These standards have been the subject of a special training session conducted in every Centre by the Project Manager and Production Manager;
- Some members have been trained in the production of marula atchar.

General Production Training

- The advent of Central Marketing has required greater consistency and uniformity of KyT branded products. This has required standards to be established, e.g. the use of lerotse in KyT Mosata, with relevant training provided;
- In 1998, members received a one day course covering food regulations, food hygiene and sanitation and basic elements of quality assurance;
- In 2002, four members from each Centre received a two day training programme in tree planting and grafting. Part of the training focused around the planting of 1,500 marula trees around Tswapong to ensure the long term supply of marula kernels.

Business Training

A Business Adviser was recruited via Skillshare Africa in 1999 to assist in the provision of business training and advice throughout KyT. A Business Skills training programme was put together and conducted in two stages. The five CDOs were given a series of 10 one-day business training modules over a six month period, covering:

- Communication Skills
- Instruction Techniques
- Facilitation Skills
- Managing your Time
- Presentation Skills 1 & 2
- Conducting Meetings
- Managing Finance
- Planning and Organising
- Introduction to Marketing

Following this training for staff in basic business skills, a condensed package of four one day modules was put together for all Centres, with the Business Adviser training in English, assisted by the Centre's CDO as co-tutor and translator. The four modules were:

- Finance and Bookkeeping
- Meetings and Communication
- Planning and Organising
- Sales and Marketing

The fourth module was not completed owing to the Business Adviser having to take on the role of Project Co-ordinator, although a two-day Principles of Marketing course was provided for one member from every Centre. A few of the Centres opening since 2000 have received some of these modules, with a full programme planned for these Centres when resources permit.

Governance Training

Each time that the Board or the Regional Councils are appointed, the members are given a one day Orientation programme covering the key issues that they need in order to perform their roles effectively. This consists of eight sections:

- Members and the Trust – democratic governance
- Expanding membership
- Donor Funding
- KyT Insurance Scheme
- KyT Finances
- Marketing
- Microlending
- Marula oil and soap

Board members are given additional training to fully appreciate the monthly finance reports and also issues of confidentiality.

Future Training Plans

The major training issue which must be addressed by the Trust in 2004 relates to the issue of HIV/Aids. While KyT lacks the trained personnel to conduct this training, it does possess a network of village groupings which can provide the core organisation for delivery of training in the 25 villages where it is present. The Trust plans therefore to link up with a training provider to facilitate delivery of training in Tswapong villages.

4. Micro Enterprise Development and Income Generation

Micro-loans have, from the outset, been a key part of KyT's programme and have been essential in encouraging micro-enterprise development. On-time repayment and levels of bad debt have fluctuated through KyT's seven year history but this has normally been attributable to organisational factors.

High debt levels in 2000 were identified as resulting from excessive paperwork and resulting confusion over amounts owed. As a result, the system was computerised and simplified. The change was termed **mobile banking**, with CDOs now permitted to handle loan disbursements and replacements. Levels of debt fell and CDOs were able to spend a much smaller proportion of their time on micro-lending. Since then, the level of bad debt has remained around 5% (+/- 1%).

Operation of the Scheme

When a KyT group has been established for 6 months, it becomes entitled to apply for a loan from the Microlending Fund. The size of such loans is shown in Table 3.2.

Table 3.2. Micro-loans available to members:

	Maximum per member	**Repayment period**
1st loan	P500	1 month grace plus 4 months
2nd loan	P750	4 months
3rd loan	P1,000	4 months for loans under P1,000, 6 months for loans over P1,000.
4th loan	P1,250	
5th & subsequent loans	P1,750	

Progress to the next level of loan is dependent on an acceptable record of repayment of the previous loan. Interest is added to the loan at a flat rate of 17.5%, whether the loan be for 4 or 6 months. On completion of repayment, 2.5% is repaid to the group. Repayments are by equal instalments (of the loan plus interest) each month over the repayment period, whether paid fortnightly or monthly at repayment meetings. Repayments are entered at that meeting on all three copies of the form, which are duly signed. In the event of late repayment, the group is due to pay a fine equal to 3% each month of the amount that is overdue. All fines are added to the outstanding loan balance but do not accrue additional interest.

The microlending scheme is one of a number of factors that have contributed to the level of microenterprise among members, although it has been difficult to isolate the true effect of the loans on microenterprise.

5. Trust Enterprises - Development of Specific KyT Products

Developing the Product Portfolio

When KyT started in 1997, mopane was effectively the only cash crop of its members. They were harvesting other produce but mopane was the only crop which they were effectively able to turn into cash. Early efforts of the Trust were therefore focused on assisting them to maximise their return on mopane, via improved processing, packaging, storage, distribution and marketing.

The same principles were soon transferred to other crops such as morogo (spinach), mosata (meat substitute), dicheru (marula kernels), ditloo (cow peas) and others. Members were trained in the production of marula jelly and lerotse jam to add to the product range.

Two sealing machines and plastic packaging were purchased, although these could only be used at the office as they relied on available electricity. Rudimentary labels were produced carrying the KyT logo, name and illustration of product.

Marketing was mostly conducted by the members themselves although they were assisted in reaching wider markets by the ability to attend Trade Fairs. On occasions, the KyT office would receive an order and would facilitate its collection and distribution. These were essential early steps in enabling members to add value to their products and to start marketing products that they had previously only used for home consumption.

With the exception of clay pots from Manaledi village, all products were food products. With the possible further exception of mosata, they were also commodity products. While KyT was gaining a reputation for high quality mopane, they were dealing in markets where it was very difficult to add much value through product differentiation. Such reliance on commodity food products also left members' personal incomes very susceptible to drought, as was indeed experienced in the summers of 2001/02 and 2002/03.

Product diversification began with the production of marula oil in June 2001. Seizing the opportunity in late 2000 to participate as the Botswana producer in the Southern Africa Marula Oil Producers' Network, the Trust began to manufacture marula oil and entered the cosmetics market with a product unique in Botswana. Marula oil is a high value product that required marketing in a totally different way to anything else in KyT's portfolio. In the home market, it offered KyT the opportunity to sell to hotels and lodges, pharmacies, health shops and many others. Product quality and presentation were critical to be accepted and to compete effectively in these outlets. Marula oil was the impetus behind Central Marketing, the holding of a central warehouse stock of quality assured products available for immediate sale. Central Marketing allowed the development of the KyT product range, as the market developed for products like monepenepe and gala la tshwene.

Table 3.4 shows the role of each product in the KyT portfolio and the role played by members and the Trust in its production.

Table 3.4. Product processing at factory and village levels

Product	**Description**	**Processes in villages**	**Processes at factory**
Cosmetics			
Marula oil	Skin care oil	Collecting and cracking marula nuts	Pressing, bottling, labelling
Marula soap	Soap from marula oil		Manufacture, labelling, packaging
Letsoku	Natural face powder	Collection, grinding	Bottling, labelling
Herbal remedies			
Monepenepe	Relief from menstrual pains	Collection, grinding	Packaging, labelling
Gala la Tshwene	Remedy for high blood pressure, strokes	Collection	Packaging, labelling
Food			
Marula jelly		Manufacture, bottling	Labelling
Lerotse jam		Manufacture, bottling	Labelling
Mopane	Edible caterpillar	Collection, processing, drying	Packaging, labelling
Morogo	Dried bean leaves	Collection, processing, drying	Packaging, labelling
Mosata	Meat substitute	Collection, processing, drying	Packaging, labelling
Marula cake	Residue from oil pressing		Packaging
Crafts			
Clay pots		Manufacture	
Tswapong Sands	Bottles of different coloured sands	Bottling	Labelling

In addition to the above, the Trust takes responsibility for quality assurance, marketing and distribution of all products. Testing of oil quality (measurement of acid value) is to be added to the factory processes for marula oil in early 2004, following the recent purchase of laboratory equipment.

Marketing Strategy

The primary aim of KyT's marketing strategy is to add maximum value to members' products by taking them as far as possible up the value chain. Much effort has been expended in building a 'Kgetsi ya Tsie' brand, synonymous with high quality, well presented products. The brand uses the marketing slogan, 'Pure and Natural Products of Botswana' and emphasizes the aspect of being a rural Women's Community Trust. It further seeks to emphasize that customers are gaining the benefit of centuries of traditional indigenous knowledge.

What the Trust has done is to take what have formerly been informal market products into more formal markets and thus charge a higher price. One interesting feature of this move has been the change from selling by volume to selling by weight, a concept new to members.

Pricing policy

The principle behind Central Marketing is that it is governed by a purchase price that provides a fair return on members' labour. However, selling price is determined by what the market will stand. Accordingly, the decision to stock a product in the range requires that products meet four criteria:

- Sufficient shelf life in relation to turnover that the Trust will not be left with deteriorated stock;
- The Trust can pay a fair price to members, who can supply it in sufficient quantities to meet market demand;
- The product has sufficient demand or potential demand to make it worth stocking;
- The Trust will make a profit on the product after all costs have been attributed.
- The Trust will at least break even on the product and it will provide significant income generation to members.

Thus, while the Trust barely covers its packaging, labelling, marketing and distribution costs for morogo and mopane, their stocking is justified by the sales they generate for members. On the other hand, for those products like marula oil and letsoku, where market conditions are favourable, profits can be substantial.

Local marketing

An additional benefit of Central Marketing is the incentive it provided to local marketing efforts. Members almost always prefer to sell their products to the Trust, thereby gaining a fair price without any need to package, deliver or market their produce. These sales, however, appear to have stimulated innovation in their own local marketing, coupled with a greater emphasis on product quality.

In volume terms, local marketing is likely to always remain higher than Central Marketing. Certain products, particularly perishable ones, will always be better suited to local marketing efforts. Mopane worm, in particular, is always likely to remain primarily an informal market product.

Effectiveness of Approach

The greatest drawback of a constant struggle for the financial self sufficiency of the Trust has been the time and effort that it has taken away from the formal educational aspects of KyT's real mission – the economic and social empowerment of the women of Tswapong. Programmes of business and social education have, over the last three years, taken second place to ensuring that the Trust remains financially viable and achieves self-sufficiency. This itself has forced reflection on business procedures. When cutbacks led to the Trust withdrawing what had been free, notably use of transport by Centres, members were forced to realistically account for the profitability of their enterprises. Many took this positively, recognising it as a real lesson in economic empowerment.

There can be little doubt also that the need to be responsive to the market has had a positive impact on members' development as micro-entrepreneurs. The recognition of KyT by numerous awards for its products, coupled with occasional rejection of members' produce by the Trust on quality grounds, have been powerful messages to the membership on the importance of quality and presentation.

6. Impact on individual women

Prior to 1997, the biggest single impact on cash incomes of the women of Tswapong was the availability of mopane worm. Mopane worm has always been an unreliable source of income owing to its dependenc on weather conditions and outbreak dynamics of it s populations. Successive droughts in the summers of 2001/2002 and 2002/2003 all but wiped out the last four mopane harvests in the Tswapong region, and also decimated the the sorghum crop that forms the major food source.

There is no doubt, therefore, that the diversification to a wider range of cash crops, brought about mainly by the Trust's marula business and Central Marketing policy, has had great economic value to the majority of KyT members. A study of 187 members in October 2001, focusing on profit rather than revenue and using different techniques, found the figure to be P2,420. The sources of this income are given in Table 3.5.

Table 3.5. Microenterprise income generation for members

Microenterprise	**Profit/month (187 members)**
Marula kernels	2,100
Jam and jelly	2,623
Mopane	1,014
Thatching grass	3,750
Vegetables	5,287
Tuck shops	4,177

Selling clothes	6,298
Sewing	1,600
Beer making	2,845
Other	6,274

This information was generated just prior to the advent of Central Marketing, which has generated extra sales income for members and shifted the balance of activity towards natural products. These figures are taken from a single month and it must be noted that income sources are highly variable through the year. Thus income generation from mopane and marula kernels is low in October and likely to be replaced by activities such as selling clothes. Currently, and since the advent of Central Marketing, average member's income exceeds P3,000 per annum, although there has been no study of how this breaks down among different income categories.

KyT operates in a free market economy. If members are able to attract a better price elsewhere for their products, they are free to do so. Similarly, members are also aware of comparative rates of return for their labour. If the Trust do not pay a high enough rate for dicheru, members will spend their time on other activities rather than cracking marula nuts. In practice dissatisfaction about a price for a product is discussed among members and the Trust to reach a solution. For example the initial purchasing price set for dicheru by the Trust (P11 per kg) was based on prices in Namibia, but this was felt to be too low because KyT members had alternative sources of income, unlike the remote Namibian communities, and so the price was raised to P13.

Perhaps the change in members' economic prospects can be summed up in the increased choices that they have for income generating activities. That greater range of choices inevitably gives women greater bargaining power over the price of their labour. The statement of KyT's overall purpose has subtly changed within the past two years from 'the social and economic empowerment of the women of Tswapong' by the transposition of 'social' and 'economic'. This is not just semantics. It follows the clear evidence that economic empowerment comes first, with social empowerment greatly stimulated by the increased confidence that comes from self generated financial independence.

There is a clear economic uplift of many, particularly the most active, members. A study by a Yale University student on placement with KyT in June/July 2003 showed that while income generated by KyT activity was spent first on essential foodstuffs, members were also able to use income to buy school uniforms and some were even able to invest in breeze block housing, thus upgrading from the traditional mud rondavel.

Summary of achievements to date

A summary review would identify the major achievements of KyT over the past seven years as follows:

- The establishment of a membership base of 1,170 rural women across 25 Tswapong villages, engaging in and gaining income from various natural resource based enterprises;
- Making loans of over P900,000 to members for investment in microenterprise activities;
- Enabling members to increase their average income from P440 pa to around P3,000 pa (both estimated figures);
- Establishing a KyT brand of pure and natural products with current sales of around P12,000 per month at home and abroad, supported by a KyT Website;
- Establishing an asset base with a market value close to P1,000,000, primarily in buildings, a revolving loan fund, vehicles and production equipment;

In identifying future developments and strategy to progress those achievements, it is always vital to reflect on lessons learned. These are critical both to KyT's future and as guidance to other Community Based Organisations wishing to draw on the experiences of KyT.

Lessons learnt

Some of KyT's lessons have been learned the hard way and others from actually getting them right. They might be summarised as follows:

Get the organisational structure right to start with. but always ensure that it helps, not hinders, the future strategy of the organisation. The separate roles of the Executive Council and the Board of Trustees need to be clearly established. As KyT grew, the Executive grew to over 30 members and became ineffective and fractious. This was solved by an overhaul of the organisational structure with the full consent of the membership. Had there been strong power bases existing within the Trust, this would almost certainly not have been achieved. The key message is**.**

Ensure that goals are internally consistent. Micro-loans to members are a crucial element of any project to develop economic empowerment. Equally, any Trust or other organisation set up to facilitate that empowerment, must set out to achieve sustainability if it is to have a long term role. Financial sustainability for the Trust was to be achieved by increasing and then maintaining its income from the interest on these micro-loans. The Trust's interests would thus be served by maximising the issue of loans while at some stage economic empowerment of its members was likely to be linked to decreased dependency on loans.

If repayment rates start to fall, identify the problem and respond quickly. There have been points in the short history of KyT when the repayment rate on loans has fallen. While this may reflect difficulty of members making repayments due to drought and/or the failure of crops, a more important reason has been insufficient clarity on loans and repayments. Failed repayments were linked to periods of organisational failure and associated with reduced meeting attendances with cascading effect through all of KyT's activities.

Be flexible, play to your strengths and be ready to diversify into profitable opportunities. Many modern management philosophies that emphasise the core business may not be appropriate for rural enterprises. Natural products are seasonal and sometimes unpredictable so it is important for members to build a complementary portfolio of products providing year round income. Like individual members, the Trust has also learnt the value of diversification. Income from interest on loans has barely reached 20% of the level required to achieve the original goal of self sustainability through loan interest. The Trust was forced to secure sustainable income from elsewhere.

Distinguishing between members and the trust. In the early days of KyT the common perception was that assets belonged to everyone collectively. In a sense that was true, but there was a failure to establish in the minds of members the legal status of the Trust as distinct from that of the membership. While the status of the Trust was an easy concept for new members, it took a long while to change the perceptions of some more established members.

Don't build in institutional expenses that you will have to take out later when donor money runs out. Upon the cessation of donor funding for the Trust financial constraints had to be introduced in early 2001. This led to considerable protest but members eventually recognised the need to secure self-sufficiency and unsupported economic viability.

The real challenge – a financially sustainable community based organisation

Long term financial sustainability and self-sufficiency of community based organisations in Africa has rarely been achieved. Two factors make Kgetsi ya Tsie's task of achieving this goal difficult.

- It is a rural project with high costs for transport and distribution of products to market;
- Market led companies must respond quickly to market demands, but community based organisations are notoriously slow in decision making.

Being located in Botswana has had both advantages and disadvantages for KyT. Botswana has a growing middle class with disposable income, able and willing to buy premium priced home produced cosmetics products. However, the size of the home market is inevitably limited in a country with a population of just 1.7m. Moreover, it is a large, land-locked country, with associated high distribution costs, whether in the domestic market or export. Even the growth in Botswana's disposable income canbe disadvantageous as donor agencies turn to more needy countries.

The potential pitfalls are numerous:

- Increased competition in marula oil and derivative products is likely as the market increases in size, and will inevitably result in reduced prices and profitability. KyT cannot rely solely on marula oil;
- Community based organisations have a strong potential for internal disputes, particularly when spread across 25 rural villages;
- At the current stage of development, members are adamant that no woman from Tswapong could ever co-ordinate the project. They maintain that it has to be an outsider, specifically a white man. There is clearly much social empowerment still to be done;
- KyT's hopes for eventual self sustainability have been raised by generating added value to its products and taking them 'up-market'. This also makes them more susceptible to economic downturn;
- In the medium term, KyT remains extremely financially vulnerable unless it succeeds in attracting a core funding donor for the projected three years (2004-2006) to self sustainability.

KyT's Future Plans

It would be wrong to start from the assumption that the Trust itself must be a permanent feature of Tswapong. Institutions that have outlived their usefulness can end up working against their original objectives. Nevertheless, there is a useful co-ordinating role for the Trust to play over the next ten years in promoting women's empowerment throughout Tswapong.

The Trust's plans for the future are focused around one or both of the categories below:

- Those plans which promote the social and economic empowerment of KyT members;
- Those plans which build the institutional capacity of the Trust to achieve its empowerment role in the long term.

KyT's Outline Strategic Plan 2003-2005 identifies the Trust's objectives for the period as:

1) **Membership** – To continue membership growth from approximately 800 members at the start of 2003 to 1,500 members by the end of 2004;
2) **Trust Enterprises –** To continue the development of income generating activities to enable the Trust to achieve financial self sustainability. The emphasis will be on activities that provide profit for the Trust and income opportunities for members.
3) **Micro-enterprise development and income generation** – To increase the average annual income generated by members from P2,500 at the start of 2003 to P4,000 by the end of 2005, and to stimulate income generating ideas by business and technical skills training.
4) **Marketing –** To support members in getting their products to market and maximising the prices obtained for products. In particular to develop marketing by three avenues:
   - developing a premium price market for products that appeal to higher income earners and tourists, focusing on a 'pure and natural, made in Botswana' image backed by effective quality control and professional presentation;
   - greater penetration of local markets;
   - develop export markets for the marula product range through website and membership of Phytotrade.
5) **Structure –** To develop the new approved structure of Regional Councils and a Board of Trustees to ensure the effective governance of KyT;
6) **Democracy** – To devise and implement a training programme to equip all levels of KyT's democratic structure with the skills and knowledge to effectively understand their roles and carry out their responsibilities;
7) **Member education** – To devise and implement education programmes for members relevant to their individual needs and to KyT's role as a key institution representing women in Tswapong;
8) **Microlending –** To continue and expand the role of microlending in stimulating micro-enterprise development among members, while at the same time reducing missed repayments to below 10% and the bad debt rate to below 4%;
9) **Natural Resource Management** – To establish programmes to ensure the improved long term supply of key natural resources within Tswapong;
10) **Premises –** To secure funding to support Centres in developing KyT Business Centres in each village where KyT operates;
11) **Skills transfer to other CBOs** – To use the skills developed within KyT to assist other CBOs throughout Botswana in their development, in co-ordination with appropriate government, NGO/CBO and development organisations.

KyT women have developed choices between income generating opportunities. With those choices has come confidence and a measure of negotiating power. In the future, many members may outgrow the Trust and it is progress on these fronts that will provide the true measure of the success or failure of KyT.

Section 4. Mopane worm markets

Relevant Activities

4.1 Survey existing literature and empirically identify the structure of the main mopane worm production-to-consumption systems (PCS) in Botswana, South Africa and Zimbabwe to identify the main marketing channels, functions, information flows, contractual arrangements and constraints at each stage

4.2 Survey the conduct of harvesters and marketing intermediaries of mopane worms and derived products to identify within- and between-year variations in traded volumes, prices, quality and grading, and market trends

4.3 Assess margins associated with value-adding processes in the mopane industry from harvesting to consumption

4.4 Survey consumer preferences, patterns of consumption, market segmentation and perceptions of product quality

The high level of collector involvement in mopane worm markets and large share of output marketed both clearly demonstrate that, in Zimbabwe, mopane worms are a highly commercialized forest resource. Involvement in mopane worm markets was widespread across all study areas and very few households did not market some of their mopane worm output. Following a poor mopane worm outbreak, a greater share of harvest is retained for home consumption but sales do not cease entirely. This is because mopane worm outbreaks occur during the early months of the agricultural season when most households have limited grain reserves and therefore have a pressing need for cash to meet immediate consumption needs

Household mopane worm utilization data show that sales account for a larger share of output than personal consumption. In six out of the seven Zimbabwean study areas the share of available mopane worms marketed ranged from 76-94 %. In contrast, one study area (Rutenga) about 50% of collected mopane worms were marketed but this is explained by the poor 2004 mopane worm harvest.

As expected, variability among households and between study areas in marketed surplus is largely explained by variability in total output. Household retentions of mopane worms for own consumption were remarkably similar across survey areas (4-9kgs per household). The only exception is Gwerima where following an exceptional 2001/2 mopane worm harvest the average household retained 19kgs out of an average harvest of 217 kgs.

Who participates in mopane worm marketing?

The collection and processing of mopane worms is traditionally regarded as women's work. As such, mopane worms offer women an independent source of income over which they retain control. However, a commonly reported phenomenon in agricultural commercialisation literature is the tendency for 'women's crops' to be taken over by men when attractive commercial opportunities emerge. A key question therefore is whether there is any evidence of increasing male involvement in mopane worm activities and if so whether women are being sidelined.

Household survey data indicate that participation in the collection and marketing of mopane worms in Zimbabwe by men and particularly youths is widespread. The level of male participation in mopane worm activities varied considerably between study areas but was generally over 50 % of available labour. Only elderly men have minimal participation (Table 3). In most age categories, 70- 90% of women took part in the collection, processing and marketing of mopane worms during the study periods.

The continued widespread participation of women in mopane worm activities suggests that, at this point in time, increased male involvement in mopane worm activities in production areas has not displaced women. However, male involvement has likely increased the total number of people in the community utilising this forest resource which may have consequences for sustainability. While the cash earning potential of mopane worms can be regarded as a 'pull factor' in attracting male involvement, other factors including, particularly in the current economic climate in Zimbabwe, the lack of alternative earning opportunities in more traditional men's jobs such as off farm employment, are likely strong 'push factors'.

How are mopane worms marketed and who is involved in the production to consumption chain?

This section provides a synthesis of research findings on the situation and structure of mopane worm markets in Zimbabwe. Numerous project collaborators were involved in market surveys, including several honours students who undertook case studies in various regional markets and collection areas. More detailed information about how markets operate and prices at different points a long the chain can be found in several individual reports (Stack 2002a, Stack 2002b, Kozanayi and Frost, 2002, Rutamba, 2003, Stack and Rutamba 2003, Frost 2003; Kozanayi 2003, Stack 2003, Stack, 2004, Chirinu and Stack, 2004).

Market Structure

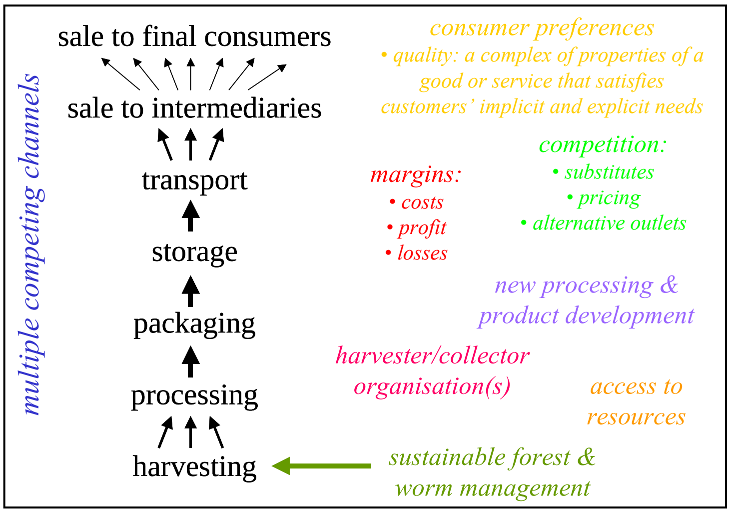
Markets for mopane worms operate predominantly in the informal sector although some private wholesalers are market participants and consumers are also able to buy mopane worms from formal retail outlets such as shops and supermarkets. A study of mopane worm markets in several producing areas, regional and urban consumption centres indicates that the production to consumption chain is long and complex with mopane worms typically passing through several intermediaries before reaching consumers. Few collectors sell directly to either urban wholesalers, retailers or consumers and few stallholders or vendors in regional markets are involved in collecting mopane worms. A schematic diagram of mopane worm marketing chain is presented in Figure 4.1.

Producers

Mopane worms reach the market from collectors in four principal ways: direct sales to rural assemblers, direct sales to regional wholesalers, direct sales to retailers and direct sales to rural and urban consumers.

Local markets are generally the most important outlets for producers and operate at appointed locations at most rural service centres and at bus halts where permanent sellers of all types of food and non food commodities maintain stalls. Typically, after collection and drying producers bring mopane worms to local markets either for exchange or sale to local consumers or rural assemblers. Collectors transport the mopane worms themselves either carrying sacks or using bicycles, wheel barrows, donkeys or scotch carts over relatively short distances of up to 20kms. In local markets mopane worms are sold dried by volume with the most common unit of sale to rural assemblers being a 20 litre bucket (approx 5.7 kgs). Most transactions are cash sales but barter exchange, where collectors barter mopane worms with traders in exchange for food items (e.g sugar, oil, maize meal), clothes or kitchen utensils also accounts for a proportion of sales. Barter trade in Chilonga in 2002 season, for example, accounted for about 18% of total sales but 53.3% collectors indicated involvement in bartered trade.

Figure 4.1. The market chain and determinants and indicators of value addition



The main buyers in local markets are various types of rural assemblers or middlemen who buy mopane worms in bulk for resale to other intermediaries or consumers. One type of rural assembler, commonly referred to as 'farmer-traders' in the rural market literature (see Hayami and Kawagoe 1993) are widely prevalent in local mopane worm markets. These are generally better off collectors or local shop owners who buy mopane worms from a large number of collectors for resale. Urban based traders are also rural assemblers and travel to production areas to buy mopane worms in local markets. Some collectors also sell mopane worms at the farm gate, often to local agents who travel from homestead to homestead buying on behalf of urban based wholesalers. During the peak mopane worm harvest period groups of sellers can also be observed along main roads that pass through the mopane belt selling direct to consumers aboard passing buses or private cars. Finally, some collectors transport their mopane worms to outside markets, including both regional centres in Zimbabwe and cross border markets, and sell directly to regional wholesalers, retailers or consumers.

For the majority of collectors, local markets are their last point of involvement in mopane worm activities. Location of sale data indicate that around 70-80% of collectors market mopane worms locally either from their homestead or at local shopping centres and that sales in local markets account for 50-60% of marketed output. (Table 4). Only a small proportion (20-30%) of collectors market mopane worms in outside markets and those that do tend to account for a disproportionate share of the harvest indicating that they are the larger collectors.

Although quite a large proportion of collectors may barter a portion of their harvest for goods such as food stuffs, clothes or kitchen utensils, the quantity of mopane worm sales transacted in this manner probably represents only 10-20 % of all trade. Most barter transactions take place at the collectors homestead and involve rural assemblers from urban areas who have easy access to the goods that households want.

Rural Assemblers

One of the most critical aspects of the marketing system affecting participation by poor producers is likely to be the existence (or otherwise) of a well developed system of market intermediaries to assemble their small surpluses at reasonable cost (Poulton and Pool, 2002, p22). This is particularly true with respect to mopane worms since, as noted by Kozanayi and Frost (2002), the source areas for mopane worms are often far from the main markets, most of which are in urban areas, and the surging cost of travel and small quantities individuals have to market inhibit most households from travelling long distances to trade.

Assemblers, both farmer-traders and urban based traders, buy mopane worms in local markets for the purpose of reselling them. Since assemblers buy in large lots they help collectors dispose of their harvest in a short time but the prices offered are generally low particularly during the peak harvest periods, and especially if traders know that collectors are selling out of desperation to raise cash for immediate consumption needs. Rural assemblers usually repack mopane worms into sacks and transport them to regional markets using local buses, hired transport or personal vehicles. Although the reselling of mopane worms by rural assemblers usually takes place at a different location to where the mopane worms have been purchased, sometimes farmer-traders don't move mopane worms to regional markets before reselling. Instead, farmer-traders, store mopane worm stocks and resell later in the off-season in local markets to consumers or traders. Seasonal price rises are usually sufficient to return a healthy profit on their mopane worm buying and selling activities, although in recent years high inflation in Zimbabwe may have led to negative returns on storage (see below). Survey results from one case study area show that nearly two thirds (65%) of mopane worms sold by farmer- traders was resold in local markets and only 35% resold in outside markets (Table 4.1).

Table 4.1: The number and proportion of sales made at different locations, in study areas, Zimbabwe, 2001/2002

	Matabeleland South Matobo District		Masvingo						Midlands	
			Mwenezi District		Chivi District		Chiredzi District		Mberengwa District	
	Kapeni	Ndiweni	Mwenezi		Gwerima		Chilonga		Bangwe	
Place of sale	% no.	% no.	% no.	% qty	% no.	% qty	% no.	% qty	% no.	% qty
Collection Area	0	Na	0	-	10	11	2	1	0	-
Homestead	45	Na	24	21	38	24	6	8	85	60
Local centres	55	Na	59	36	38	46	11	7	0	-
Main roadside	0	Na	0	-	13	15	0	0	0	-
Urban centre	0	Na	17	43	10	4	55	49	15	40
Outside country	0	na	0	0	0	0	19	35		

Although farmer-traders and urban based traders typically operate independently, either may also act as agents for other traders including cross border traders on a fixed fee or commission basis. For example, in Zimbabwe in recent years, traders from the Democratic Republic of Congo (DRC) have been very active in procuring mopane worms for export. Typically a DRC trader arrives in a regional market centre, such as Bulawayo, and makes an arrangement with a local group of people who travel to the mopane worm production areas and buy mopane worms in local markets on their behalf. These local agents buy mopane worms from collectors or rural assemblers in local markets, repack unto 90 kg grain sacks (approx 30-35kgs of dried mopane worms) and ferry the mopane worms by road to the regional market where the foreign trader waits. In the field we observed one group of five buyers operating as a team waiting with more than 200 bags of mopane worms at the roadside outside Beitbridge hoping to negotiate a lift with a lorry returning empty to Bulawayo. The team of buyers had travelled on public transport to buy mopane worms, using Zimbabwe dollars supplied by a foreign trader. The group expected to get a lift for themselves and their load before nightfall but were prepared to sleep overnight by the roadside if they had to wait until the next day This group of traders indicated that they undertook several similar trips on behalf of the DRC traders each mopane worm season.

Regional wholesalers (Sellers and buyers)

At the level of the regional market, there are various types of mopane worm sellers involved in wholesaling, including food packaging companies (e.g. Quality foods, Jasbro, Premier Foods), urban bulk traders and cross border traders, such as the DRC traders mentioned above. All of these wholesalers generally buy in bulk from both individual collectors and from rural assemblers with much of the buying activity taking place in or around the long distance bus terminus. Regional wholesalers are sometimes difficult to distinguish from rural assemblers since as well as buying in bulk in regional markets they often send agents into rural areas to buy on their behalf. In fact few of the wholesalers contacted during fieldwork relied exclusively on mopane worm stocks brought to regional markets. During the mopane worm season competition to buy mopane worm stocks is quite fierce and anyone arriving with stocks at a bus terminus in the main regional markets such as Bulawayo and Beitbridge is met by a jostling crowd of touts representing potential buyers interested in their mopane worms. Generally all transactions are cash and payment is on the spot. Barter exchange is not common for either wholesale transactions or transactions between sellers and traders at the level of regional markets.

Wholesalers have three major market outlets; they may sell to other traders, to retailers, or directly to consumers. Some of the market services that may be provided by wholesalers include storage, transport to other regional markets (such as Harare) or repackaging as in the case of food processing companies who repack mopane worms into 50 or 100g packs for retail distribution. In some cases sellers offer mopane worm stocks on credit to regular retail customers such as a permanent stallholder in the market or tuckshop owner in a residential area.

Retailers

There are various types of retailers of mopane worms including stallholders at long-distance bus termini and open markets, street vendors, tuck shops and supermarkets. The main retail centres are the regional markets in and around the production areas (Bulawayo , Masvingo and Beitbridge) and the capital city (Harare) but mopane worms have been found on sale throughout the country. Sellers are usually concentrated around the long-distance bus termini and in the main open market but during the mopane worm season it is common to see vendors selling mopane worms outside shopping centres and along roadsides .

Retailers purchase mopane worms in semi wholesale quantities (a few bags or less) and typically mopane worms are purchased loose. Mopane worms supplied to retailers by the wholesale food processors are prepacked in 50g 100g or 200g packs and some traders supply pre-packed mopane worms to tuckshops. During the mopane worm season when supplies are arriving in regional markets on a daily basis, retailers indicate that they restock frequently, often daily, rather than buying and storing (Stack 2002b). This enables retailers to operate with limited capital. Some retailers with more capital to invest buy supplies from traders in the mopane worm season to store for off season sales .

Since mopane worm markets predominantly operate in the informal sector supplies reach these sellers through various pathways. Some buy mopane worms directly from collectors, some from rural assemblers, some from urban traders and some from wholesale packaging companies. Some sellers go from retailer to retailer offering mopane worms for sale whilst in other cases the retailer sources supplies. Survey data from the four major regional markets (Bulawayo, Beitbridge, Harare and Masvingo) give some indication of the characteristics of retailers operating in the informal sector and the variety and importance of different supply sources. The data are from a survey of mopane worm sellers at various market locations between January and February 2002, when the mopane worm season was well underway (Tables 4.2 and 4.3).

Table 4.2. Comparison of Location of MW Sales by type of seller

Location		MW collectors		Farmer-Traders	
		Quantity	% Share	Quantity	% Share
Local	Rutenga	50	62.5	80	39
	Bus stops	30	37.5	52	26
Outside	Harare	0	0	36	18
	Masvingo	0	0	21	10
	Bulawayo and others	0	0	15	7
Total		80	100	204	100

Source: Rutenga Case study 2003/2004 MW harvest

Table 4.3. Characteristics of MW sellers at Main Regional Markets in and around Production Areas and Sources of mopane worms, January/February 2002, Zimbabwe

Location of sellers		Gender	No.	Age in years (row %)				Source of mopane (row %)				
				20-29	**30-39**	**40-49**	**>50**	Trader: Bus terminal	Brought to their home	Trader: Main market	Rural Area	Gift
Bulawayo	Renkin Bus terminus	Female	16	56	13	18	13	81	13	0	6	0
		Male	8	50	25	0	25	100	0	0	0	0
		Total	24	54	17	13	25	88	8	0	4	0
	Main market	Female	21	38	29	29	8	52	5	19	14	10
		Male	3	67	33	0	0	100	0	0	0	0
		Total	24	42	29	25	4	58	4	17	12	9
	Roadside vendors	Female	4	25	50	25	0	25	25	25	25	0
		Male	2	0	0	100	0	50	0	50	0	0
	At home	Female	2	0	0	50	50	0	0	50	50	0
		Male	0	0	0	0	0	-	-	-	-	-

								Collector at bus terminal	Traders: bus terminal	Bought from collector in rural areas	Collector at rural area	Gift
Beitbridge	Bus terminus	Female	8	63	13	24	0	62.5	12.5	12.5	12.5	0
		Male	6	67	33	0	0	66	0	0	34	0
		Total	14	64	21	15	0	64	7.5	7.5	21	0
	Roadside	Female	2	0	50	0	50	50	-	-	50	0
		Male	0	-	-	-	-	-	-	-	-	-
Masvingo	Bus terminus	Female	2	50	50	0	0	0	100	0	0	0
		Male	0	-	-	-	-	-	-	-	-	-
	Stalls nr Shops	Female	2	0	100	0	0	0	100	0	0	0
		Male	0	-	-	-	-	-	-	-	-	-

In regional centres in or around production areas stallholders and vendors mainly purchase mopane worms from collectors or rural assemblers at the long distance bus termini (Table 5). In contrast, mopane worms on sale in Harare markets are mainly purchased from traders who come to the markets although a few sellers travelled to collection areas to get supplies. Some sellers in Bulawayo and Beitbridge had purchased mopane worms in rural areas or received mopane worms as a gift from a relative in a rural area. Some vendors were retailing mopane worms they had collected themselves but these tended to be the roadside vendors rather than the stallholders in markets.

Most sellers of mopane worms at market stalls or by the roadside are women (Table 5 and 6) They sell mopane worms alongside a wide variety of goods traditionally associated with vending including beans, dried fish, bananas, onions, tomatoes and green and dried vegetables. All age groups are represented but sellers under 30 years were most prevalent in the 2002 survey especially at the bus termini. The average age of vendors was higher in the main markets where the more established stallholders tend to be located. Most sellers are self-employed although owners of some permanent stalls in the open markets employ someone to run their business.

At the retail level, selling mopane worms is often an important source of livelihood for people who have few alternative employment prospects (urban unemployed, youth and women) who engage in petty trading and vending of dried mopane worms or prepared mopane worm snacks.

Consumers

Consumers generally buy mopane worms as a relish to accompany the local staple although mopane worms can also be found on sale as a prepared snack outside beer halls and as a prepared relish in some supermarkets providing take away foods. In October 2004 a major supermarket in Harare (Fife Avenue Spar) was selling cooked mopane worms at Z$80,000 per kg as a take-away food alongside chicken portions, macaroni cheese, fish, rice and mashed potatoes. Mopane worms are a traditional food consumed by all income groups but are especially attractive to lower income consumers owing to the escalating cost of other protein sources such as meat. Consumers have a number of supply sources. They can purchase mopane worms directly form collectors, from assemblers, from regional traders, from various types of stallholders or vendors and from supermarkets. In addition some consumers receive mopane worms as a gift from rural relatives. Although the quality of supplies may vary considerably between sellers there are only two main forms in which dried mopane worms are sold – loose or pre-packed mopane worms sold in supermarkets are generally pre packed whilst other retailers sell mopane worms loose by volume. Common units of sale include cups and mugs of varying sizes and empty 2L cooking oil tins. Some stallholders and tuck shops also sell pre packed and labelled mopane worms but the packing is generally an informal service undertaken either by the stallholder, who puts a specific volume of mopane worms in a plastic bag and seals it over a charcoal burner, or by the trader who supplied the mopane worms. Plastic bags, labelled with a variety of product names are widely on sale in central markets and stallholders buy packaging to suit the product they are selling. Consequently vendors can often be observed selling a packaged and labelled product but the packed product has been prepared by them and sourced from a wholesale packaging company!

Household consumer surveys in Bulawayo and Harare provide some indication of the relative importance of different supply sources (Table 7). Collection of mopane worms in rural areas or mopane worm gifts from rural relatives were the main sources of mopane worms for both lower income and better off households in Bulawayo. Half the mopane worm consuming households in the Bulawayo high-density survey area collected their own mopane worms in rural areas. This implies that 'non purchased sources' are the main source of mopane worms for mopane worm consuming households in Bulawayo. This is consistent with the fact that Bulawayo is located close to the main mopane worm producing areas and that we would expect links between urban households and rural routes to be strong. In contrast, Harare consumers rely entirely on purchased mopane worm supplies from various outlets (market, roadside, tuck shops, and supermarket) (Table 7). The higher dependence on mopane worm collection and gifts in Bulawayo probably explains why a higher proportion of consumers in Bulawayo than in Harare only consume mopane worm when they are in season. The importance of mopane worm gifts from relatives among Bulawayo consumers was also confirmed in focus groups discussions that indicated that mopane worm consumption among better off households in Bulawayo was frequently associated with gifts of mopane worms from rural relatives.

Relative Importance of Market Outlets

As the marketing of mopane worms takes place predominantly in the informal sector obtaining accurate information to estimate market flows and the relative importance of different market outlets is problematic. Estimates in Fig. 3 were derived from:

- Information on estimated number of households in the mopane belt using population census data.
- Survey data on proportion of households engaged in mopane worm collection and average mopane worm collected per households from six 2001/2002 case studies across the mopane belt.
- Analysis of location of sales data provided by producers.
- Official export figures for mopane worm exports multiplied ten fold to reflect unofficial mopane worm trade supplemented by estimated exports of mopane worms to DRC based on key informant information from DRC traders.
- Information from Bulawayo and Harare consumer surveys on sources of mopane worm supply and quantity of mopane worms consumed.
- Information from wholesalers package companies on mopane worm purchases.

The estimates represent a reasonable guess using knowledge gained from key informant interviews with market participants and survey data from producers and consumers. However, the data available are limited and should be used with caution.

Points to note:

- The volume of direct sales from producers to consumers is relatively small (probably 10-15%)
- Sales by producers directly to regional traders or consumers in markets outside of production areas plays a relatively minor role, comprising no more than 20-25% sales
- The most important pattern is seen in sales by collectors to rural assemblers, which make up around 60-70% of producers sales.
- The bulk of sales by rural assemblers (50-60%) is to traders at regional markets.

Issues related to the marketing chain

- Little if any transformation of the product tales place along the market chain. Apart from the drying process undertaken by collectors, preparation of mopane snacks by vendors and debulking and repacking of mopane worms into plastic packets by some wholesale distributors and individuals, mopane worms undergo minimal value added processing along the marketing chain. This suggests that beyond transport and limited storage, few market services are provided by intermediaries.
- Absence of a system of grades and standards especially at the retail level leads to considerable scope for imperfect trading practices. Whilst 20L containers are commonly used in transactions between collectors, rural assemblers and regional traders, only wholesale food packaging companies provide weighed and labelled mopane worms at the retail level. The bulk of sales between consumers and retailers are transacted using a variety of non-standard cups and tins. Consequently, consumers have little idea of price per kg and sellers have considerable opportunity to enhance their earnings by varying the unit of measurement.
- It is common practice for the container in which mopane worms are transported to be changed at every transfer of ownership in the marketing chain. This is because it enables buyer to physically assess the volume and quality of the product.
- Not just rural poor but also urban poor are involved in market chain. Urban market participants may lose out if better organised and better informed producers take over some of the services previously offered by intermediaries.

Market Behaviour

The prices which mopane worm markets generate play several important roles in both the welfare and decision making of market participants. For example, mopane worm prices are an important determinant of the level of collectors income and the profits and returns for rural assemblers and traders. In addition, the retail price of mopane worms determines their affordability to consumers and mopane worm attractiveness compared to possible substitutes.

The purpose of this agricultural price analysis is to demonstrate how mopane worm markets behave and to identify the scope for poor collectors to improve returns from competing in these markets. In this section mopane worm price information is used to provide insights into several areas including :

- Spatial dimensions of mopane worm markets including market integration
- Temporal dimensions of mopane worm marketing
- How incentives to producers and consumers have changed over time

- Different participants relative market power positions

We begin with an overview of how prices are determined in mopane worm markets and a comment on the practical realities of observing and monitoring mopane worm prices.

How are prices determined

For many agricultural commodities in Zimbabwe, including maize and most smallholder cash crops, prices are set by a monopoly marketing board. For some commodities, such as tobacco, prices are discovered through auction. Private treaty trading, where individual buyers and sellers negotiate prices, is the basis of exchange in most informal produce markets and is typical of transactions in local and regional mopane worm markets.

In common with most commodities traded in informal markets there is no system of standard weights and grades, and mopane worms are sold in containers of various volumes. The most prevalent unit of exchange for mopane worms sold for resale is the 20L tin or bucket (approx 5.7kgs). The 20L tin is a standard unit of exchange throughout local and regional markets for many dry commodities such as maize, beans, groundnuts, dried fish and sorghum etc. Rural assemblers and traders usually repack mopane worms into 90kg grain bags (approx six 20L tins or 36kgs of mopane worms) for transport and/or storage. Mopane worms would generally be unpacked and measured in 20L tins before changing hands again further along the marketing chain. Other units of exchange include 5L and 2L tins and various cups used to measure amounts from open sacks. As a general observation, the degree to which prices are negotiated tends to decline as mopane worms move along the market chain from producers through intermediaries to the consumer, and as the unit of exchange gets smaller. Individuals consumers buying mopane worms from market stalls, street sellers or tuck shops, in relatively small amounts (a few hundred grams) tend to face a set price with limited room for negotiation. In the informal retail sector it is more common for preferred customers to receive extra value through the addition of a few extra mopane worms or credit than for prices to be negotiated downwards. Shops sell mopane worms in sealed packets (50g, 100g or 200g) at fixed prices.

Discussions with informants suggest that the bargaining position of buyers often appears to be stronger than that of sellers both due to the limited fall-back positions of individual collectors and because of unequal access to information about current supply and demand conditions and their influence on price in regional markets. This often results in accusations by collectors that they are being cheated by traders because they have no choice but to accept prices that represent a small share of the value of mopane worms in the main consumption centres. Sellers in regional markets, such as Beitbridge, also indicate that the process of selling mopane worms may be marred by intimidation and abuse from touts for different maguma gumas (traders) who coerce them into accepting low prices (Kozanayi and Frost, 2002). The high cost of accommodation in regional markets such as Beitbridge and Bulawayo also means that sellers from rural areas are under pressure to sell their stocks quickly and attempt to return home the same day. This often results in them accepting lower prices, as they do not have the time to engage in protracted negotiations.

Wholesale food packaging companies such as Jaggers, Jasbro and Quality foods do not negotiate prices with sellers but rather set their own buying prices, based on prevailing market conditions. Discussions with wholesalers indicate that they are very aware of the competition from other traders to buy available stocks. Buying prices per kg are usually clearly displayed outside buying depots, with on the spot cash payment and generally no minimum quantity required before the wholesaler will do business with a seller. In theory, the presence of formal wholesalers in the market offers sellers some protection against unscrupulous traders but in practice this may not be the case because wholesale companies only operate in a few regional markets (Bulawayo and Masvingo) and only purchase mopane worms during certain periods of the year. For instance, in 2002 wholesalers in Bulawayo did not begin buying mopane worms until around March/ April when there was a temporary drop on mopane worm prices as the second mopane worm outbreak reached the market. At this time one wholesaler in Bulawayo was offering better prices that rural assemblers and traders in collection areas but generally below the prices that mopane worms were being exchanged for in the adjacent market at the bus terminus.

It is common in rural areas for traders to offer goods such as mealie meal, sugar, oil, cooking utensils or clothing in exchange for mopane worms instead of cash. Traders use this method of exchange as a way of increasing their own profits by purchasing mopane worms with goods that are valued at less than the market price for mopane worms. Interviews with various collectors involved in barter exchange indicate that an assessment of the monetary value of the goods being offered in exchange for mopane worms is an important factor in the negotiating process. Although barter trade often appears to be offering a poor deal for collectors this method of selling can be attractive to some collectors if traders are offering a commodity that is needed and cannot be easily bought locally. Some collectors also suggested that in the current inflationary environment barter transactions were a way of ensuring that the exchange value of mopane worms was maintained. For example, discussions about prices of mopane worms with collectors in Plumtree District during the 2003 mopane worm season, elicited the information that based on past experience collectors knew that one bucket of mopane worms was worth at least one bucket of maize. This knowledge was a starting point for negotiating prices and rates of barter exchange even in the absence of market information from regional markets.

In practice the price at which mopane worms are exchanged and variations in prices at different points along the market chain and with time are very difficult to monitor because exchange is characterized by large number of transactions in relatively small quantities and very many factors affect the bargaining position of buyers and sellers. Field observations demonstrated that prices may vary considerable at the same location even within a single day. For example, in Bulawayo regional market, a trader was observed buying from farmers who delivered their produce to the market early in the day and a few hours later selling the same mopane worms to other traders in the same market place for a profit (Stack, 2003). At Rutenga growth point in the 2004 season, some rural collectors, who wanted to avoid paying levies to the local council, sold their mopane worms to other traders outside the market place at a price that was lower than local market price (Chiringu, 2004). In January – February 2002, shops in Masvingo had mopane worm on sale in sealed 100g packets at prices that differed by more than 100%, probably because some outlets were selling old stock from last season's harvest and some had just received new stock. At the beginning of the mopane worm season it is common to see stallholders in Bulawayo and Harare markets disposing of the previous seasons stock at a discounted price alongside fresh mopane worm stocks (Stack, 2002).

Investigating temporal dimensions of mopane worm marketing is further complicated by Zimbabwe's hyper-inflationary environment which has seen even the official consumer price index registering double digit inflation on a monthly basis since mid 2002.

In an attempt to overcome some of these difficulties price monitoring tried to ensure that the price data captured was for mopane worms of a reasonable quality collected in the season under observation. In addition, when prices are reported the unit of sale is also quoted, as this is a source of systematic variability in the prices. For instance, price relationships at different points along the marketing chain are derived from prices per 20L Tin the most common unit of exchange between producers and traders. The following price analysis uses mid-range prices and converts nominal prices to real prices using the All Items Consumer Price Index to look at mopane worm prices through time.

How do prices vary between locations and at different points in along the marketing chain?

The price of mopane worms differ considerably among localities and selling points reflecting not only the position of the sale point along the producer to consumer chain and the kind and amount of value added up to that point, but also the number and kinds of competing buyers and the unit of sale. For example, in February 2002, collectors in Mwenezi, Gwanda and Kezi received around Z$600-1100 per 20L tin (Z$105-193 per kg) whereas rural assemblers and traders were reselling mopane worms at between 1500-2000 per 25L tin (Z$210 – 280 per kg) in Beitbridge regional market and around Z$1200 –1500 per 20L tin (Z$210 – 263 per kg) in Bulawayo regional market. In Harare, which is more than 600 km from the main mopane worm production areas and some 438 km from Bulawayo, traders were selling mopane worms to stallholders at Mbare market for around 2000 –2500 per 20L tin (Z$350-438 per kg) in February 2002. Using the mid price level of the above ranges, the wholesale price per kg was around 58-65% higher in regional markets closest to the production areas (Bulawayo and Beitbridge) than the price received by collectors in the production areas. In Harare, a regional market some distance from the production areas, the wholesale price is around 160% higher than the price paid to producers.

Prices are highest in urban markets because they are closer to the final consumer but within urban markets prices also differ depending on the unit of sale. For example, in February 2002, consumers in Bulawayo and Beitbridge buying in quantities of less than 100 grams paid around Z$ 25-30 per tea cup ($313- $375 per kg) from stallholders and vendors and around Z$40 per 100g (Z$400 per kg) for mopane worms in sealed and labelled packets from supermarkets. In Harare, stallholders at Mbare were selling mopane worms at Z$35-45 per tea cup (Z$375 - 563 per kg).

Using the above price data collectors received around 37- 43% share of the final value of mopane worms in regional markets close to production areas and a slightly smaller share (around one third) of the final value of mopane worms in Harare. Frost (2003), using data from case studies of collectors in Ndiweni and Kapeni, calculated that in January 2002 and January 2003 rural producers captured around 27.8% and 28.8 % respectively of the final value of mopane worms.

In rural areas prices that collectors receive tend to vary depending on where the sale takes place. For instance, a survey of mopane worm sales by collectors from Mwenezi found that the mean price per 20L tin, was around 13% higher for sales at the local growth point than for sales that took place at the collectors homestead. (Gwavuya, 2003 p.46).

Prices in regional markets in the producing areas also vary depending on the numbers and quantities of buyers competing for sales and the mopane worm supply situation in surrounding production areas. This is often demonstrated in the price relationship between Beitbridge and Bulawayo regional markets (Figures 4.2 and 4.3). Both centres are important hubs of marketing for the surrounding mopane worm production areas but Beitbridge, located on border with South Africa, has for many years been the centre of a thriving cross border trade in mopane worms to South Africa. A survey of mopane worm markets in January 2002 by Kozanayi and Frost (2002) noted that of all the towns surveyed in southern Zimbabwe, Beitbridge was the most vibrant and had the largest volumes of mopane worms being traded. In 2002, a good outbreak of mopane worms in the producing areas around Beitbridge led to a plentiful supply of mopane worms and lower prices than the prevailing prices in Bulawayo (Fig 4.2). However, around April/ May, as the mopane worm production season finished, there was a steep increase in mopane worm prices in Beitbridge which rose above those in Bulawayo. A similar pattern was repeated in 2003 (Fig 4.3). The price relationship between Beitbridge and Bulawayo is driven largely by supply during the mopane worm season and by demand after the outbreak season is over as Beitbridge prices are generally bid upwards by strong demand from cross border traders. However, these price relationships are very dynamic and sensitive to new developments in the market. For instance, the growing presence of bulk buyers from DRC in Bulawayo is intensifying competition between traders in this market.

Figure 4.2. Trends in mopane worm prices January to September 2002 (nominal prices)

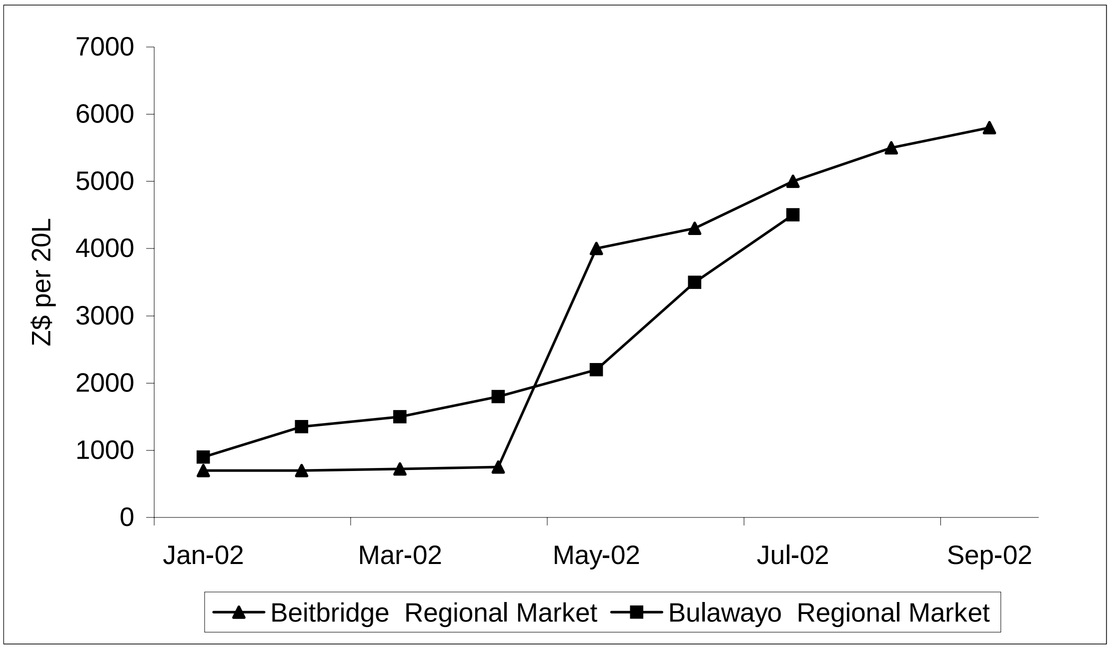
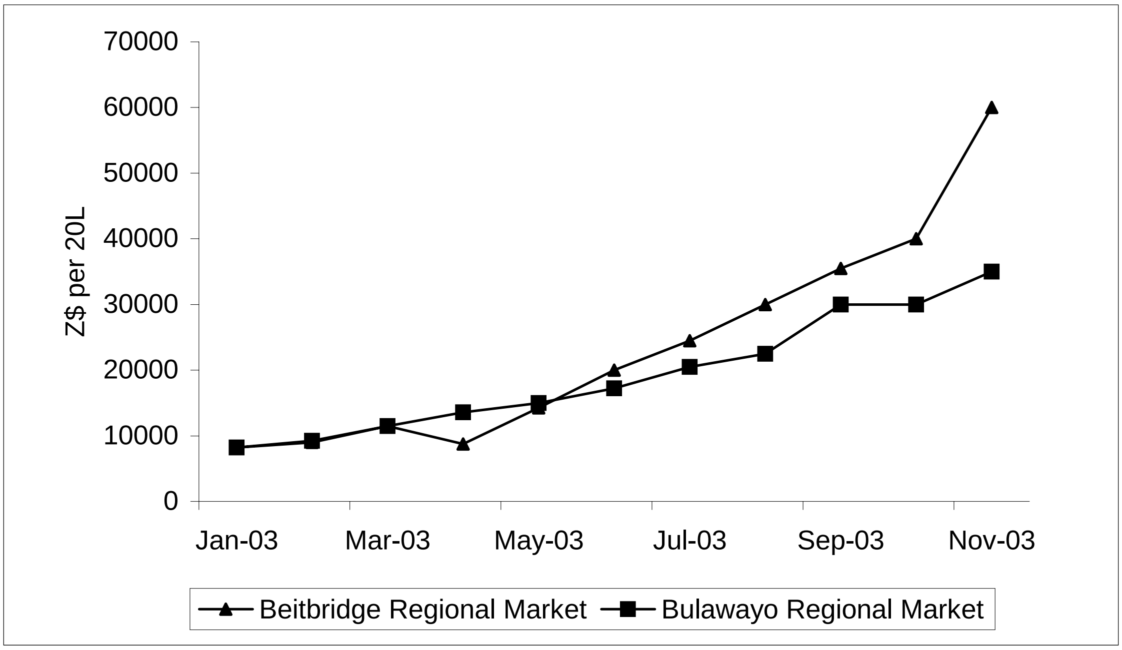


Figure 4.3. Trends in mopane worm prices January to December 2003 (nominal prices)

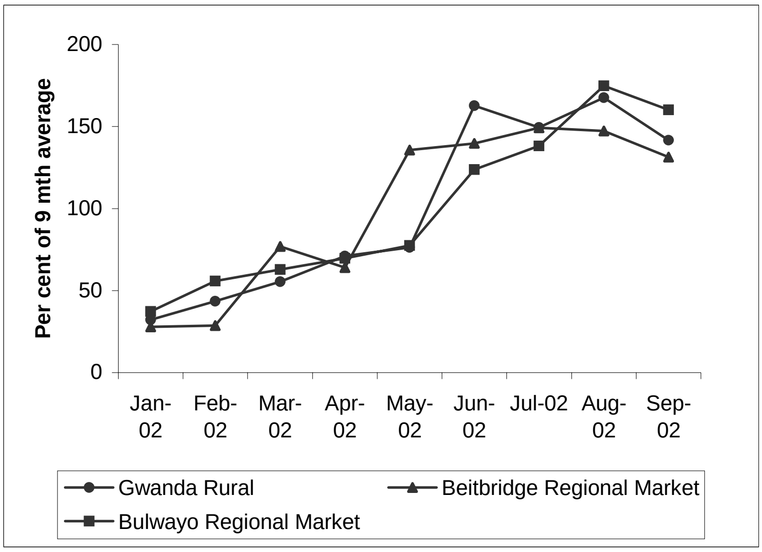


How do mopane worm prices vary within and between seasons?

Understanding price movements over time and particularly seasonal movements in prices are important to market participants who have to make decisions about storage, timing of purchases and timing of marketing. Mopane worm prices tend to vary predictably through time as a result of seasonal variations in supply and demand. There are usually two mopane worm outbreaks a year in December/January and March/April, when mopane worms are widely harvested. For the remainder of the year mopane worm consumption is provided from storage stocks. This pattern of availability tends to result in prices that are lowest at the time of each outbreak, with a slight rise in prices between outbreak periods and then prices increase out of season in line with the cost of storing stocks over the year and finally prices begin to decrease as the next harvest begins. Even though this pattern is similar from year to year the timing and the magnitude of the high and low points will change because of factors such as weather which may delay or significantly reduce an outbreak or because of shifts in determinants of the position of supply and demand curves.

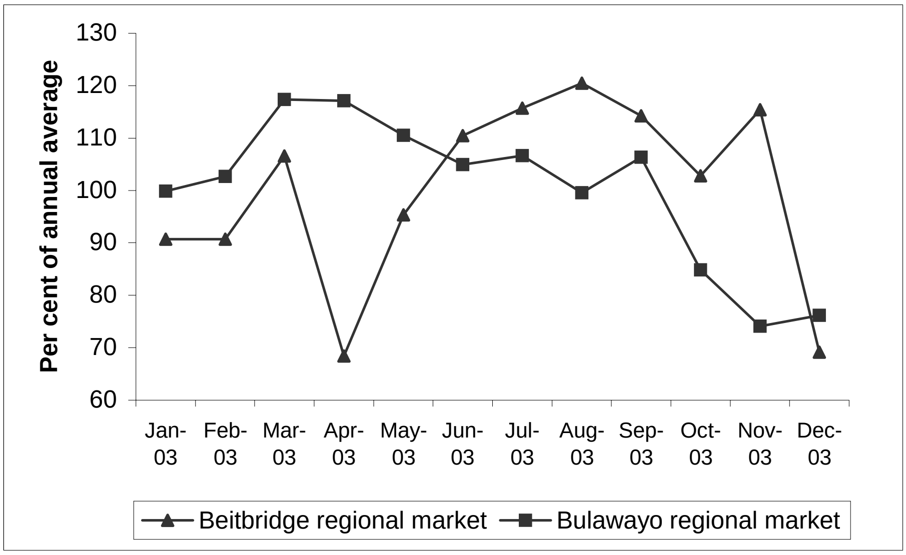
An index of seasonal price changes in mopane worm markets is illustrated in Figure 4.4. Nominal prices were first converted to real prices using the CPI. The seasonal index was calculated by taking the average of the monthly prices for the nine month period as the base value (index value of 100). Dividing each monthly price by the base value provides a measure of seasonal variability. In Beitbridge, the index indicates that prices were lowest during January and February, after the first mopane worm outbreak, at around 30% of the nine months average. The index rises in March immediately prior to the second outbreak to around 76% of the average and then falls back slightly to 63% of the average around April as the market is flooded with supplies from the second outbreak. From May onwards the index increases to a peak of just under 150% of the nine month average in July and August. A similar pattern is observed for Gwanda collection area and Bulawayo regional market but without a temporary dip in the seasonal index in April when supplies from the second outbreak are usually expected to reach the market. This may be because the production areas around Gwanda and Bulawayo didn't experience a very good second outbreak in 2002.

Figure 4.4 Seasonal index of monthly wholesale prices for mopane worms January to September 2002 at different markets (real prices in Z$)



A similar seasonal pattern in prices can also be observed in the 2003 data but due to substantial inflation seasonal price rises were not sufficient to give sellers a positive return on storage (Fig 4.5).

Figure 4.5 Seasonal index of monthly wholesale prices for mopane worms January to December 2003 at different markets (real prices in Z$)



For Bulawayo, the index illustrates that in real terms prices peaked just after harvest in March and declined steadily through the year to a low in November of 75% of the annual average price. In nominal terms, the wholesale price of mopane worms peaked at $40,000 per 20L tin in December 2003, which was more than four times the prevailing price of Z$8,250 per 20L tin January/February 2003. However, mopane worm prices did not rise in real terms through the year. Considering that the actual rate of inflation was probably significantly higher than that indicated in official statistics the actual seasonal index was probably even lower at the end of the year than indicated in our calculations. The seasonal index calculated using price data from Beitbridge shows a dip in prices in April as mopane worm supplies from the second outbreak reach the market. From May onwards real prices show the expected steady seasonal rise but this is not sustained and the index remained fairly stable between June and September indicating that prices were relatively constant in real terms. The wholesale price of mopane worms in Beitbridge in December 2003 was only 69% of the annual average.

One possible reason why wholesale prices of mopane worms did not keep pace with inflation during 2003 is that mopane worms are a food consumed by lower income groups and therefore probably face a fairly elastic income and price elasticity of demand. Under these circumstances demand is likely to fall at a faster rate than income and a given upward adjustment in mopane worm prices is likely to result in a larger decline in demand. Both of these factors make it difficult for traders to pass on the real cost of holding stocks.

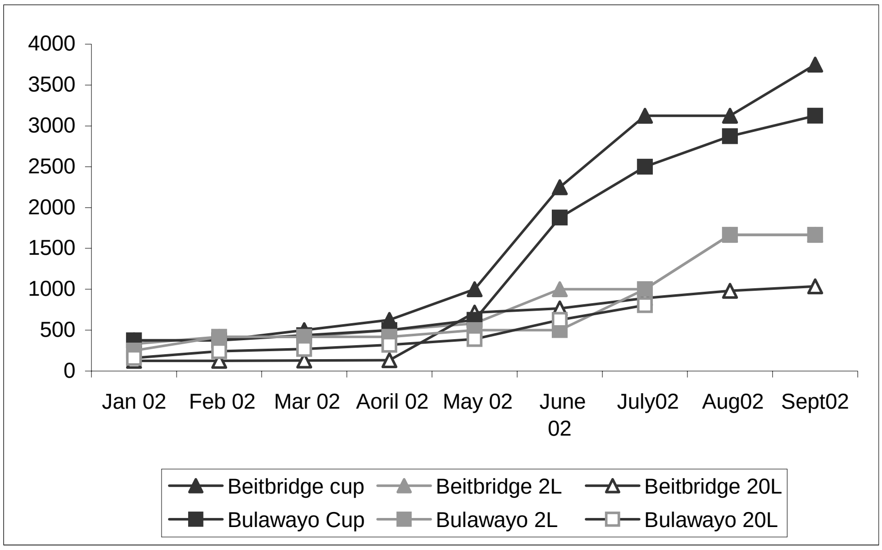
Whereas in 2002 mopane worm prices out of season were generally several times higher than those achieved during the peak harvest period indicating opportunities for storage 2003 price data adjusted for inflation demonstrated how difficult it is for market participants to make decision about storage, timing of purchases and timing of marketing in a hyperinflationary environment. In 2002, collectors and traders who stored mopane worms to sell later in the year realized substantial profits, adopting a similar strategy in 2003 would have led to a strong likelihood that earnings from stored mopane worms were worth less in real terms than if the trader had sold soon after harvest.

Seasonal price changes also vary depending on the unit of sale. Figure 4.6 compares the price per kg of mopane worms sold by the cup with the price per kg of mopane worms sold in 20L tin. The prices have been left in nominal terms to highlight seasonal changes. The fact that consumers buying in quantities of less than 100 grams pay a higher price per kg than buyers who purchase mopane worms by the 20L tin is predictable and expected but what is interesting is how the relationship between the retail and wholesale price varies over a season:

- Retail prices rise more steeply than wholesale prices out of season demonstrating greater seasonality.
- Wholesale prices and retail prices show the narrowest spread in January – March during the mopane worm season when supplies are likely to be most abundant, and the largest spread in November/December when stored supplies are likely to be at their lowest.

The above observations suggest an inverse relationship between the availability of mopane worms and the difference between the retail and wholesale prices with the difference in prices being greatest in the off season period and lowest during the mopane worm season. This pattern reflects a deliberate strategy and preference on part of sellers to sell mopane worms in small units to make more profit. As stored supplies decrease sellers are increasingly less willing to sell mopane worms in large containers and prefer to increase returns from storage by selling by the cup. In fact, by October/November it is increasingly difficult to find mopane worms in the market being sold by the bucket, particularly in markets such as Harare which are a long way from production areas. This is why some of the price series are missing price data for months.

Figure 4.6. Standardised values (Z$) of dried mopane worms sold in different-sized containers between markets, January to September 2002 (Kozanayi and Frost, 2002).

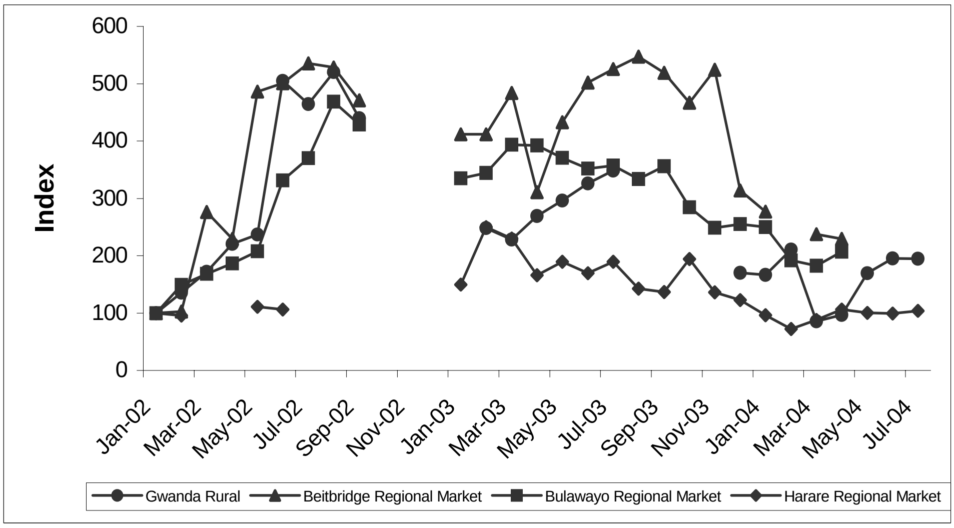


Long term price trends

Price monitoring surveys indicate that there was a strong upward movement in mopane worm prices in both collection areas and regional markets between January 2002 and mid 2004 (Figure 4.7). For example in January 2002, the price of mopane worms in Gwanda collection area was around Z$600 per 20L tin. In the following season the January 2003 price had increased almost 10 fold to Z$5000 per 20L tin and a further 5 fold increase to Z$25000 per 20L tin had taken place by January 2004. Over a period of three seasons, prices in Gwanda collection area appear to have increased more than 40 fold. Price rises in regional markets have been just as dramatic. In January 2002, mopane worms were selling at around Z$700 per 20L tin and two seasons later, the price had risen more than 60 fold to Z$45 000 per 20L tin. The same pattern occurs if out of season prices are compared for the same month each year. For example, comparing prices in July of each year for Beitbridge regional market indicates that prices increase from Z$5000 per 20L in 2002 to around Z$65000 per 20L in July 2004.

Before these price trends can be taken as an indication that producers have benefited from substantial increases in mopane worm prices due to increased effective demand relative to supplies it is necessary to take into account the substantial inflation that took place in the economy over the same period. By deflating the price series using the Consumer Price Index (CP1) the effects of inflation can be removed (Figure 4.7). The trend now shows increasing real prices through 2002 and real price levels in January 2003 were above January 2002. However, price increases are not as dramatic as indicated by nominal price data. For instance, real prices of mopane worms in Gwanda and Beitbridge markets increased 270% and 400% respectively. January 2004 mopane worm prices were in real terms below January 2003 prices but were higher than January 2002 prices. If out of season peak prices are compared, there appears little change in real prices between July 2002 and July 2003. By July 2004, real prices were beginning to fall.

Figure 4.7. Mopane worm real price index (January 2002 = 100)



Overall, the adjusted price trends indicate that prices increased in real terms during 2002, remained at similar levels in 2003, and have subsequently fell but remained slightly higher than January 2002 prices in Beitbridge and Bulawayo regional markets. In Harare, prices did not change significantly in real terms after experiencing a period of increased prices in 2003.

Price correlations to assess market integration and coordination efficiency

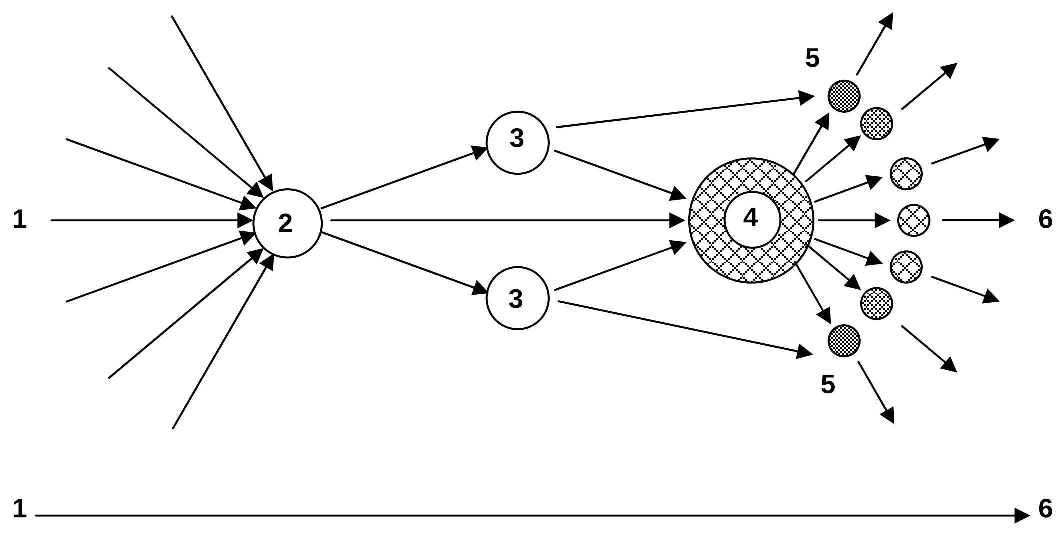
Analysis of spatial price variations can provide snapshot evidence of market integration, or lack of it, and evidence of price transmission between locations at a given point in time. High correlation between prices indicate effective regional integration and/or competition and provide indirect evidence that markets are operating efficiently.

Mopane worm prices in Zimbabwean markets are strongly correlated across, space, time and form suggesting that information on prices, supply and demand is being efficiently transmitted along the market chain and that markets are fairly competitive and traders are aware of profitable market opportunities. However, some producers and traders lack the ability to respond to market opportunities due to constraints such as lack of working capital and transport bottlenecks.

What value adding processes take place from harvesting to consumption of Mopane worms

Market participants add value primarily through changing the spatial location of mopane worms from areas of supply to areas of demand. The main features of value adding processes from harvesting to consumption can be illustrated using a stylized marketing chain from Kozanayi and Frost (2002) (Figure 4.8). Mopane worms are an irregularly occurring dispersed resource (1). Initial value is added to mopane worms through harvesting and processing which changes the form of the mopane worm and the concentration of the product (2). Batches of processed and dried mopane worms situated in collection areas, are then moved to regional markets mainly through intermediaries (rural assemblers) (2-3) but also directly by collectors themselves (2-4 or 2-5). Value is added to the product through aggregating supplies of many small producers, transportation and limited storage. Intermediaries usually resell mopane worms in wholesale markets (4). Wholesalers may move the product in bulk to other regional markets or cross border markets, repackage their stocks into smaller sealed, labelled packs for sale in formal outlets (shops, supermarkets) or sell in bulk direct to stallholders in open markets or other intermediaries. Retailers (5), whether trading with consumers (6) through shops or formal or informal markets can also obtain stocks direct from intermediaries. Informal vendors in urban markets may further add value by cooking mopane worms before selling them on to consumers. For example, women vendors selling fried mopane worm snacks by the scud lid are a common sight outside beerhalls in Mabvuku high density suburb, Harare (Stack, 2002).

Figure 4.8. Stylised marketing chain for mopane worms in southern Zimbabwe (see text for explanations), from Kozanayi and Frost (2002).



Urban traders and stallholders get their mopane worms from many sources, but the main sources are rural assemblers and traders, who bring the mopane worms to the urban areas. These intermediaries accounted for 70% of all mopane worms purchased by sellers interviewed (Stack and Rutamba, 2003). This finding supports other market surveys (Stack 2002a, 2002b) which indicated that few participants in the marketing chain near the point of final sale are involved in mopane worm collecting.

Strategies adopted to enhance returns from mopane worm marketing

In this section a series of case studies are used to take a closer look at the characteristics of different categories of market participants, the value adding activities they are involved in and the profitability of the various strategies used to enhance earnings from mopane worms.

Strategies collectors pursue to enhance earnings

Most marketing strategies pursued by collectors are aimed at increasing returns to mopane worm sales and most of the options pursued generally involve changing the location of sale. This may involve taking mopane worms to markets in local service centres for sale rather than selling mopane worms at collection sites or waiting for rural assemblers or their agents to visit the homestead. It could involve selling mopane worms directly into regional or cross border markets. Collectors within easy walking distance of a main trunk road, such as the Masvingo-Beitbridge road may also choose to sell at the roadside to passing traffic with the hope of realizing higher returns. Some collectors are involved in storing mopane worms for sale in the off season and some households retain a portion of their mopane worm stocks to sell to local consumers by the cup.

Household survey data from four Zimbabwean studies, with detailed information on marketing of mopane worms, provide some insight into how location of sale influences the prices collectors receive for mopane worms. The lowest prices are found at collection sites. In the two study areas where some collectors sold dried mopane worms to buyers who visited collection sites net returns were between 25-28% below the price prevailing in local market places. When prices at other locations within the study areas are compared collectors received higher prices for sales made at the homestead than in local markets in two study areas and in one study area net returns were better for sales made at the local market place than for sales made from home. The higher prices realized by some collectors for sales at the homestead may be due to the fact that these collectors have made special arrangements to sell there mopane worm stock to specific mopane traders from outside the area (rural assemblers) who come to their homestead to collect the mopane worms. This is supported by the observation that around 30% of collectors in Chilonga indicated that in most years they entered into some form of special selling arrangement with urban traders (Rutamba, 2003). In all four study areas, collectors who bypassed intermediaries and sold mopane worms directly into regional markets earned a higher net return per kg than collectors who sold locally. Net Prices in urban wholesale markets were between 23 – 40% higher than local prices.

A simple budget exercise demonstrates clearly the need for collectors to have a minimum quantity of mopane worms to market before they can increase earnings through selling in distance urban markets (Table 4.4). Early January 2003, prices offered for mopane worms by bulk buyers at the main bus terminus in Bulawayo were around Z$5-10 000 (20-30%) higher per 20L tin than prices realized in local markets in production areas such as Kezi, Filabusi and Gwanda. However, moving mopane worms to urban markets involves transport costs for the collector (Z$30,000 return bus fare) plus money for other travel expenses such as food (Z$6,000 per trip) and freight costs for mopane worms ($1000 per 20L tin).[11] Since by far the greatest proportion of marketing costs are fixed costs associated with travel, average total costs per 20L decline steadily as the quantity of mopane worms marketed increases. The break-even quantity of mopane worms, representing the minimum quantity of mopane worms marketed for returns to exactly offset costs varies depending on the difference in mopane worm prices between local and urban markets. For instance, if collectors could be sure of getting an additional Z$10,000 per tin in Bulawayo, then the break-even quantity would be around four buckets, but if gross value added by accessing the Bulawayo market was only Z$5000 per 20L tin then the break-even quantity increases to around ten 20L tins. If transport costs increase and/or the differential in prices between markets in areas of supply and markets in areas of demand declines, this has the effect of raising the break-even quantity.

Table 4.4. Costs and returns of marketing MW in Bulawayo, January 2003

No of 20L tins Marketed	Average Fixed costs per 20L	Variable cost Per 20L	Average total costs per 20L	Gross Value added per 20L by accessing Bulawayo market	Net value added per 20L by accessing Bulawayo market
1	36000	1000	37000	5000-10000	(-)27000 to 32000
2	18000	1000	19000	5000-10000	(-) 9000 to 14000
3	13000	1000	14000	5000-10000	(-) 4000 to 9000
4	9000	1000	10000	5000-10000	-5000 to 0
5	7200	1000	8200	5000-10000	-3200 to 1800
6	6000	1000	7000	5000-10000	-2000 to 3000
7	5143	1000	6143	5000-10000	-1143 to 3867
8	4500	1000	5500	5000-10000	-500 to 4500
9	4000	1000	5000	5000-10000	0- 5000
10	3600	1000	4600	5000-10000	400-5400
11	3200	1000	4200	5000-10000	800-5800
12	3000	1000	4000	5000-10000	1000-6000

11 Estimates of return bus fare, freight and associated travel costs provided by collectors attending community mopane worm workshop in Plumtree in January 2004.

Source: Information based on price monitoring surveys and cost data provided by collectors at a community workshop in Plumtree, January 2003

Given this scenario it is not surprising that key informant interviews found some collectors operating informally in groups in outside markets. A case study of collectors in Rutenga, discovered a group of collectors who nominated one of their members to travel to Bulawayo by train and market the group's mopane worm stocks. (Chirinyu, 2004). Individually the collectors had insufficient mopane worms to cover the cost of accessing Bulawayo but through selling as a group these collectors increased their returns by 30%. Similarly, Kozanayi and Frost (2003) when researching the formal wholesale market in Bulawayo were told about women who sold mopane worms on behalf of several individuals and obtained separate receipts for each collector's mopane worms.

Some collectors sell mopane worms to local consumers by the cup. For example, in January 2002 Mrs Ncube, a mopane worm collector, was selling mopane worms from her home in Romwe at Z$50 per 80g cup (Kozanayi and Frost, 2002, p21). By making mopane worms available in a quantity that consumers want (sufficient for a single meal) Mrs Ncube increased her returns per 20L tin by around 250% compared to what she would have realized by selling mopane worms by the 20L tin to a rural assembler. It should be noted that like most vendors, Mrs Ncube sold other farm produce such as tomatoes and onions from the family gardens alongside mopane worms.

A few individuals pursue marketing strategies for objectives other than maximizing earnings. For example, some collectors use mopane worms as surety for a loan from a rural assembler (local farmer-traders and urban based bulk buyers). In exchange for credit or goods to meet present consumption needs the collector agrees to repay the loan through providing a specified quantity of mopane worms to the lender. Other collectors use mopane worms to build up social capital by sending mopane worms as gifts to relatives in town. Consumer surveys in urban Bulawayo found that during the mopane worm season gifts from rural relatives were the main source of mopane worms for 42% households in medium/low density residential areas and 23% households in high density areas (Stack, 2003).

Another example of a marketing strategy that aims to maximize the utility of the mopane worms sold rather than maximizing earnings is when mopane worms are bartered rather than traded for money. For many collectors some proportion of each harvest is bartered for household requisites. If the value of goods exchanged for a given volume of mopane worms are compared to local cash value of the same volume of mopane worms it can be shown that collectors who barter realized between 10-20 % less than if the mopane worms had been sold for cash. However, bartering trade is often an important way for rural households to get goods which are not available in rural areas and it is quite common for collectors to make contact with traders in advance to tell them what goods they want them to bring them.

The relative importance of bartering to cash sales varies between and within communities but appears to be affected by both the remoteness of the collection area and social status of the collector. Bartering was more prevalent in case study areas more distant from consumption centres and poorer households are more likely to engage in barter deals than better off households.

In deciding on appropriate selling strategies collectors face a fairly common set of constraints. Individually most collectors have relatively small quantities of mopane worms to sell. For example, in five out of the seven studies synthesized in this paper the average quantity of mopane worms sold for cash per households was less than 50kgs. Imperfect knowledge of prices in alternative markets is also an important source of uncertainty and risk. Even if collectors have fairly good information about prices in alternative markets finance to transport mopane worms to outside markets is a barrier to marketing. Further, the opportunity cost of allocating family labour to marketing in distance markets may be very high, particularly during the first harvest period which coincides with a busy agricultural period. Collectors are also constrained in their ability to delay sales to benefit from high prices for mopane worms in the off season. For many households high seasonal food and cash requirements increases the perceived value of immediate post-harvest sales and reduces the benefits of delaying trade for better prices.

The appropriate marketing strategy for any individual collector depends on several factors including how much mopane worms they have for sale and how willing or able the collector is to transport and/or store mopane worms to widen their marketing opportunities.

Strategies adopted by rural assemblers

Rural assemblers are market intermediaries who buy and assemble produce from individual collectors for resale mainly to other intermediaries who buy in bulk. Most rural assemblers add value by either moving mopane worms to a different location or through storing and making mopane worms available at a different point in time. Some do both.. Apart from repacking mopane worms into sacks for transport, mopane worms undergo minimal value added processing or changes in form. This suggests that beyond transport and limited storage, few market services are provided by this type of intermediary. Some of the larger operators have their own vehicles but most appear to depend on public transport (rail and/or bus) or hired vehicles to ferry mopane worms from areas of supply to the main regional markets. Several brief cameos of various types of rural assemblers together with their mode of operation and margins provide insights into way rural assemblers operate.

Firstly, many rural assemblers carry out their business with relatively modest stocks of mopane worms (100-125kgs), although some of the urban based assemblers operate at a much larger scale than this (> 3000 kgs).

Secondly, both small and large operators buy, assemble and resell mopane worms continuously throughout the season, making several trips between the supply areas and regional market centres. However, there are also examples of rural assemblers who buy and store for resale at a later date. The rural assemblers who engage in frequent buying and selling trips have a rapid turnover of stock and are continually investing working capital in mopane worms, liquidating it and reinvesting. In some cases, capital is only tied up for a few days. In this way a modest amount of working capital is able to sustain a mopane worm business. This strategy also gives rural assemblers the flexibility to respond to changes in market conditions.

Thirdly, although the start-up capital required for a rural assembler is not large it is probably still beyond the means of most collectors unless they have savings or an income source outside of agriculture. At 2004 prices a rural assembler would need to invest around Z$600 000 (just over US$100) to buy 100-125kgs of mopane worms. This is around 2-3 times the likely monthly earnings of unskilled labour. Groups of buyers assembling a large quantity of mopane worms would, at 2004 prices, need to invest around Z$12-13m (over US$2000) per trip to buy around 3000kgs of mopane worms.

Fourthly, marketing margins ranged from 20%-148% but were generally below 100%. However, margins are an imperfect indication of profitability since the length of time rural assemblers took to earn this margin ranged from a few days to several months. Further, since quantity bought and sold influence total net earnings, margin information is not a reliable indication of total earnings. For example, the Rutenga farmer- trader involved in adding value by storing mopane worms for resale at a later date had the highest net margin but probably had the smallest turnover. Consequently she probably had the lowest total income from trading mopane worms as her capital was tied up in mopane worms for several months and could not be reinvested in other trading activities. Other rural assemblers sold immediately and reinvested earnings in additional trips to get more mopane worms. The returns from one trip might be relatively small but if rural assemblers made weekly trips to obtain supplies during the mopane worm season total earnings would exceed those of the farmer-trader who stored mopane worms for sale at a later date. Traders operating as a group appear to be earning relatively large incomes from assembling mopane worms for resale to bulk buyers mainly because they operate in large quantities and make several trips a season to areas of supply.

Fifthly, discussions with rural assemblers highlighted the importance of market information to business success. Generally rural assemblers kept themselves informed about current prices and seasonal price movements in various regional markets and rural supply centres by developing their own information networks. Some traders used contacts in areas of supply to provide information about the quality of the mopane worm season and what goods collectors wanted in exchange for their mopane worms. Larger traders carry mobile phones which enable them to keep in contact with potential buyers in regional market centres.

Sixthly, most rural assemblers specialise in mopane worm trading during the mopane worm season. Few engage in other types of trade or income earning activities during the mopane worm season, but once the season is over they are likely to turn their attention to other trading activities.

Strategies used by regional wholesalers and other intermediaries

The main wholesale markets for mopane worms are found in regional markets in areas of supply (Bulawayo, Beitbridge and to a lesser extent Masvingo). Within these markets, there are a wide variety of operators who carry out some wholesaling activities. A few wholesalers are also assemblers, suggesting some development of vertical integration in mopane worm markets. To varying degrees all wholesalers are involved in adding value by changing the timing of sales and form in which mopane worms are sold. Some wholesalers are also involved in moving mopane worms to other markets within Zimbabwe and outside the country. Others appear to confine their wholesale functions to a single market. Wholesale businesses do not appear to be fully specialized in mopane worm trading, with many traders indicating that they are engaged in other types of trade or income generating activities. Some traders have several income sources indicating that they combine multiple livelihoods. For example, a survey of traders operating in Beitbridge and Bulawayo during the 2003 mopane worm season found that 88% of traders sold other goods besides mopane worms, 17.6% were involved in agriculture and 35.3% had some formal sector employment (Rutamba, 2003). The main service that wholesalers provide is to aggregate the supplies and to make mopane worms available in bulk at a location and time desired by other intermediaries and retailers. Key observations include:

- Regional wholesalers include both male and female traders, but men predominate.
- Although large operators exist, there are many wholesale traders are modestly-sized, owner-operated businesses with relatively few fixed resources.
- Wholesalers usually have several years experience in trading mopane worms indicating that wholesaling is not generally an ‘entry level’ position in the marketing chain. This is probably mainly due to capital requirements.
- In comparison to the rural assemblers, wholesalers had significantly larger working capital requirements (Z$ 1.5-3.0m (US$200-500)). Wholesale food packaging companies probably invest considerably larger amounts of capital in mopane worms.

- Marketing margins varied between 6-167% but these are not a good indication of total earnings as turnover differed considerably. For example, the wholesaler with the lowest margin was a young man whose business strategy was to arrive at the bus terminus early in the morning to buy mopane worms from collectors as they arrive at the market. He then resold mopane worms later the same day in the same location for a small profit. This operator based his strategy on the knowledge that many collectors arriving by bus are keen to sell their mopane worm stocks quickly, shop and return to their rural area the same day. The trader assembled supplies from individual sellers, and buyers who came later in the day were obviously prepared to pay a small premium for this service.

Strategies used by retailers

Retailers of mopane worms are a very diverse group of market participants, including both formal and informal sector retailers, and following very varied strategies to earn an income from mopane worms. Mopane worms are sold in the main urban markets, supermarkets, shops and tuck shops throughout the year. During the mopane worm season, and in the off season depending on supplies, mopane worms are on sale at roadside vendors and stalls outside the main shopping centres.

Retailers commonly add value by providing mopane worms in a location agreeable to consumers and by changing the form in which mopane worms are sold (selling in small units by the cup or pre-packed and/or cooking). However, some well established stallholders also purchase mopane worms in the mopane worm season for resale at a profit in the off season, thereby adding value by changing the time when mopane worms are available. The varied characteristics of some of these market participants are illustrated in Table 4.5 which illustrates the different types of vendors in Mabvuku high density suburb in Harare.

Apart from traders selling from their homes and stallholders in the main urban markets, many of the smaller retailers and stallholders operated with stocks of less than one 20L tin (< 6kgs) making their total investment at January 2004 prices around Z$50,000-60,000 (< US$100). This indicates that potential sellers do not need a large amount of capital to enter the mopane worm trade at the retail level. However, if stallholders want to stock other goods this increases capital requirements. Permanent stallholders in regional markets such as Mbare Musika in Harare sold a variety of dry goods.

Few retailers sourced supplies direct from collectors but instead relied on intermediaries some of whom delivered supplies to the seller and gave credit. Stallholders at Harare open market (Mbare) indicated that membership of one or more rotational savings clubs helped to fund the purchases of mopane worm stocks and other goods for their stall. Most retailers supply mopane worms direct to consumers but some stallholders at the main urban markets are also sources of mopane worms for sellers of dried and cooked mopane worms in the suburb.

Table 4.5: Characteristics of different types of vendors, Mabvuku high density suburb, Harare

Type of Retailer	Location	Characteristics	Other goods sold	Units of sale	Investment	Source of mopane	Gross margin (est)	Serve
Loose mopane								
Stallholder	Shopping centres	Men and women usually self employed	Dried fish, salt, tomatoes and other fresh and dried goods depending on season	Small units: Tea, coffee cups & lids	One 20L tin	Traders or vendors in Mbare or Mabvuku	150 % - 200%	Locals
Roadside vendor	Along roadside	Mainly Self employed women	Smaller range of fresh or dry goods than stallholders and sometimes mopane only	Small units: Tea, coffee cups & lids	One 20L or less (2.5L)			Locals
Collector/ Trader	A few traders operate from residences	Men and women with links to collection areas	Specialise in mopane during collection season and may or may not trade in other goods the rest of the year	Varying, commonly 20L tins but also smaller units (2.5L)	Several sacks 100-200kg	Rural areas or markets in the south	?	Local vendors
Packed mopane								
Tuck shops	Scattered along residential streets	Owner and non owner operated, mainly men	Variety of dried, tinned and fresh goods and everyday articles like biros and razor blades	100g plastic packs packed in informal sector	20 x 100g on credit	Traders who visit tuck shop	25% - 40%	Locals
Cooked mopane								
Food vendor	Outside beer halls	Women only Self employed	Specialise in mopane snacks	Beer scud lid	2.5L or less	Local & Mbare vendors	50% (net)	Beer drinkers

Adapted from Stack, 2002b.

Off Season Mopane Worm Trading

Although MW are seasonal, once processed and dried, they store fairly well and can be found on sale in rural and urban markets and shops throughout the year. This implies that MW are stored somewhere in the marketing chain to smooth out seasonal supply and to meet off-season demand. A study of off-season MW marketing by traders in Beitbridge and Bulawayo during the period July – September 2002, by Rutamba and Stack (2003) provides information on who participates in the off-season MW market and the market functions those participants perform. The main findings are that:

- More than 80% of all MW marketing by collectors takes place in the MW season indicating that collectors play a minimal role in storing MW (except for own use).
- The peak MW purchase period was February to April. MW purchased during this three-month period accounted for 83% of total MW purchased by traders between February -August 2002. Only 17% total quantity of purchased MW over this seven-month period was obtained out of season (May – August).
- Nearly two thirds of the sellers (64.7%) marketing MW in the off season, relied on own stored MW stocks that they had purchased during the MW season. The balance of sellers (35.3%) purchased supplies of MW during the off-season as and when required from urban markets (17.7%) or from collectors in rural areas (17.6%).

Overall, Rutamba and Stack (2003) find that in Beitbridge and Bulawayo and probably other regional markets, wholesalers, urban traders and stallholders are responsible for providing the storage function for the bulk of MW sold in the off-season period. Collectors and rural assemblers play a minimal role in adding value through storage. This points to a clear specialization in marketing services.

Information was collected about where traders stored MW. Urban areas were the main storage location with 64% of traders indicating that they held their stocks in urban areas. 18% of traders kept stocks in rural areas and the other 18% indicated that they held their stocks outside the country for cross-border trading (Rutamba 2003, p51). Some traders (23.5%) indicated that inadequate storage space was a problem for them but most traders (70%) indicated that they experienced no storage difficulties. Having capital tied up in MW is the main cost and risk associated with MW storage according to just over half the traders interviewed. The other costs and risks mentioned included deterioration in quality of MW during storage (12% traders) and the chance of losing MW to thieves (12% traders).

Traders provided information about the amount of working capital required for their trading business. At 2002 prices this was around Z$ 65 000 (US$ 260)[12]. About 60% of total working capital was for MW stocks and the other 40% for other goods that traders stocked (Rutamba, 2003).

The profitability of off-season MW marketing varies depending on when traders purchased MW and whether MW were marketed locally or in markets outside the country. Rutamba and Stack (2003) use three case studies of traders in Beitbridge who were trading during August 2002 to compare the returns from different trader strategies relative to capital requirements and risks. These are summarized in Table 4.6.

Table 4.6. Performance comparison off-season trading strategies (2002 prices)

	Business Strategy		
	Case study 1	Case study 2	Case study 3
Time of Purchase	Off season (Aug)	Season (Jan)	Season (Feb)
Location of Purchase	Collection area (Beitbridge Rural)	Regional Market (Renkini bus terminus, Bulawayo)	Regional Market (Renkini bus terminus, Bulawayo)
Method of purchase	Barter Exchange	Cash	Cash
Time of sale	Off season (Aug)	Off season (Sept)	Off season (Aug)
Location of sale	Regional Market (Beitbridge)	Regional Market (Bulawayo)	Cross-border market (South Africa)
Period of storage	None	7-8 mths	5-6 mths
Changed location	Yes	No	Yes
Any changes in form	Yes – some sales in 5L units	Yes – all sales in small units (5L, 2L & cups)	

12 Base on parallel market exchange rate of Z$ 250 = US$ 1

The first case study is an off-season trader selling MW in August who was sourcing his stocks in the rural areas around Beitbridge during the off-season. This trader had no stored MW but just purchased stocks as and when required, making about two trips a week to rural areas of supply around Beitbridge. He resold MW to customers in Beitbridge town. About 60% of his sales were by the 20L tin and the balance in 5L tins. His main customers were vendors and cross-border travellers. The trader did not purchase MW for cash but acquired MW in exchange for goods (oil, flour, footwear) he had purchased in Beitbridge. From the trader's point of view barter exchange enabled him to acquire MW more cheaply than would have been possible using cash. As these goods were either unavailable or expensive in the area where he sourced his MW the trader effectively added value to the barter goods by moving them to a location where MW sellers wanted them. The trader's main costs were transport and subsistence for his trip to buy MW and the monthly rent of his market stall. His margin was 70% or $0.70 per $ dollar spent. The quantity of MW per trip was relatively small (< 30 kg MW) but by making several buying trips per month he was able to earn a reasonable income. The trader faced little market uncertainty as he was buying MW during the same period that he was selling.

The second case is a female trader who sourced MW from rural assemblers at an urban bus terminus during the MW season. The MW that she was selling during September had been in storage for about six months. There were minimal travel costs associated with acquiring MW and she stored MW at home. MW prices in real terms increased by more than 400% between January 2002 and August 2002 indicating positive returns to storage. Since this traded was buying stocks during the MW season, her working capital requirements were considerably lower than the trader in case study 1 even though she bought around double the quantity of MW. She was also able to increase her marketing margin by selling MW in small units and estimated that about 40% of her sales were cups of MW and the balance 5L tins. Although her margin of 990% was several times greater than the trader in the previous case study both traders had similar weekly earnings due to the fact that trader 1 had a higher weekly turnover.

The third case study illustrates the profitability of off-season cross-border trading. It is based on a female trader who sourced MW in February from rural assemblers at a regional market and after storing them for several months marketed them in South Africa. Her total working capital requirements were similar to the trader in case study 1 but only half of this was invested in stocks. The cost of her trip to South Africa to market MW accounted for the other half of her working capital requirements. She only took one bag (6 x 20L) MW to sell in South Africa and she was away two weeks. She sold all her MW by the 2L tin and received payment in Rands that she brought back to Zimbabwe and changed on the parallel market. This trader indicated that sometimes she used her Rand earnings to buy goods to resell in Zimbabwe but during 2002 she preferred to return with Rands due to the attractive parallel market exchange rates. Her net margin was estimated at around 1550% or $15.50 per $1 invested. Cross-border trading offers profitable marketing opportunities. However, cross-border trading is also associated with higher risks than domestic trading due to price uncertainty and uncertainties about transport, food and accommodation and personal security during the trip. In addition, traders have to have a good knowledge of both the MW market in another country and of how best to use the foreign exchange earned. On paper, the profitability of off-season cross-border trading looks very attractive but success requires adequate finance, business acumen and an ability to take risks. Only astute business people are likely to succeed.

Problems, constraints and opportunities

Barriers

- Geographical constraints constitute barriers to information flows and physical flows of produce. Remote sellers do not have timely access to salient and accurate information on prices, locations of effective demand, alternative marketing channels
- Capital constraints
- Other factors which affect market efficiency and may constitute barriers to market access are gender, education levels and wealth status.

As a result of these barriers there are under exploited market opportunities and inequitable returns to producers.

Product Quantity and Quality

An inherent characteristic of forest products is the variability in quantity and quality of supply. Mopane worms are no exception with outbreaks being seasonally unpredictable owing to droughts or disease which can destroy almost the entire outbreak. Outbreaks are also spatially unpredictable. The quality of production is highly variable although this is something that can be improved through better processing practices.

Packaging of the product is often of very poor quality. The thin plastic bags that are often used are easily punctured by remaining spines on the dried product leading to infestation of pests and uptake of water. The visual appearance of the product could also be greatly improved using better packaging and labelling.

Complexity of marketing channels

Market systems for NTFPs are often more complex than those for staple foods. This is in part due to the importance of the informal sector in marketing of NTFPs. Returns to producers and traders are affected by their knowledge of alternative supply sources and market outlets, and the ease of access. Choice of competing channels and markets conditions the profitability of trade as does the level of business skills and ability of participants to take risks

Market Information

Increasing returns depends in part on better flows of information, and in the mopane market chain there is virtually no flow of information from rural or urban markets to collector communities. This exposes collectors to exploitation by traders and wholesalers.

Access to finance

Barriers to entry into the mopane worm business are low for collectors and traders. Barriers to expansion, however, depend on ability of traders to secure sufficient capital to purchase in bulk. Due to perceived favourable returns to mopane worm trading, new entrants are common. It is interesting to observe some of the mechanisms that traders use to build up the working capital of their businesses. Many traders indicated that they had been involved in trading some other commodity, before trading in mopane worms, with the main objective being to build up the capital they required to enter the mopane worm business. For instance, one young cross border trader began by buying sugar and reselling by the cup until she had built up enough money to purchase a bag of mopane worms. These she sold by the cup in local markets until she had sufficient capital to operate as a cross border mopane worm trader. All these examples provide useful insights into the mechanisms that the informal sector use to overcome capital constraints but they also illustrate a natural process by which traders develop essential business skills such as being able to identify profitable opportunities and assessing risks. By starting small and allowing a business to develop in line with its ability to fund its own expansion, traders are adopting a tried and tested successful business strategy. There is a danger that initiatives to provide finance for groups of mopane worm collectors to access urban and cross border markets could fail because a loan allows many collectors to bi pass the means by which most traders learn to be successful in business. Lack of finance is only one of many barriers facing potential mopane worm traders.

Potential Interventions

The main goal of any livelihood activity is to achieve worthwhile benefits in relation to the time, costs, risks and hardships spent on that activity. Many people harvest and sell mopane worms as a way of earning money. However, a common complaint among collectors is that the income received for the harvest is low when measured against the time; risks and hardships spent collecting and preparing the product: to what extent is this an unavoidable characteristic of trading in forest resources. What, if anything can be done?

Direct state Involvement

Generally there is a role for governments and local administration in the creation of enabling conditions, by specific local interventions and by providing infrastructure. However market improvements are most likely to arise as response by private sector on an individual, firm or collective basis.

Individual Approaches to Marketing

The factors which prevent collectors adopting more profitable marketing strategies are complex. Households face numerous constraints (high marketing costs, inadequate market information, urgent seasonal cash demands) that limit their ability as individuals to be more involved in value adding. These sellers can benefit from the provision of information about how value can be added and appropriate skills training in negotiating and price searching but development activities most likely to succeed for the poorest collectors are those that encourage farmer collaboration to benefit from economies of scale in marketing and value added processing.

Various case studies of how collectors and various market participants use location of sale, form in which mopane worms are sold and timing of sales to influence earnings from mopane worms demonstrate some interesting relationships between risk, earnings, returns to various inputs (capital, labour) and returns to different value adding strategies. For instance, participants in the mopane worm business with sufficient capital to fund a high volume mopane worm business tend to pursue strategies which involve changing the location or timing of sale in order to enhance earnings. These activities require a fair amount of capital investment, are associated with a degree of price uncertainty and other risks but produce high net profits for the astute business person. However, returns per dollar invested tend to be moderate and high turnover is an important contributor to total profits. On the other hand, traders with limited capital tend to pursue strategies which involve changing the form in which mopane worms are sold (e.g. selling mopane worms in small units such as cups or selling prepared mopane worm snacks). These activities give sellers high returns to their most limiting resource (capital) although returns to labour and total earnings from these types of activities are relatively low.

Developing a marketing strategy to sell mopane worms depends on several factors that vary from collector to collector:

- How much mopane worms a collector has to sell (if a collector only has a small quantity to sell the higher price received in a distant urban market is unlikely to be sufficient to cover marketing costs)
- Urgency of need for cash (if collector needs to sell harvest quickly to get money to buy food or pay school fees s/he will not be able to delay selling mopane worms to obtain better prices
- Pressure of other responsibilities, (women have responsibilities at home or in the fields may not be able to spend much time away from home marketing mopane worms)
- Availability of capital to invest in buying mopane worms from other collectors – individual collectors who buy mopane worms from other collectors for resale are able to acquire sufficient volume to warrant transporting and/or store mopane worms to widen their marketing opportunities
- Ability to cooperate with other collectors in marketing mopane worms in urban centres where returns are generally higher – collectors who are able to develop relationships of trust can cooperate in marketing and benefit from economies of scale
- Expectations with regard to future prices – if collectors keep a proportion of their harvest to sell out of season when prices are higher there is a risk that the prices of what they want to buy increase at a faster rate than the value of mopane worm stocks. In 2003, rampant inflation eroded the real value of out of season mopane worm prices. If collectors expect this will happen in any given year it is better to get the best price for mopane worms as soon as they can after harvest and buy what is needed or invest the money in assets for other livelihood activities without delay.

The implication is that different strategies will be appropriate for different collectors since the natural and socio economic environments in which the rural poor are located vary.

Collective Approaches to marketing

Informal groups

Various case studies have illustrated informal collaboration between collectors and traders. For example, small groups of women who delegate one member of the group to market their combined harvest in an urban market, sharing costs of marketing and benefiting from higher prices, groups of traders who come together to act as rural assemblers or trade in outside markets, or stallholders who form informal savings groups to overcome capital constraints.

Community Trusts (KyT)

At the outset of KyT’s formation in 1997 mopane worms were effectively the only cash crop of its members and early efforts focused on assisting rural women to maximise their return on mopane. However, mopane worms are now one of the least important products in KyT’s portfolio largely because it is difficult to add value through product differentiation. The Trust barely covers it’s packaging, labelling, marketing and distribution costs and mopane sales generate little revenue towards the Trusts operating costs. However, mopane worm sales remain important to members and the product is retained within the Trust portfolio. Diversification and new product development, mainly into a range of natural resource products including marula oil and soap, food products and traditional herbal remedies has been critically important in raising members incomes and moving towards the goal of establishing a financially sustainable community based organisation. The latter still remains a real challenge, mainly because a rural community project faces high transportation and distribution costs of products to a market.

Conclusion

An important conclusion is that there are significant opportunities for greater participation by collectors in value adding activities but that the institutional arrangements for facilitating and sustaining participation, with a fair distribution of outcomes between the poorest and better off collectors, is likely to be a serious challenge.

We also identify a number of issues that need to be taken into account when considering various possible marketing innovations:

- Evaluation of trade-offs and complementarities. For example trade offs between better resourced/ less remote/ larger scale groups price benefits from certification /niche market development/ value added processing and possible exclusion for poorer/ remote/ small scale collectors.
- Climatic variability and the episodic characteristics of mopane worm outbreaks means that households relying on mopane worms adopt highly opportunistic and adaptive livelihood strategies, and this affects their reliance on and involvement in mopane worm collection and marketing. This must also be built into processes of innovation development. For example, value added processing activities should not rely on fixed capital specific to mopane worm activities and needing regular utilisation to provide a satisfactory return, markets should not be developed that need reliable and regular supplies – unless technologies can be developed to overcome the uncertainty in outbreaks.
- Although the importance of mopane worms to poor rural collectors is recognized, in the course of work conducted, other groups of poor people for whom the mopane industry is important, have also become apparent: rural based traders, urban based traders, urban unemployed youth and women involved in petty trading and vending. Different innovations may have different effects on these different groups. Their concerns and welfare must be considered when developing and evaluating different innovations.
- Large scale procurement and processing activities are very likely to impinge on resource management, marketing patterns and therefore long term sustainability of mopane worm harvesting and livelihood contribution
- Gender issues – it is mainly women who harvest and process non-timber products for sale. Commercialisation offers opportunities but it may also lead to exploitation of the harvesters actually doing the work. Much of the work goes on in nearby forests and at home which allows women to combine their income generating activity with child rearing, domestic chores and farming. Unless carefully designed, projects to encourage processing and sale of NTFPs may have a negative effect on women. In the development of mopane worm value addition and commercialisation strategies, there is a need to include project components that help women defend their economic interest in mopane worms.

Decentralisation processes

Support from central government to local government needs to be better defined. Substantial efforts are necessary to improve the capacity of local institutions to carry out their new functions which in Tanzania include needs identification, planning, budgeting and joint implementation with other institutions. Even then, in under-resourced areas it is unrealistic to expect local government to take full responsibility for the provision and maintenance of essential infrastructure such as roads and transport, which constitute a major bottleneck to regional development;

The relationship between elected local government and traditional authorities can be especially critical in peri-urban areas, where it overlaps with tensions between statutory and customary land tenure systems. The potential for conflict is much higher in areas with low levels of social and political cohesion, showing that in many cases the new unit's boundaries do not reflect social, economic and political realities.

Following economic reform in the 1980s, public funding to essential services such as health and education, and to infrastructure such as water has declined, while user fees have been introduced. In many African countries, international donor agencies, churches and NGOs have taken over service provision, often concentrating in rural areas on the assumption that this is where poverty is concentrated. The result is that while local government will play an increasingly important role in regulation, planning and implementation, better synergy with other actors, from international donors to local institutions will be essential to ensure coordinated and equitable provision of such services.

Capacity building

Capacity building has been defined as 'any intervention designed to reinforce or create strengths upon which communities can draw to offset disaster-related vulnerability' (Lautze 1997). Whilst capacity-building within communities is certainly important, there is also a very real need to build capacity within operational agencies (Montani and Majid 2002), not the least local service providers (Christoplos 1998). In terms of capacity-building, what emerges is a wide array of different approaches: building productive capacity through enhancing specific assets; building capacity among individuals and local communities through skills training and the development of committees; building capacity within implementing agencies through information-

Section 5 Livelihoods analysis of mopane worm use

Relevant Activities

3.1 Document institutional arrangements and conflicts concerning access to and use of mopane resources
3.2 Conduct field work to investigate institutional arrangements and the nature and extent of conflicts and conflict resolution mechanisms in mopane woodland resource access and utilisation in six study sites in three countries
3.4 In conjunction with relevant stakeholders, explore the formation of networks of producers for sharing information and experiences in mopane worm harvesting, processing, marketing and other activities

The mopane worm is one of the best-known and economically important forestry resource products of the mopane woodland in Botswana, southern Zimbabwe and the northern Transvaal (Timberlake, 1996; Bradley and Dewes 1993). The involvement of households in mopane activities is generally widespread when outbreaks occur and they provide an opportunity, particularly for poorer households, to improve household food security and generate modest income for other household requirements. Outbreaks of MW, although seasonal, are timely in that they occur during the early months of the rainy season which is traditionally referred to as the hunger season, when most rural households are in dire need of cash for food and school fees and general up keep of families. In recent years there has been growing interest in the actual role and potential opportunities for forest resource products, such as mopane worms, in poverty alleviation. Much of the work done to data on mopane is vulnerable to the criticism that the results are 'just case studies' that do very little to provide knowledge rather than hearsay about the wider population of users of this forest resource. In addition, few studies examine variability in the nature of involvement in mopane activities between different socio-economic groups or communities. This section presents a synthesis of the major findings from a variety of surveys and case studies conducted as part of the Mopane Worm project in communities across southern Zimbabwe, Botswana and South Africa to gain an overall picture of similarities and variability in mopane worm utilisation among communities and different household groups. The analysis provides a basis for considering a range of possible innovations (technical, institutional and market) that have the potential to enhance the role of this forest resource product in rural livelihoods, recognising that different innovations will be appropriate in different circumstances.

Historical Profile of Gwanda

The historical profile dates back to the late 1940s for both Silonga and Manama wards. Villagers forced to leave their original homes were resettled in these wards in 1947 and in the following few years. There was little rainfall in these years of resettlement and the government imported maize to alleviate starvation. However, people also turned to wild fruit and hunting but this is no record of either the availability or consumption of mopane worms. Mopane worms first began to be widely collected for subsistence around 1960 when an outbreak of a cattle disease (probably Foot and Mouth) resulted in the culling of diseased cattle and confiscation of healthy cattle. Deprived comunities were therefore forced to turn to other resources including mopane worms. Many domestic and wild animals were succumbed to a severe winter in 1968 which resulted in famine. Mopane worms became an important alternative food source and in the following years their importance for subsistence as well as commercially began to increase. By 1970 a bucket (20 litres) of mopane worms was sold at Z$1.00 - Z$3.00 in urban markets.

Following independence in 1980 mopane worms continued to contribute to rural economies despiete excellent agricultural harvests indictating that mopane worms were no longer considered as a 'safety net' food. Disturbances in Matebeleland in the early 1980s led to a temporary cessation of the moapne worm trade.

Between 1990 and 1992 famine induced by drought affected livestock and conditions were exacerbated by very poor mopane worm outbreaks during these years, perhaps as a direct result of the extended drought. By 1997 improved rainfall was coupled with large outbreaks of mopane worms which were now being processed and commercially exploited on a large scale and attracting interest from traders outside mopane regions. Incomes received from mopane worm sales were now contributing substantially towards school fees, clothing and other items used in the home.

Large mopane worm outbreaks following cyclone Eline in 2000 mitigated the damage to homes and crops. However, conflicts were increasingly arising among rural mopane producing communities and commercial harvesters from outside the district. Talks were initiated with rural district councillors to introduce laws governing entry by outsiders to the community for harvesting mopane worms.

Socio-economic status

Sources of livelihood and livelihood indicators

Social classes based on wealth are differentiated mostly by material possessions including livestock and poultry, farming implements, amenities at the homestead such as water, toilets and structure of housing, transport including scotch-cart, bicycle, wheelbarrow or car, level of education of the children and businesses owned. Community members identified four wealth rankings with which they identified certain indicators listed in Table 5.1.

Members of all wealth categories harvest mopane worms although for different reasons. The 'Very Poor', also described as 'lazy', collect enough worms for subsistence only.

The Poor form the largest group of mopane worm harvesters and depend on mopane worms as their major source of livelihood. They collect large quantities of mopane worms most of which are sold for cash or bartered for clothing and basic food items. A small fraction of the worms are kept for household consumption. If the family is in urgent need of cash they will sell even that which was reserved for household consumption.

Table 5.1 Wealth Ranking

Very Poor; 'Lazy'	**Poor**	**Moderately wealthy**	**Rich**
• Very thin dog • No livestock • Cannot send children to school • No field • Is a gossipmonger • Is lazy • Has no money • Small, thatched, dilapidated house • Many children	• 1-5 cattle. • Owns 2-5 goats • Works for other people to buy food • Few chickens • Simple tools used in the fields eg, hoes • Children have basic education up to grade 7 • Can afford 2 meals a day	• At least 20 cattle • At least 50 goats • Large field • Cart • Donkeys • Plough and other tools • Bicycle • Many chickens • Scotch-cart • Well built house, toilet, borehole and granary • Educated children • Children attend school up to form 4 • Can afford 3 meals/day	• Car • 50-100 cattle • At least 100 goats • At least a 500 sheep • At least 15 donkeys • A scotch cart • Several fields • Plough and many tools • Owns a store/shop • Grinding mill • Well educated children working in towns • Well built brick house with asbestos or tile roofing, a borehole, a granary and toilet • Can afford > 3 meals/day

Members of Moderately Wealthy households have paid employment and are engaged in farming and trading of livestock for additional income. They will harvest mopane worms as a supplementary source of income and do not depend on its proceeds.

The families in the Rich category rarely harvest mopane worms though they will often send employees to do so for them. This group own shops some members may buy mopane worms in large quantities from harvesters to trade them elsewhere as part of their business.

Livelihood sources

Mopane worms form only one of a number of income generating options available to the Gwanda communities. Other options include livestock, crops, carpentry, sewing, fishing, market gardening, gold panning, beer brewing and selling mats.

Table 5.2. Pairwise matrix comparing the relative importance of different options for income generation. Sources of income are listed in the leftmost column and their numerical codes listed along the top row.

	1	2	3	4	5	6	7	8	Score	Rank
1 MW trade	-	2	1	1	1	1	1	8	5	3
2 Livestock sales		-	2	2	2	2	2	2	7	1
3 Crop sales			-	3	3	3	3	8	4	4
4 Money from children				-	4	6	7	8	1	7
5 Mat and basket sales					-	6	7	8	0	8
6 Manufacture of tools						-	7	8	2	6
7 Market gardening							-	8	3	5
8 Second hand clothing								-	6	2

Table 5.3. Pairwise matrix comparing the relative priorities on which income is expended. Categories are listed in the leftmost column and their numerical codes listed along the top row.

	1	2	3	4	5	6	7	8	Score	Rank
1 School fees	-	2	3	1	5	1	7	8	2	3
2 Food		-	2	2	5	2	7	8	4	4
3 House building			-	3	5	3	7	8	3	5
4 Clothing				-	5	4	7	8	1	7
5 Livestock					-	5	5	5	7	1
6 Agricultural inputs						-	7	8	0	8
7 Home utensils							-	7	6	2
8 Transport								-	5	6

Using a pairwise matrix the communities were asked to rank the different livelihood sources in order of greatest return (Table 5.2) and also how the income generated was used (Table 5.3). Selling livestock gave the highest income, although most people did not own livestock. Mopane worms also provided substantial returns and are accessible to everyone. Poor soils and inadequate rainfall limited the productivity and value of agricultural crops as an income generating strategy, although small scale market gardening contribute a little towards household incomes.

Table 5.4. Activity calendar of main activities of people from Gwanda district.

	J	F	M	A	M	J	J	A	S	O	N	D
Ploughing	*										*	*
Weeding	*											*
Fencing of fields								*	*	*	*	*
Harvesting			*	*	*	*	*					
Collecting mopane worm	*	*	*	*								
Marketing mopane worms		*	*	*	*	*						
Winnowing					*	*	*					
Fetching water	*	*	*	*	*	*	*	*	*	*	*	*
Going to South Africa							*	*				
Preparing new fields				*	*	*						
Fishing	*	*	*						*	*	*	*
Gathering berries		*	*									
Herding livestock	*	*	*	*								*
Making anklets and leglets			*	*								
Spreading manure in fields									*	*		
Growing vegetables				*	*	*	*	*				
Livestock rustling	*	*	*	*	*	*	*	*	*	*	*	*

Throughout the year the communities engage in a variety of livelihood activities and these sometimes coincide. Mopane worm harvesting in November and December coincides with the peak of the agricultural season when planting and weeding the crops takes place. At this time mopane worms may be collected close to the fields and on completion of the day's agricultural work. However, other families may leave the children to attend to the fields while the women harvest mopane worms over several days. Children are frequently taken out of school until the parent returns. The second mopane worm outbreak occurs in April and May which coincides with school holidays. At this time the children will help in the fields or in harvesting mopane worms. Mopane worm selling is mainly done from February to June although this period may be extended in years when the harvest is very good. An activity calendar shows the timing of various activities through the year (Table 5.4).

Services

There are various departments and institutions, identified by community members, who work with them on various issues (Table 5.5). Only CAMPFIRE has been working on mopane worms. CAMPFIRE helps these communities in natural resources conservation generally, and promotes conservation of mopane trees specifically to ensure good harvest of mopane worms for sale. No assistance has been received in marketing the worms though.

Table 5.5. Departments and institutions identified by community members as providing benefits to them.

Institution	**Assistance**

Health	Hygiene and cleanliness, disease prevention and cure, e.g. malaria, AIDS, measles, diarrhoea
Social welfare	Sending children to school, and helping to clothe them. Provide food to old and disabled people.
Veterinary services	Livestock health problems, e.g. dipping cattle. Dosing and injecting against Lampskin, foot and mouth, black leg.
Agritex	Help in ploughing, e.g. contour ridging and crop rotation.
CAMPFIRE	• Conservation of resources through controlling tree cutting and regulating hunting. • Collect mopane worms and sell them to buy food and clothes. • Controls access to mopane worms
Water and sanitation	• Construct dams • Promise to provide cattle
Councillor	• Represent sections • Relay messages to and from RDCs • Mediate conflicts among kraalheads and chiefs
Ministry of Education	Teach children to be doctors, teachers and drivers and pilots.
Lutheran Church of Zimbabwe (ELCZ)	• Provide food and seeds. • Helps build dams and boreholes • Provide toilets, churches, schools and hospitals
Traditional leaders	• Maintain the law • Mediate conflicts among people (this is done with the help of Councillors, VIDCO, Village Community Worker [VCW], headmasters). • Kraalheads forbid starting of veld fires during the mopane season
Village Development Committee (VIDCO)	• Development and building assistance • Kraalheads help us in matters of the law
SAFIRE	• Provide knowledge about resources and the environment (incl. mopane worms)
Home-Based Care	• Help in home-based care • Help the orphans

Health and Education

There are few health facilities in the area the largest health institution being Manama Hospital although this hospital is not easily accessible to many. Health workers from the Ministry of Health have been operating in every village 1985 and assist the villagers with basic health care.

The largest health threat to the community is HIV/AIDS with many families have been affected in some way by the disease. There is a general belief among community members that mopane worms can help alleviate AIDS complications. There is no scientific basis for this belief but mopane worms are an important source of nutrition and provide both essential and non-essential amino and fatty acids that contribute towards an improved constitution.

Schools are often far from the villages – as far as 14km from some villages in Gwanda. School fees are also comparatively high making education inaccessible to many. Income from mopane worms contributes much towards school fees and materials.

Agriculture

This region of Zimbabwe is susceptible to frequent and sometimes severe droughts which, coupled with the poor soil quality, often causes the failure of drops and death of livestock. Lack of livestock forces many people to plough their fields using hoes, which is not only labour intensive but also of limited effectiveness in generating a good crop. Villagers have little knowledge of market prices for crops, livestock or mopane worms and have little bargaining power with outside buyers.

Transport

Public buses and combi vans are the only means of long-distance transport in Gwanda. People who harvest mopane worms far from home are forced to walk long distances. In Gwanda district it was reported that mopane worms are no longer found in the vicinity of the villages as most of the mopane trees have been cut. Donkey-pulled scotch-carts are the most commonly used means of transport and they may be hired to carry large quantities of harvested mopane worms to back to the village. Traders from outside the area generally depend on public transport to travel to mopane worm producing areas, although some traders bring their own vehicles to buy and collect mopane worms from the villagers.

Basic Commodities

In Zimbabwe during the course of the study the prices of basic commodities increased dramatically owing to national inflation. Prices of mealie meal and other basic foods stuffs rose on a daily basis making them inaccessible for the majority of community members who have very limited financial capital. A more recent problem is the shortage of basic commodities owing to drought that affected much of Southern Africa in 2001 and 2002. During such crises mopane worms becomes a particularly valued alternative food source.

Harvesting and processing of mopane worms

Although community members felt that they had some knowledge on mopane harvesting and processing, there remains a need for further education and assistance to develop safer processing methods. Community members specifically requested knowledge on caring for mopane and breeding techniques so that they could bring the mopane worm closer to home. Villagers recognise the need to maintain mopane trees close to the villages to overcome the distance and transport problems.

Degutting mopane worm causes irritation to unprotected hands due to the spines. Bottles are sometimes used to disembowel the worms or gloves are worn, but these methods slow down the rate of processing. People who process the caterpillars also run the risk of contaminating their blood with micrococci bacteria that are found in the bowels of mopane worms. Strains of this bacteria can, apparently, produce toxins that can prove fatal.

Another problem identified by the villagers is harvesting by people from outside the community. Harvesting by outsiders was claimed to be more destructive and contributed to woodland degradation and depletion of the worms themselves. Villagers requested assistance from law enforcement agencies to protect user rights over the mopane worms.

Storage

The community members have no dedicated storage facility for the collected mopane worms. Each individual stores processed worms in their own home. Poor processing or storage leads to spoilage of the worms by micro-organisms or fungi. Occasionally the worms are laid out in the sun after a period of storage to prevent moisture accumulation.

Marketing of mopane worms

Domestic markets are considered good and there is a large demand the mopane worms. However, harvesters recognise that traders often give them a poor price for the mopane worms. Harvesters identified the need for assistance in the formation of marketing groups as well as a common marketing place such as a warehouse.

Unemployment

Unemployment in the area is very high stemming from Zimbabwe’s general economic decline. Decline in school attendance has also declined due to reduced household finances. The number of people resorting to mopane worm harvesting as an important livelihood option has been increasing in recent years. Unemployment has led to an increase in the crime rate in the area with increased reports of mopane worm stock thefts. Some youths are migrating to South Africa where employment is easy to find.

Conclusions and Recommendations

Mopane worm collection, processing and marketing is a process which occurs within a framework of livelihood activities which are perceived to be the cornerstones to the survival of people carrying out this process. Other highly rated livelihood activities include crop and livestock production. Mopane worm collection competes with these alternative livelihood activities for time and manpower.

Mopane worm collection is prominent in the remotest districts of Zimbabwe, which are characterised by poor infrastructural development in terms of road networks, communication systems, clinics and schools. These areas are completely cut off during the wet season which coincidentally is the mopane worm production season.

Some broad similarities among communities and within socio-economic groups include the following:

- The majority of communities involved in mopane worm collection are located in areas of low natural resource potential where communities experience high vulnerability to food insecurity.
- Widespread involvement in mopane worm collecting wherever outbreaks occur, confirming that utilisation of this forestry resource is not limited to poorer households but is an opportunistic activity undertaken by most households in the community.
- In all communities and across all socio-economic groups the combined share of the mopane worm harvest bartered or sold is greater than the quantity retained for home consumption demonstrating the strong commercialisation of this forestry product.

- In absolute and value terms, poorer socio-economic groups harvest more mopane worms than better off households. However there was evidence that some of the value of the higher harvest is lost through lower prices achieved by mopane worm sellers from poorer households compared to those from better off households. The factors accounting for this include the greater likelihood that poorer households engage in barter transactions, the lower involvement of poorer households in mopane worm markets outside the community and therefore higher dependency on market intermediaries, and the pressing cash needs of poorer households which provide little scope for storing mopane worms to take advantage of anticipated upward seasonal price movements.
- Survey data confirm that mopane worms are seldom the most important source of household income, particularly among livestock owning households, but that they can be crucial in filling seasonal cash flow gaps.
- The commercialisation of mopane worm has brought about a wide range of social, economic and environmental problems including conflicts between residents and outsiders on access and use mopane resources, increased use of non-traditional harvesting methods (often blamed on non-locals) which are resulting in environmental degradation, changes in processing methods which compromise the quality and storability of mopane worms, and marketing problems.
- The widely observed phenomenon that income from forest products tend to be of greater importance to poorer socio-economic groups but that better off households capture a larger share of the benefits appears not to be the case with mopane worms at present. However, the possibility of better-off households capturing benefits of any interventions that enhance productivity should be taken into account in any suggested development options.

It is against this background that the following recommendations are made.

1 There is need to organise mopane worm collectors into viable production units with well-defined institutional arrangements. This would strengthen information sharing to secure fair prices and bargaining power through group marketing. Communities should organise themselves into groups that will trade with outsiders as one. They can even assign one of their members to commute to the towns and sell on their behalf rather than wait for traders to travel to the villages. Product quality is also likely to improve as producers aim to standardise their produce.

2. By-laws should be revised to clarify user-rights and to prevent encroachment or regulate collection of mopane worms by outsiders. These by-laws should be negotiated between village headmen, tribal chiefs and the Rural District Councils. Local police should be engaged to enforce these by-laws.

3. There is need for capacity building of institutions that contribute training on costing or pricing. Producers should also be linked with potentially better paying urban and cross-border markets such as Beitbridge, Bulawayo, Botswana and South Africa.

4. Since mopane worm collection is a labour intensive exercise, there is a need to develop appropriate technology to ease hardships in processing, preservation, packaging and storage. Protective clothing is necessary during the collection and processing stage to protect the collectors and prevent contamination of the worms with various coliform and other bacteria transmitted by poor hygienic practices. Storage facilities need to be improved to ensure effective and safe long-term storage.

5. Alternative sources of income for households should be identified to cover the gap of critical shortage of such income during the period December to April. Provision of such a source of income would mean that mopane worm collectors would not sell the bulk of their worm during this period thereby flooding the market (leading to reduction of prices). Collectors would be able to keep their worms until the market offers satisfactory prices.

6. There is need for institutional interventions to moderate marketing of mopane worms. Local authorities could play an important role in ensuring that traders do not take advantage of mopane worm producers. This has already been attempted in some areas, for example in Plumtree district, by fixing a minimum price to be paid to producers, but the fixed price does not currently reflect market realities (see marketing section in this report). Local authorities could in turn benefit from permit fees or percentage royalties.

7. An improved and subsidised transport system would allow mopane worm producers to take their products to the rural or urban markets where they could secure better prices for their products and avoid paying inflated prices for the commodities they buy.

8. There is urgent need to assess the state of the resource base (mopane worms and mopane trees) and establish a system for its continued monitoring and management to avoid the degradation of mopane woodlands and their resources that is prevalent in the vicinity of many urban centres and some rural areas.

9. Create opportunities for information sharing among rural communities particularly across districts where mopane worm activities provide a substantial share of household income as in Chiredzi, Beitbridge, Mwenezi, Gwanda and Plumtree.

Although most mopane worm abundant areas are found in environments of low agro-ecological value, significant variation in mopane worm production, market systems and environments is apparent, both between and within countries.

Differences between countries include:

- *Botswana* has a growing economy and (in some areas at least) declining interest in mopane worm collection as other more lucrative income generating opportunities and jobs become more widely available. The devaluation of the Rand against the Pula has depressed export prices, while there is only a small domestic market.
- *Zimbabwe* has a contracting economy and growing interest in mopane worm collection as other more lucrative income generating opportunities and jobs become more difficult. The devaluation of the Zimbabwe dollar against the Rand (in the parallel market) at least maintains export prices, but there is in any case a large domestic market which is probably growing as mopane worm presents a cheap protein source for urban dwellers.

Differences within countries, that is between areas/communities and within areas/communities:

- In *Botswana*, poorer people in less accessible villages are more dependent on mopane worm as an income source (and are likely to remain more dependent for longer) as compared with those in villages that are more accessible.
- In *Zimbabwe,* there are large differences in access to other sources of cash and to markets, in pressure on mopane woodland and on mopane worm outbreaks, and in the nature of access to mopane resources (communal lands, commercial farms, state farms, with differing systems and costs for gaining access).

Variation between households and communities (as described above) has important implications for the range of technical, institutional and market innovations that are appropriate to different mopane worm users. A range of possible mopane worm development strategies may be followed by households on the basis of their assets and market opportunities. For the very poorest mopane worm collectors, mopane worms are likely to be important in helping them to 'hang on' by providing important buffering and insurance roles by which they maintain precarious and vulnerable livelihoods. Beyond the minimal maintenance roles, a capacity for involvement in mopane business may enable advancement through value-added processing (the 'stepping up' strategy) or by accumulating a set of assets that can be used to gain entry to other livelihood activities (the stepping out' strategy). Thus, income from mopane worms may be used to fund investments in, for example, education and health (human capital), social networks (social capital), productive assets such as livestock (physical capital), or out-migration in search of non-farm income (financial capital). Mopane worm based strategies have to be evaluated against alternative means of 'hanging on', 'stepping up' and stepping out'. In addition, they have to be adapted to local conditions and the different context of households that utilise this forest resource.

A final issue considered is the difficulty of achieving a balance between improving the livelihoods of poor rural households and sustainable use of forest resources. Mopane worms, like many forest resource products, generally occur in open-access forests. It is common practice for people from outside the resident communities and even from outside the district, to come to harvest this resource during outbreaks. This often leads to conflicts between outsiders and residents over the administration and right to benefit from mopane resources. In addition there is a danger that growing commercial opportunities for mopane and the poverty of many households in mopane worm abundant areas may force harvesters to maximise short term income by harvesting as much as possible at the expense of future income There is a need to develop local participation in planning institutional arrangements governing access to and control and use of mopane resources of mopane worms so as to enhance the contribution of mopane resources to poverty alleviation and food security in local communities and to ensure sustainability.

Finally, it should also be noted that in seeking to alleviate poverty in rural districts of southern Africa we need to bear in mind that the poor are not restricted to the rural producer communities. Traders and urban retailers as well as many of the urban consumers of mopane worms are also poor. Adopting strategies that benefit mopane worm producers may disadvantage these other elements of society that may lack wealth or alternative livelihood opportunities.

Section 6 Social preferences to Mopane worm farming innovations in Zimbabwe's rural woodlands

Activities

6.1 Design choice experiments at planning workshop

6.2 Undertake field surveys to implement choice experiments

6.3 Analyse data and present results from choice experiments

1. Introduction

In Zimbabwe, a contracting economy and high unemployment has led to increased interest in Mopane worm collection. Currency devaluation has increased food import prices and the Mopane worm is growing in popularity in urban areas as an affordable source of protein (Stack et al., 2002). In the southern arc of Mopane woodlands it is reported that most households harvest the Mopane worms when outbreaks occur and that over three in four households will sell some of their harvest (Frost, 2005). Rural-urban value chain analyses indicate that consumers may pay four or five times the price received by a rural harvester. These trade linkages stretch across neighbouring borders into South Africa, Botswana, Zambia and the Democratic Republic of Congo. It is estimated that income from Mopane worm harvesting may contribute up to a quarter of total annual cash income for rural households (ibid). These factors make Mopane worms an important forest resource for rural people and contribute to livelihood security in various ways:

- Off-setting seasonal shortages of income or food;
- Buffering households against drought, illness or other shocks;
- Supplementing household expenditure on education, health, food, agriculture or other productive or consumptive activities.

Recent efforts have attempted to better understand improved market opportunities for Mopane worms (Stack et al., 2003), how to sustainably manage and use the woodland resource (Frost, 2005) and opportunities for farming Mopane worms at the household level (Gardiner, 2005). The latter initiative responds to recent findings of important biotic factors, principally disease and parasite pressure, that limit Mopane worm populations in the wild. Wild outbreaks are unpredictable as they are influenced by a complex range of biotic, climatic and other factors that make harvesting and harvest income undependable. Research indicates that some of the biotic factors can be controlled or reduced in semi-domesticated farming systems13. This has led to trials to test the feasibility of a household-scale semi-domestication system for breeding and rearing Mopane worms for income and food benefits.

Understanding the preferences of likely participant households across a range of exploratory harvesting and management scenarios is important for decision-makers to design feasible and desired interventions. The purpose of this study is to answer:

- Who are more likely to adopt Mopane worm farming innovations, and
- What level of attributes are more likely to increase participation.

2. Methodology

2.1 Stated choice methods

Stated choice methods provide an approach to evaluate the impacts, adoption or preferences of target groups to a proposed future scenario that cannot be assessed with existing knowledge (e.g. climate change, price shifts, new technology). It allows decision-makers to estimate and predict people's behaviour to alternative scenario designs. Such techniques have been commonly used in marketing, transport economics, medicine and psychology for many years with the methodological basis, design criteria and econometric models tested and developed into a broad range of tools and modelling approaches (Louviere et al., 2000).

A limitation of the approach is that choices will be shaped by the way they are framed. Scoping analysis and identification of key attributes are critical to informing a valid and legitimate experimental design. To improve experimental design, a pilot study was conducted in the study area in September 2005. Prior to the pilot phase, a project workshop discussed the applicability of the methodology and questionnaire design

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13 Mopane Woodlands and Mopane Worms project (R7822, DFID FRP)

with local researchers with extensive knowledge of biological, social, economic, marketing and institutional issues. The pilot phase led to revisions and amendments which informed the final experimental design.

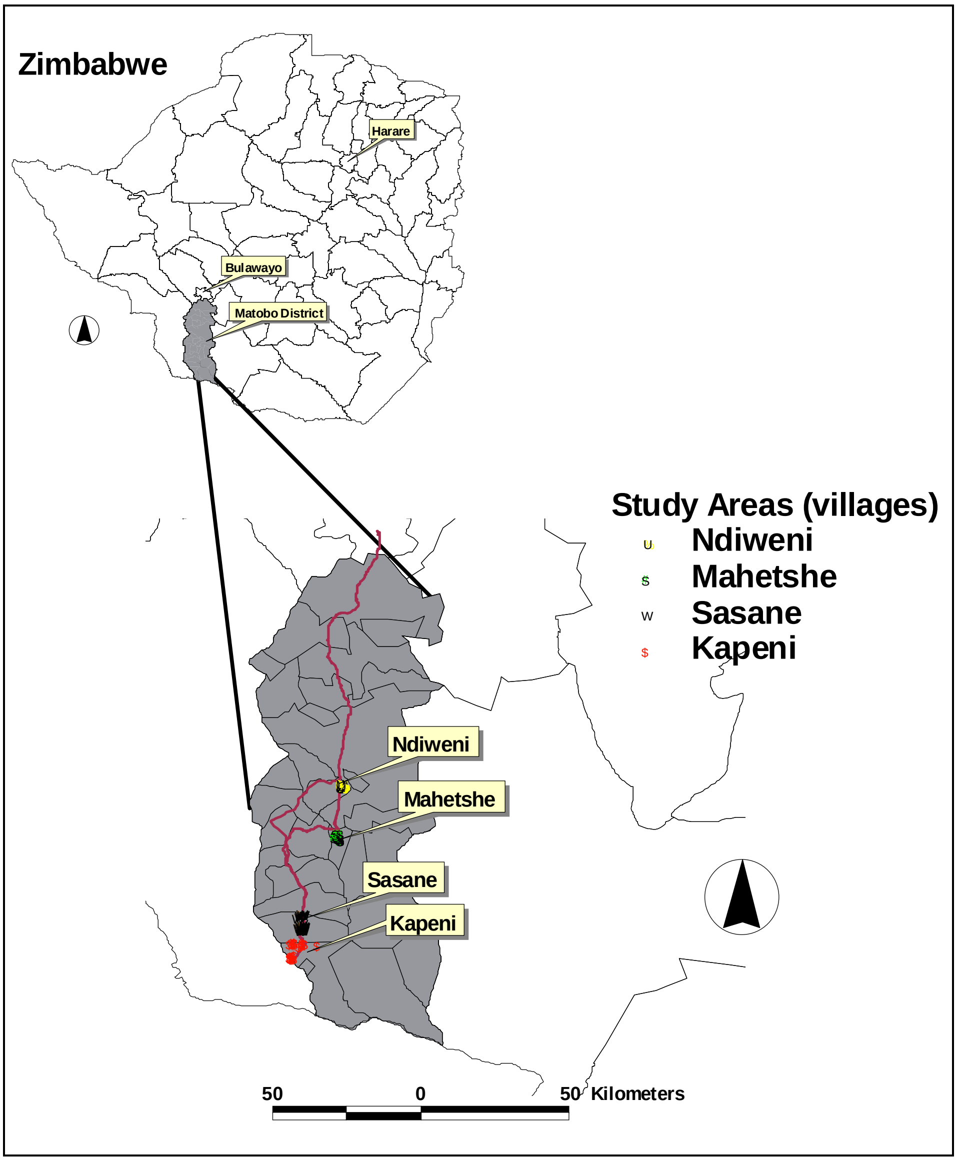
2.2 Questionnaire design

The design of the questionnaire aims to capture specific data related to current Mopane worm practices with particular interest in current harvesting practices and impacts of harvesting. The questionnaire has four sections: 1) household selection and data quality; 2) Mopane worm harvesting; 3) choice experiment; and, 4) household characteristics (Appendix 3).

2.3 Sampling frame and sampling strategy

The sampling frame was informed by existing research by the project in four villages in Matobo district (Figure 1). The sampling frame is not representative of the wider Mopane woodland area in Zimbabwe but is purposively determined by existing villages where the project team has worked. Sampling within villages was randomized with transect walks attempting to capture a systematic sample of households across the village area.

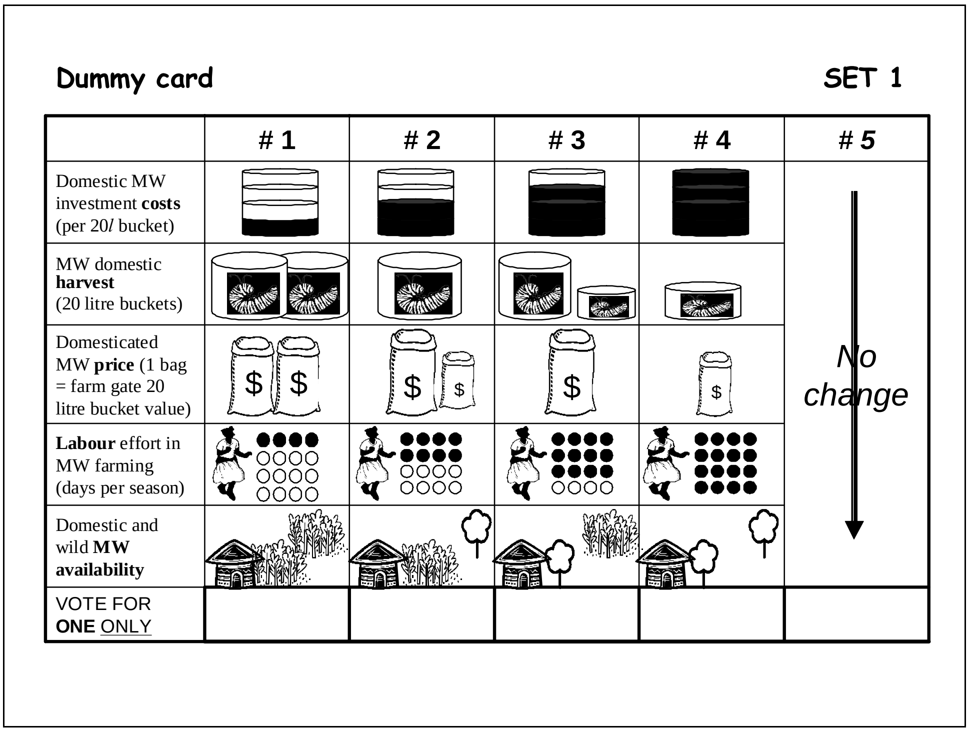
Figure 1. Location of study sites



2.4 Choice experiment design

Following the pilot phase, attributes and attribute levels were finalised (Appendix 4). A feature of the design was to have four standard choices for investment costs for a standard 20 litre bucket of dried Mopane worms. Choice 1 is equivalent to one quarter of the market price of a 20 litre bucket of dried Mopane worms, Choice 2 is equal to half the bucket price, Choice 3 is three quarters the bucket price, and Choice 4 equals the full bucket price. This approach was chosen for two particular reasons. First, devaluation and multiple currency exchanges make it difficult for local people to follow price changes over time. However, longitudinal price research conducted by the Institute for Environmental Studies estimate that real prices in US$ have remained broadly constant at US$4 per 20 litre bucket of dried Mopane worms for consumers. The investment cost illustration thus represents moving from lower (US$0.50) to higher (US$4) cash investments (Figure 2). This reduces cognitive complexity and provides a 'signpost' from which respondents could vote on the various choice cards generated. Second, analysis is improved by using comparable units.

Figure 2. Dummy card for choice experiment



Attribute levels for domestic Mopane worm harvest were difficult to determine due to harvest variability influenced by size of tree, number of trees and a natural variability in outbreaks even under semi-domesticated conditions. Two buckets was considered an upper harvest limit but field trials are likely to be the only accurate method to estimate domestic harvest levels and factors in practice. Harvest price was depicted in grain sacks (e.g. ½, 1, 1½, 2), with a full sack equivalent to the value for a 20 litre bucket of dried Mopane worms. Price levels are estimated at US$2, US$4, US$6 and US$8[14].

Labour effort in farming is illustrated by a 16 pin die with the image of a woman. No firm understanding is established of the additional effort required in farming Mopane worms and scenarios of 4, 8, 12 and 16 days reflect the best guess of the team based on field experience. Harvest scenarios are depicted by a hut, leafy tree and bare tree. The hut represents the homestead. The tree closest to the homestead represents the domestic harvest (good=leaves; poor=bare) and the distant tree the wild harvest. All four permutations are included in the design. Finally, a status quo choice is included in all of the choice cards as a fifth option (or 'no vote' clause). The status quo option is an important design component as respondents must always be given the opportunity to opt out or reject the scenarios presented.

The attribute levels result in a 4^5 factorial design. Running a mains effects orthogonal design function in SPPS (version 11.5) resulted in a 16 card design. It was decided that respondents were able to answer up to 8 choice cards each. To test each choice card, 2 questionnaire sets are designed, e.g. 8 cards per respondent

14 There is evidence that producers can share in a greater proportion of the final consumer price through a range of storage, marketing and management approaches (Stack et al., 2003)

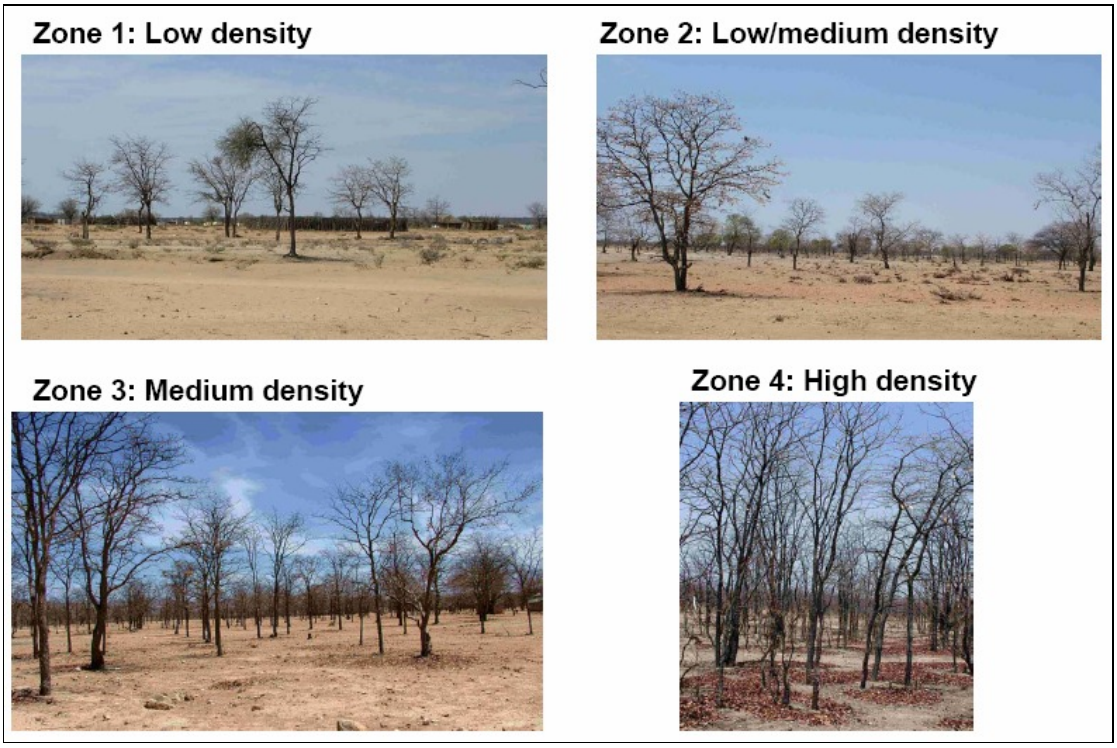
with 2 sets equal to 16 cards. The 16 cards are shown systematically in the first choice of each. Choices from each of the 16 cards are placed systematically in the first column (choice 1 of 5) starting with 25% investment of one bucket. For example, for Set 1/Card 1, choices from card 1 are placed in the 25% column; in Set 1/Card 2, choices from card 2 are placed in the 25% investment column, until Set 1/Card 8 is complete. Then choices from card 9 are placed in the 25% investment column in Set 2/Card 1; this continues until choices for the 16th card is placed in the 25% investment column of Set 2/Card 8. A random rotation allocates cards to columns 2, 3 and 4 with no duplication. All 16 cards are thus tested with no repetition.

2.5 Study location
Four villages were purposively selected. They are located in the main woodland zone in Matobo district. The sample is not necessarily representative of Mopane woodlands or the rural population, but is characterised by isolation from major conurbations and low levels of development by infrastructure, resource, asset or income measures (see below).

2.6 Mopane woodland zones

Mopane woodland density is likely to influence the opportunity for and interest in domestic farming. To account for changing density between and within communities, four Mopane woodland zones were identified: low, low/medium, medium and high (Figure 3). Enumerators classified each household aided by a pictorial reference sheet.

Figure 3. Mopane woodland zones



3. Results
The questionnaire was administered in December 2005 to 30 households in each of the four study villages. Enumerators included both native Ndebele (dominant local language) and Shona speakers (dominant outside southern Matabeleland). Other languages (e.g. Kalanga) are found in this area along with occasional immigrants from neighbouring countries. The questionnaire was administered from an English language version and the team of three male enumerators did not report difficulties in respondent comprehension in post-interview data reviews. Respondents took on average 46 minutes (standard error (se) 1.44 minutes) to complete the questionnaire with a range of 25 to 75 minutes. All respondents confirmed that they individually and their household collected Mopane worms in the introductory section. Enumerators ranked

respondents at the end of the questionnaire on a capability scale with 82% classified as 'cooperative and capable', 16% as 'cooperative but not capable' and 2% as 'reluctant'15.

The majority of respondents were women (81%)16 with a sample average age of 45 years (se 1.85 years, range 15 to 85 years)17. A skewed profile of female respondents is expected for social and economic reasons, however the sample ratio of 24 men to 100 women is far lower than expected. In earlier project studies, a 63:100 male-female ratio was estimated for Mopane worm collection. In a 1992 Limpopo basin census, the gender ratio for an area that corresponds to the study sites was 80:100 (P. Frost, personal communication). Modelling choice profiles from a naïve sample will result in biased estimates and is adjusted by weights that correspond to the range indicated above. In some models, a intermediate ratio of 75:100 is used when multiple weights are inappropriate. From a policy and historical perspective, migration in out of rural villages is an enduring feature of African livelihoods and socio-political change. Providing a range of weights offers a level of sensitivity analysis for decision-makers to gauge how people may behave given different and changing gender compositions in villages.

3.1 Exploratory data analysis

3.1.1Household composition and assets

Two language groups are dominant in the study villages: Ndebele (55%) and Kalanga (41%) (Table 1). Languages tend to dominate by village. For example, Ndiweni and Mahetshe are mainly populated by Ndebele speakers (83% and 80% respectively) while Sasane and Kapeni have larger numbers of Kalanga speakers (80% and 60% respectively).

Dwelling condition classification indicate that almost one in two of respondents' homes rank as 'good' (48%) as characterised by a brick house with a tin roof. A third of homes were rated as 'average' with either a mud structure or a tin roof. The remaining 19% were classified as 'poor', which is described here as a mud hut and thatched roof. Decomposing dwelling codes by village indicates that Sasane and Kapeni have more 'good' dwellings (50% and 63% respectively) while Ndiweni and Mahetshe have more 'average' houses (40% and 43% respectively). No village-language pattern emerges for 'poor' dwellings as 23% of houses in Mahetshe and Sasane are identified as poor compared to 17% and 13% in Ndiweni and Kapeni, respectively.

Sanitation access is mainly through Blair toilets18 (66%) with 31% of households citing an 'open field'. Ndiweni has the highest level of access to Blair toilets (83%) with Mahetshe households having the lowest level of improved sanitation access (40% cite 'open field').

Community boreholes, river water and springs are the main points of access to drinking water in both the dry and wet season. In the dry season, 50% of households identify community boreholes as the main drinking water source with 27% of households using river water and 13% of households using spring water. In the wet season, river water use increases to 32% of households and community borehole use falls to 45% of households and spring water use falling to 12% of households. Most households (73%) are further than 500 metres to their main drinking water supply in the dry season. This falls to 68% of households in the wet season.

Village decomposition reveals different levels of drinking water access within and between villages. Sasane is entirely reliant on community groundwater in the dry season with limited (<10%) access to other sources in the wet season. Ndiweni households mainly depend on river or spring water throughout the year. In Mahetshe, access is distributed across various sources throughout the year with community borehole and river water being prominent. Kapeni illustrates a shift in the majority of households changing from community borehole use in the dry season to river water use in the wet season. Self-reported household incidence of diarrhoea19 in the last 30 days indicates 5% of households had one person over 5 years who had suffered diarrhoea in the last 30 days compared to 2% of households with one child under 5 years and 1% with two children under 5 years.

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15 'Busy' and 'other' categories were not marked.
16 This female bias is likely explained by male migration within and outside Zimbabwe in search of work due to high unemployment compounded by a sequence of poor rainfall years.
17 Respondent age varied by village: Ndiweni – 45.43 (3.75); Mahetshe – 48.83 (4.02); Sasane – 44.97 (3.55); Kapeni – 38.87 (1.82). Mean (standard error).
18 Named after the inventor and characterised by a chimney window that traps flies.
19 Incidence of diarrhoea is a common indicator of household welfare though no causality is inferred between the general poor level of drinking water access and people reporting diarrhoea.

Socio-demographic household profiles indicate a average household size of just under seven people per dwelling (Table 2). There tend to be more adults (here, over 16 years) in Ndiweni and Mahestshe (3.50 adults per household each) and more school-age children (5-16 years) in Sasane and Kapeni (2.90 and 2.97, respectively).

Roughly one in two adults has primary education or less across the sample. Mahetshe households report lower education attainment (58% of adults with primary or less) and Ndiweni villagers achieve slightly higher standards (45% of adults with primary or less, i.e. 55% with secondary or higher). Almost one in seven household members over 5 years usually collect Mopane Worms. Kapeni report a higher proportion (0.73) and Ndiweni a lower proportion (0.65) to the sample average.

There is no electricity access in any of the four villages and minimal access to a landline telephone (Table 3). Less than 5% of households have a television or water pump though radios are owned by roughly a quarter of households in Mahetshe and Sasane with Ndiweni (47%) and Kapeni (63%) recording more households with a radio. Over one in two households report owning a bicycle with Ndiweni reporting the lowest level of ownership (40%) and Kapeni the highest rate (80%). Carts are reasonably common with one in three households in Ndiweni and Mahetshe owning one and over one in two households in Kapeni with a cart. Solar panels (for cooking) are more common in Ndiweni (23%) and Kapeni (20%) than the other two villages. On average households own just under seven goats though there is variation between and within village households. Cattle are less common with average stocking rates above two head except Sasane which has an average of one cattle per household. Pigs are not generally kept except for Sasane[20].

3.1.2 Mopane woodland access and Mopane worm harvesting

As noted, four MW zones were identified to permit each household to be classified in terms of the distribution of Mopane trees in their immediate surroundings. Ndiweni and Mahetshe are characterised as a low or low-medium Mopane tree zones in comparison to the medium or high zoning for Sasane or Kapeni (Table 4). This zoning is reflected by the harvesting preferences and behaviour of households (Table 5). Respondents from Sasane and Kapeni tend to harvest more commonly from their homestead (70% and 63% respectively) and rate this site as their second best (37%). This contrasts to Ndiweni and Mahetshe where homestead collection preference is lower (37% and 47% respectively) and the homestead is rated as a less favoured harvesting site (3% and 17% respectively).

Crop fields are usually harvested by roughly a third of households across the sample though it rates as the third best site. Grazing areas are the most popular site for Sasane and Kapeni households (50% each) with over two thirds of households usually harvesting there. Grazing areas are less commonly harvested by households from Ndiweni (23%) and Mahetshe (37%) though it is the second best site for both villages (10% and 27% respectively). State forest is more commonly harvested by households from Ndiweni and Mahetshe (77% and 40% respectively), which reflects its rating as the best harvesting site by both villages (70% and 33% respectively).

Distance to the main harvest site is on average less than 5 km (Table 6). Two modal values are reported of 4 km and 5 km (n=14, each) with 75% of the sample reporting travelling less than 5 km. Consistent with village zoning data, households in Ndiweni and Mahetshe report travelling an average of 6 km to their main harvest site in comparison to under 4 km for harvesters from Sasane and Kapeni. Estimates for the average time collecting worms indicate a mean value of over 6 ½ hours collecting on an average harvesting day with 76% of the sample spending 8 hours collecting. Most households spend 5 hours collecting (mode) with the median value being 6 hours. Village estimates broadly reflect the sample averages except for Ndiweni which has a higher mean collection time of just under over 6 hours collecting per average household. People tend to harvest individually (78%) then as a household unit (22%).

In a good year[21], household harvest estimates (20 litre buckets of dried worms) are an average of 8 buckets per household (se = 0.49). Median and modal values are equivalent at 6 buckets. Ndiweni households report higher average harvests with a value of almost 9 buckets per household. Households from the other three villages report harvests slightly lower than the sample average. In a bad year, all villages report are harvest of just over two buckets of dried worms. The sample median value is two buckets with a modal value of one bucket.

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20 Donkeys are relatively common in the area for traction use but this information was unintentionally omitted from the final questionnaire.

21 While labelling years as ‘good’ and ‘bad’ is highly subjective, it permits some level of comparative assessment given limited other available data.

Mopane woodland management is considered to be fair with no need for change22. Eight in ten respondents agreed with the statement that Mopane woodlands are well-managed with fair access by all community households. Only a minority of respondents considered that non-local people take an unfair share of the Mopane Worms (6%). Less than one in ten people agreed with the statement that woodlands are poorly managed with destructive harvesting practices, which result in loss of woodlands and reduced harvests. In terms of alternative woodland management scenarios, there is little support for either community management (8% in favour) or joint government-community management (8% in favour) of the woodlands.

3.1.3 Harvest allocation

Harvest allocation across good and bad years is explored under four general headings: a) sell the harvest immediately, b) use as a household food source, c) store for off-season sale, and d) other (Table 7). In a good year, households on average sell 40% of the worms immediately. Households in Kapeni and Ndiweni sell slightly more (52% and 45% respectively) while households in Mahetshe and Sasane sell slightly less (31% and 30% respectively). These latter villages use around a quarter of the harvest as a food source while Ndiweni and Kapeni report using 17% or 14% of the harvest for household food. Households across all four villages report storing at least a quarter of the harvest for later sale. Other uses represent generally less than 10% of the harvest.

In a bad year, household priorities for harvest allocation decisions change. In general, households use a higher proportion of the harvest as a food source resulting in proportional reductions in worms sold or stored or available for other uses. Mahetshe and Sasane report using over half the smaller harvest for household food in a bad year compared to a quarter allocation in a good year. Only households in Ndiweni continue to sell a similar proportion of the MW harvest reflected by a lower increased allocation of the harvest to household food needs (from 17% to 33%). Across the sample, the proportion of the MW harvest allocated to household food increases by 28% (from 19% to 47%) in a bad year. This results in a proportional fall of 7% in immediate MW sales, a 12% fall in MWs stored for off-season sale and a 10% fall in allocation to other uses compared to a good year. It is noteworthy that the median harvest difference between a good and bad year results in a small aggregate change in worms allocated to food across the sample23 with impacts largely felt through immediate lost income from immediate sales and future reduced income from premium prices through storage for off-season sale.

Selling points include are local centres (48%) or the homestead (44%). Only six households identified ‘urban centres’ as a secondary or tertiary selling point with one household citing ‘roadside’ selling.

3.1.4 Welfare impacts of Mopane worms

An attempt was made to capture the impact of Mopane worms on household welfare over time. A Likert scale of five importance ratings (much more to much less) asked respondents to estimate how Mopane worms as source of income or food had changed over the last five years (Table 8). Findings indicate that the sample is split between one group that views income as being ‘more’ important (31%) and another group that sees income as being ‘less’ important (42%). Decomposing the data by village reveals that at least a fifth of households from each village consider income to be ‘more’ important with 4 in 10 respondents from Ndiweni reporting income as ‘more’ important than five years ago. In contrast, a third of households from Ndiweni and Sasane and half of the respondents from Mahetshe and Kapeni consider MW income as being ‘less’ important.

The majority of the sample (51%) consider that MW harvest has the ‘same’ importance as source of household food during the last five years with over one quarter recording MW income as being ‘more’ important. At least three in ten households in each village consider MW as a food source as being ‘more’ or ‘much more’ important. Mahetshe households rate the food importance of MW lower than the other three villages with one in five households choosing the ‘less’ important category.

Coping strategies in bad harvest years are estimated from four scenarios: a) not pay school fees, b) sell more livestock, c) borrow money, or d) rely on family support. Findings indicate that households are more likely not to pay school fees (44%) closely followed by the other three categories (Table 9). Across the villages, Ndiweni households seem more likely to rely on family support in contrast to Sasane where the majority of respondents appear likely not to pay school fees or sell more livestock. Over one in two households from

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22 No data table is given for this information.

23 Median harvest values for a good year (6 buckets) and bad year (2 buckets) are multiplied by proportional allocation to food in a good year (0.19) and bad year (0.47) to result in a net loss of MW food allocation of 0.20 buckets in a bad year.

Kapeni indicate they would borrow money in contrast to Mahetshe were less than one in five households would pursue this strategy.

3.2 Choice experiment

Cross-tabulation of voting choices against model predictions confirm that respondents prefer lower investment costs to higher costs (Table 10). Voting preferences are skewed to the first two choices (69% of actual votes cast). Just under one quarter of responses (24%) were allocated to the third choice with less than four percent of votes for the fourth option. Less than 3% of sampled responses (n=25) chose the fifth choice of a status quo option (no change).

3.2.1 Multinomial logit models

The multinomial logit (MNL) model is specified in Table 11. Three models are presented: a) unweighted, b) weight 1 (63:100 male-female ratio), and c) weight 2 (80:100 male-female ratio). Comparison of the log likelihood function for the unweighted and weighted models highlights how the model fit is improved after applying weights24. A number of model estimates vary subject to weighting, which affects interpretation and decision-making. As mentioned, a third weight (75:100 male-female ratio) is also (later) used as an intermediate weight to overcome modelling complexity. Testing the MNL for Independence from Irrelevant Alternatives (IIA) suggests exploring less restricted model specifications (see latent class model below). The failure to pass this test suggests that more complex modelling is justified to explore preference heterogeneity not revealed by an aggregate specification.

In the weighted models, all attributes are significant at the 1% level with expected signs – positive for harvest and price attributes and negative for cost and labour attributes. There is a close agreement between coefficient estimates in the two weighted models. Investment cost results in a higher level of disutility with a higher male ratio (0.02) but a lower level of utility for harvest level (0.01). Price and labour estimates match and there is broad agreement in harvest scenario estimates. Where there is a difference this provides a useful range to reflect changing gender composition of harvesters influenced by economic migration cycles.

A useful approach to interpret the coefficient estimates is to consider the marginal rate of substitution between specific attributes. This involves identifying relationships of interest and then simply dividing one attribute by another. For example, the difference in disutility (negative value) attached to investing cash in farming can be compared with the utility estimate for labour required for farming. A unit of investment cost (-0.50) has a level of disutility five times greater than a unit of labour time (-0.09). This implies that across the models the disutility associated with a day's labour farming is US$0.17-0.18 (-0.09/-0.50 and -0.09/-0.52). If the local market value of a bucket of worms is equivalent to US$2 then this would be equivalent to 11-12 days effort farming25.

Comparing the value of cash investment in farming to the value of a bucket of farmed worms indicates a range of US$0.71-0.76 per bucket. If we consider an arbitrary US$2 locally-price bucket, this is equivalent to one third of the cash value. This fits well with a comparison of the value of the price of a farmed bucket to the value of cash investment (0.31-0.32). This indicates that an investment of one third of the cash value is plausible based on US$2 bucket though local prices and people's ability to invest may vary significantly.

Harvesting scenarios suggest two relationships are of particular interest for domestic farming: a) the impact of a good domestic harvest to a poor domestic harvest when the wild harvest remains good (GDGW vs. PDGW) and b) the impact of a good domestic harvest to a poor domestic harvest when the wild harvest remains poor (GDPW vs. PDPW)26. Results indicate that respondents gain 2.3 times more value (utility) from the first scenario compared to 1.9 times more value in the second scenario27. This is somewhat counter-intuitive as it may be expected that when the wild harvest fails is the time when a domestic back-up would be most valued. Nevertheless, the results demonstrate that there are likely to welfare benefits from domestic farming innovations irrespective of the wild harvest condition.

Woodland zoning allows an understanding of how farming preferences may vary by Mopane tree access. The four zones were simplified into two composite groups described here as low (low and low/medium) and

24 Log likelihood function reduced by 595 and 618 points by applying weight 1 and weight 2, respectively.

25 The sale value at the homestead may be lower/higher resulting in a lower/higher number of equivalent labour days.

26 The latter is the scenario that largely informs the rationale for domestic MW innovations as a means of cushioning social impacts of a failed wild harvest.

27 Rounding across the estimates of scenario 1 (2.29 and 2.28) and scenario 2 (1.95 and 1.93) for weights 1 and 2, respectively.

high (medium and high) (Table 12). The low group are estimated to value a labour day farming at US$0.14-0.15. This compares with an estimate of US$0.2428 per labour farming day for the high group. This difference is influenced by the low group having a lower willingness to invest in domestic farming and lower level of disutility with labour investment than the high group. While valuing labour differently for domestic farming is expected given the different levels of woodland access, the difference in willingness to invest in farming is likely to be influenced by other socio-economic variables.

Estimates for willingness to invest per bucket indicate overlapping values for the groups of US$0.70-0.71 per bucket (high) and US$0.71-0.77 per bucket (low). The relationship between cash investment to bucket price indicates that the low group are less likely to invest per domestic bucket unit (0.28) compared to the high group (0.36-0.37). Harvesting scenarios are only reported for the low group as estimates for the high group are not significant. Respondents in the low group are estimated to be gain 3.18-3.24 times more value from domestic farming when the wild harvest remains good and 2.53-2.54 times more value when the wild harvest fails. The results for the high group are not significant.

Age of respondent is explored with a cut-off age set at 40 years to reflect the median age of respondents (Table 13)29. Younger respondents value their time more highly. Estimated willingness to invest per unit of labour is US$0.24 for respondents under 40 years and US$0.15 for the older group. Older respondents are willing to invest US$0.75 per bucket. This is higher than the younger group, though their estimated willingness to invest of US$0.68 is not significant. Younger people want more value per unit investment, which is consistent with valuing their time more highly. Estimated willingness to invest per unit harvest price is 0.22 for the over 40s and 0.47 for the under 40s. Finally, harvest scenario indicate that older respondents gain higher levels of value from domestic farming both with a good wild harvest (2.77 and 1.84) and when the wild harvest fails (2.02 compared to 1.79).

3.2.2 Direct elasticities

Measuring direct elasticities of attributes is a way of estimating responsiveness to farming system scenarios. Data are presented for investment cost and labour effort across the four choice scenarios which each reflect a cash investment increment of US$1 per choice (Table 14). Results for investment cost elasticity reveal that for a one percent increase in an investment cost of US$1 will result in a 0.23 percent decrease in the overall probability of participating in domestic farming. It is estimated that participation probabilities will decrease by 0.44 percent for a US$2 investment, 0.93 percent for a US$3 investment and 1.85 percent for a US$4 investment for an equivalent one percent increase in respective costs. This suggests investment scenarios of greater than US$2 are unlikely to be adopted.

Labour elasticities are also negative. They are equivalent to a 0.37, 0.35, 0.52 or 0.91 percentage decrease in the probability of participation for a one percent increase in each of the four choices. This suggests that respondents are less likely to participate if investment is in labour rather than cash investments for a US$1 investment though this likelihood is then inverted for investments of US$2 through to US$4 when participants are more likely to prefer substituting labour for cash.

3.2.3 Latent class specification

Latent class specifications overcome a limitation of understanding preference heterogeneity in the MNL model by assuming there are hidden classes in the population which can be revealed by assigning individuals simultaneously to classes and inferring welfare estimates. This approach is more exploratory than the MNL model as the analyst governs model design parameters. The analyst aims to uncover classes that are both helpful and hidden in the aggregate MNL model or purposive decomposition, e.g. zone or age. One specification did reveal two groups of interest and results are presented in table 15. Estimated probabilities of class membership are significant for both classes at the 1% level though not all attributes are significant. Respondents are more likely to belong to Class 1 (68% probability of membership) then Class 2 (32% probability of membership).

There are three key findings. First, Class 2 respondents report the highest level of resistant to invest cash in farming; a value almost three times than Class 1 respondents. Second, Class 1 respondents are the only group that report a higher coefficient for harvest than investment cost. This results in the only estimate greater than US$1 in terms of willingness to invest per bucket (1.27). Third, Class 2 respondents are 2.9 more likely to gain a welfare benefit from domestic farming when a wild harvest fails; again, a value higher than any other group so far. This suggest Class 2 respondents would value farming innovations but cash is a

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28 Estimates are equivalent at US$0.24 per day although derivative coefficients differ.
29 Data here is weighted by a 75:100 male-female ratio to avoid lengthy number reporting.

significant constraint that makes them either unwilling or unable to invest. Alternatively, Class 1 respondents have a preference profile suited for farming adoption but welfare benefits appear less uncertain.

An attempt is made to better understand which respondents fall into either class. For Class 1 respondents, the estimated willingness to invest per labour day is equivalent to US$0.24 per day, which is higher than the aggregate for the sample (0.17), the low zone (0.14) and older respondents (0.15) (Table 16). The estimate for Class 2 respondents is lower at US$0.08 per day but is not significant. The Class 1 estimate for willingness to invest per unit bucket of domestic worms is US$1.27, higher than all other estimates. The estimate for Class 2 respondents is not significant (0.14). The marginal rate of substitution between harvest price and investment cost is 0.68 for Class 1; this is lower than all groups but the under 40s. The Class 2 estimate is not significant (0.22). Only the harvest scenario for the value of a domestic harvest with the wild harvest remaining poor is significant across the four alternatives; this estimate is 2.90 for Class 2. These findings suggest that Class 1 respondents are more likely to be found amongst people under 40 years of age living in medium or high Mopane woodland zones and Class 2 respondents are characterized by older people living in low or low/medium zones.

Based on this interpretation, a simple example illustrates management guidelines for targeting older people in the low zone or a younger group in the high zone based on a local effective price of US$2 per bucket. It is estimated that the old-low group will be willing to invest roughly 25% in cash and the remainder would be paid for in labour; this would equate to a US$0.50 cash investment and 10 days in farm labour per harvested bucket. Alternatively, taking mid-point values for the young-high group, this would equate with US$0.80 cash investment and 5 farm labour days. These estimates provide some basic guidelines for design and targeting purposes but will require modification subject to wider biological, social and economic considerations.

4. Conclusion

This report has explored social preferences to adopt Mopane worm farming innovations in the rural woodlands of southern Zimbabwe. The choice experiment method has provided insights into which incentives, and levels of incentives, are likely to influence the decisions of different groups of people to try out domestic farming of Mopane worms in or around the homestead. It has also attempted to gauge who is likely to gain welfare benefits from domestic production across different Mopane worm harvesting scenarios. Results suggest if farming innovations can deliver a reliable and healthy stock of Mopane worms of sufficient quantity on Mopane trees that people can effectively manage there are likely to be welfare gains from semi-domesticated Mopane worm farming. Findings present exploratory evaluation of who is more likely to benefit and what is more likely to make people willing to participate.

Who is most likely to participate and benefit is partly answered by the findings from harvest scenario analysis. Older people and people living in low and low/medium Mopane woodland zones are found to be more likely to benefit from domestic farming in both good and poor wild harvest years. This contrasts with no significant estimates for the medium/high density zone and estimates lower than the aggregate model for the young group. The older group and people in the low zones appear better able to participate in terms of their lower investment cost per average labour day both against the aggregate (US$0.17 per day) and within their respective groups. This highlights the results of the elasticity estimates which suggest labour should be substituted where possible for cash investments in any domestic farming system design above a US$1 investment. That might mean sewing netting for the trees or making pupae hibernation boxes but will contribute to higher participation than a cash only alternative.

However, results do indicate that younger people and people in higher density woodland zones are willing to invest more cash in relation to harvest price (0.47 for the young, 0.36 for the high zone). In comparison, the older and low zone groups are only willing to invest 0.22 or 0.28 per each US$1 realised in harvest price. Trade-offs between labour and investment cost is likely to be a central feature of farming uptake by social groups. As illustrated, different people are likely to participate with different levels of cash and labour depending on the density of Mopane woodland. While older people in less dense woodlands appear most likely to value the intervention, it is important to know what ecological parameters are required for farming to be successful in less wooded areas. Younger people in denser woodland zones will invest more cash but are likely to allocate a less labour effort. The combination and importance of interactions between woodland density, people’s willingness to participate cheaply or people’s willingness to invest cash on domestic harvest levels is key to determining feasible and desired farming systems.

This analysis has explored social preferences which are influenced by how scenarios are framed. Given scenarios are valid, results suggest cautious optimism in terms of welfare benefits from domestic farming innovations. Guidelines are proposed for which specific groups will be willing to participate, and what incentives and inputs will be required for implementation. Integrated initiatives to optimise domestic harvest levels and increase harvest prices for producers are considered important to increasing social benefits and widening adoption of Mopane worm farming innovations for rural development goals. These findings must be set in the context of the harsh socio-economic conditions in these study villages where assets are minimal and basic housing, healthcare, education, drinking water access provision are low. People are understandably willing to try anything that makes a difference; domestic worm farming appears one of few practical interventions that may make help some rural people get by a little better in difficult times.

Table 1. Descriptive household characteristics

		Sample villages				Full sample (n=120)
		Ndiweni (n=30)	Mahetshe (n=30)	Sasane (n=30)	Kapeni (n=30)	
Main language (%)	Ndebele	83	80	17	40	55
	Kalanga	13	10	80	60	41
	Other/missing	3	10	3	0	4
Dwelling condition (%)	Good	43	33	50	63	48
	Average	40	43	27	23	33
	Poor	17	23	23	13	19
Sanitation access (%)	Blair toilet	83	60	63	57	66
	Open field	10	40	37	37	31
	Other	7	0	0	7	3
Drinking water access (%)						
Dry season (wet season)	River	37 (33)	27 (33)	0 (3)	43 (57)	27 (32)
	Spring	43 (43)	7 (3)	0 (0)	0 (0)	13 (12)
	Community borehole	10 (13)	40 (37)	100 (93)	50 (37)	50 (45)
	Private borehole	10 (10)	17 (7)	0 (0)	3 (0)	8 (4)
	>500 metres	67 (67)	77 (70)	73 (70)	73 (70)	73 (68)
Diarrhoea in last 30 days (% of households)	Under 5 years	0	10	0	0	2.5
	Over 5 years	10	3	3	3	5

Table 2. Socio-demographic characteristics

	Ndiweni	Mahetshe	Sasane	Kapeni	Full sample
Total household members	6.67 (0.50)	6.87 (0.58)	6.47 (0.46)	6.50 (0.39)	6.63 (0.24)
Household members > 16 years	3.50 (0.36)	3.50 (0.35)	2.93 (0.24)	2.93 (0.28)	3.22 (0.16)
Household members 5-16 years	2.30 (0.29)	2.27 (0.28)	2.90 (0.26)	2.97 (0.28)	2.61 (0.14)
Proportion of members over 16 years with primary education or less	0.45 (0.05)	0.58 (0.05)	0.53 (0.06)	0.50 (0.06)	0.51 (0.03)
Proportion of household over 5 years who usually harvest MWs	0.65 (0.04)	0.67 (0.05)	0.68 (0.04)	0.73 (0.04)	0.68 (0.02)

Mean (standard error)

Table 3. Household assets: Mean (standard error)

	Ndiweni	Mahetshe	Sasane	Kapeni	Full sample
Electricity (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Radio (%)	47 (0.09)	23 (0.08)	23 (0.08)	63 (0.09)	39(0.05)
Television (%)	10 (0.06)	7 (0.05)	0 (0)	0 (0)	4(0.02)
Landline telephone (%)	3 (0.03)	0 (0)	0 (0)	0 (0)	1 (0.01)
Water pump (%)	3 (0.03)	3 (0.03)	3 (0.03)	0 (0)	3 (0.01)
Bicycle (%)	40 (0.09)	47 (0.09)	63 (0.09)	80 (0.07)	57 (0.05)
Cart (%)	33 (0.09)	33 (0.09)	47 (0.09)	57 (0.09)	43 (0.05)
Solar panel (%)	23 (0.08)	10 (0.06)	7 (0.05)	20 (0.07)	15 (0.03)
Cattle	2.57 (0.89)	2.83 (0.86)	1.07 (0.36)	2.67 (0.73)	2.29 (0.37)
Goats	5.97 (0.85)	6.93 (1.67)	7.48 (0.99)	7.33 (1.11)	6.92 (0.60)
Pigs	0 (0)	0 (0)	0.38 (0.35)	0.03 (0.03)	0.10 (0.09)

Table 4. Mopane woodland zones

		Ndiweni	Mahetshe	Sasane	Kapeni	Full sample[a]
Mopane woodland zone (%)	Low	90	60	20	20	48
	Low-medium	10	13	10	13	12
	Medium	0	13	30	20	16
	High	0	13	40	47	25

[a] rounding error.

Table 5. Harvest site preferences

		Ndiweni	Mahetshe	Sasane	Kapeni	Full sample
Usual MW harvest sites (%)	Homestead	37	47	70	63	54
	Crop fields	33	30	27	37	32
	Grazing areas	23	37	67	70	49
	State forest	77	40	7	7	33
	Other	37	7	3	0	12
Best MW harvest sites (%)	Homestead	3	17	37	37	23
	Crop fields	7	17	13	13	13
	Grazing areas	10	27	50	50	34
	State forest	70	33	0	0	26
	Other	10	7	0	0	4

Table 6. Location, collection and harvest

		Ndiweni	Mahetshe	Sasane	Kapeni	Full sample
Distance to main MW collection area (km)[1]		6.00 (0.99)	6.00 (1.27)	3.32 (0.74)	3.51 (1.00)	4.70 (0.51)
Collection time on an average day (minutes)		493 (25.34)	377 (25.07)	333 (26.90)	382 (28.55)	396 (14.20)
Harvest of dried MWs (20 litre bucket)	Good year[2]	8.98 (1.19)	7.51 (0.90)	7.78 (0.92)	7.98 (0.86)	8.07 (0.49)
	Bad year[3]	2.03 (0.35)	2.34 (0.33)	2.20 (0.27)	2.04 (0.20)	2.15 (0.14)

mean (standard error). [1] Outliers > 30 km are excluded (n=117); [2] Outliers > 25 buckets are exclude (n= 119); [3] Outliers > 6 buckets are excluded (n= 116).

Table 7. Harvest allocation

		Ndiweni	Mahetshe	Sasane	Kapeni	Full sample
Good year[1]	Sell immediately	0.45 (0.06)	0.31 (0.05)	0.30 (0.04)	0.52 (0.06)	0.40 (0.03)
	Food source	0.17 (0.03)	0.23 (0.03)	0.25 (0.05)	0.14 (0.01)	0.19 (0.02)
	Store for off-season sale	0.29 (0.06)	0.32 (0.06)	0.36 (0.06)	0.25 (0.06)	0.31 (0.03)
	Other	0.09 (0.03)	0.14 (0.04)	0.09 (0.04)	0.09 (0.03)	0.10 (0.02)
Bad year[2]	Sell immediately	0.44 (0.08)	0.24 (0.06)	0.28 (0.06)	0.39 (0.07)	0.33 (0.04)
	Food source	0.33 (0.07)	0.55 (0.07)	0.53 (0.07)	0.46 (0.07)	0.47 (0.04)
	Store for off-season sale	0.23 (0.08)	0.21 (0.06)	0.18 (0.06)	0.14 (0.05)	0.19 (0.03)
	Other[3]	0	0	0	0.01 (0.01)	0

Note: mean (standard error). * 20 litre buckets of dried MWs; [1] outliers > 25 buckets are exclude (n= 119); [2] outliers > 6 buckets are excluded (n= 116); [3] to two decimal places.

Table 8. Harvest importance

			Ndiweni	Mahetshe	Sasane	Kapeni	Full sample
Importance of MW harvest over last five years as source of household …	… income	Much more	3	13	7	3	7
		More	40	27	33	23	31
		Same	17	7	7	10	10
		Less	33	50	33	50	42
		Much less	3	3	10	13	8
	… food	Much more	23	3	3	10	10
		More	17	27	33	23	25
		Same	47	50	57	50	51
		Less	10	20	0	17	12
		Much less	3	0	0	0	1

Percent values.

Table 9. Coping strategies in a bad year

	Ndiweni	Mahetshe	Sasane	Kapeni	Full sample
Don't pay school fees[1]	37	39	55	43	44
Sell more livestock	40	30	53	40	41
Borrow money	37	17	43	57	38
Rely on family support	47	27	40	43	39

[1] households reporting children aged 5-16 years included (n=94). All households own some form of livestock or could pursue the other listed strategies (n=118). Figures are percent of total responses, more than one response was permitted.

Table 10. Choice cross-tabulation

Choices	1	2	3	4	5	Actual
1	178	65	62	15	7	328
2	79	188	41	18	10	335
3	66	45	100	15	7	233
4	14	8	10	4	1	37
5	9	8	6	1	1	25
Predicted	346	314	219	53	25	958*

* two missing observations.

Table 11. Multinomial logit model

			Probability weighted[a]	
		Unweighted	Weight 1[b]	Weight 2[c]
Mopane worm domestication investment (US$)		-0.44**	-0.50**	-0.52**
Mopane worm domestic harvest (buckets)		0.39**	0.38**	0.37**
Mopane worm price (US$ per bucket)		0.14**	0.16**	0.16**
Labour investment in domestication (days)		-0.09**	-0.09**	-0.09**
Mopane worm harvest scenarios	Good domestic, good wild	4.45**	4.37**	4.36**
	Good domestic, poor wild	3.66**	3.66**	3.67**
	Poor domestic, good wild	1.93**	1.91**	1.91**
	Poor domestic, poor wild	1.86**	1.88**	1.90**
Model specifications				
Observations		958[d]	958	958
Log-likelihood function		-935.25	-340.66	-317.33

** significant at 1% or less.
[a] Probability weights estimated from w(*t,j*) = Estimated *P(t,j)*/$\sum_t$ Estimated *P(t,j)* where *t* indexes individual observations and *j* indexes alternatives. Here, no difference is found between the Pwt estimates and naïve estimates. [b] Weight 1 is based on a 63:100 male-female population ratio. [c] Weight 2 is based on a 80:100 male-female population ratio. Weights attempt to correct for the 24:100 male-female sample (unweighted above) and are informed by earlier project studies in Zimbabwe and a 1992 Limpopo Basin census data that covered the southern rural Mopane woodland area (P. Frost, personal communication). [d] Independence of Irrelevant Alternatives (IIA) test is violated suggesting applying less restricted models (exclude choice=2, Chi squared (8) = 65.83, Prob [C > c] = 0.001).

Table 12. Preferences by woodland zone

		Low and low/medium^		Medium and high	
		Wt1	Wt2	Wt1	Wt2
Mopane worm domestication investment cost (US$)		-0.527**	-0.541**	-0.464**	-0.482**
Mopane worm domestic harvest (20 litre buckets)		0.405*	0.382*	0.325*	0.344*
Mopane worm price (US$ per bucket)		0.147**	0.153**	0.172**	0.174**
Labour investment in domestication (days)		-0.077**	-0.078**	-0.112**	-0.115**
Mopane worm harvest scenarios	Good domestic, good wild	3.761**	3.751**	34.403	34.434
	Good domestic, poor wild	3.025**	3.050**	33.717	33.742
	Poor domestic, good wild	1.160*	1.178*	32.083	32.110
	Poor domestic, poor wild	1.191*	1.204*	31.998	32.054
Model specifications					
Observations		566		392	
Log-likelihood function		-208.89	-196.06	-124.98	-114.77

** significant at 1% or less; * significant at 5% or less. ^ Mopane woodland zoning densities were determined by Dr. Alan Gardiner and were included as a pictorial reference sheet for the enumerators (see Figure 2). Wt1 is weight 1 and Wt2 is weight 2, as before.

Table 13. Preferences by age of respondent

		Under 40 years	Over 40 years
Mopane worm domestication investment cost (US$)		-0.47**	-0.55**
Mopane worm domestic harvest (20 litre buckets)		0.32	0.41*
Mopane worm price (US$ per bucket)		0.22**	0.12*
Labour investment in domestication (days)		-0.11**	-0.08**
Mopane worm harvest scenarios	Good domestic, good wild	4.82**	4.16**
	Good domestic, poor wild	4.36**	3.28**
	Poor domestic, good wild	2.62**	1.50**
	Poor domestic, poor wild	2.43**	1.62**
Model specifications			
Observations		448	512
Log-likelihood function		-134.30	-186.13

Probability weighted with 75:100 male: female ratio.

Table 14. Direct elasticities

	Choices			
	1	2	3	4
Investment cost in domestic MW farming (US$)	-0.23	-0.44	-0.93	-1.85
Labour in domestic MW farming (days)	-0.37	-0.35	-0.52	-0.91

Probability weighted and a 75:100 male: female weight applied.

Table 15. Latent class model

		Class 1	Class 2
Mopane worm domestication investment (US$)		-0.37**	-1.08**
Mopane worm domestic harvest (buckets)		0.47**	0.21
Mopane worm price (US$ per bucket)		0.25**	-0.15
Labour investment in domestication (days)		-0.09**	-0.09
Mopane worm harvest scenarios	Good domestic, good wild	33.56	5.01**
	Good domestic, poor wild	32.25	5.48**
	Poor domestic, good wild	31.33	-0.45
	Poor domestic, poor wild	30.77	1.89**
Estimated latent class probabilities		68%**	32%**
Model specification	Observations	960	
	Log likelihood	-311.48	

**significant at the 1% level or lower; *significant at the 5% level or lower. Weight 2 (63:100) is applied; no significant results were found for weight 3 (80:100).

Table 16. Marginal rates of substitution

		MNL	Low	High	Young	Old	Class 1	Class 2
Unit cost per farm labour day		0.17	0.14	0.24	0.24	0.15	0.24	NS
Unit investment cost per bucket		0.71-0.77	0.71-0.77	0.70-0.71	NS	0.75	1.27	NS
Unit investment per harvest price		0.31	0.28	0.36	0.47	0.22	0.68	NS
Domestic harvest gains	Good wild	2.3	3.2	NS	1.84	2.77	NS	Ns
	Poor wild	1.9	2.5	NS	1.79	2.02	Ns	2.9

Estimates are rounded and averaged. NS – not significant.

Contribution of Outputs

The most immediate output of this programme of research that directly benefits the mopane worm collector communities is the dissemination of information, though workshops, posters and manuals, on improved processing and handling methods that should reduce incidence of illness resulting from the consumption of poorly or unhygienically prepared mopane worms. The research has shown that dried mopane worms commonly consumed by people can harbour dangerous levels of bacteria and pathogens. The importance of washing hands before and after preparation of mopane worms, and proper drying and storage of the dried product has been emphasised to several collector communities in Botswana and Zimbabwe, and this information is likely to reach many more through the posters and manuals that have been widely distributed among collector communities in Zimbabwe.

New technologies for processing mopane worms have been developed and piloted, and some of these have proved successful in producing a better quality product. These require further development to reduce costs of production.

The second main tangible output and benefit is the development of mopane worm domestication units, at a large scale requiring the cooperation of several collectors, and the small household scale that can be managed by a single individual. Although uptake of domestication strategies remains uncertain owing to problems of disease control and initial start-up costs, wider promotion of these methods will likely stimulate local innovations that refine and adapt the methods developed by this project for local suitability. Our research has already demonstrated that individuals adopting the household scale domestication system adapt the system to match their own needs and resources. The potential for predictable supply of high quality mopane worms, a current constraint on their marketing, using domestication strategies is high. However, more research and development is needed to overcome remaining problems associated with disease particularly.

The project has made considerable progress in understanding the marketing web of mopane worms. This research shows that there are a number of market opportunities for enhancing the value of the mopane worm product by improving processing, packaging, labelling and possibly through value addition activities. Better packaging would also improve the shelf life of mopane worms thereby enabling traders and collectors to secure the higher prices consumers are willing to pay for out-of-season worms. Nevertheless it should be noted that enhancing value at one point in the marketing chain has impacts on subsequent links, and while the collector communities are among the poorest components in the chain, other traders and retailers are also poor and could be adversely affected by realising higher values early in the marketing chain.

Promotion pathways

The project has worked closely with SAFIRE that is disseminating the project results to the producer communities with which it works. As a local NGO working with Zimbabwean rural communities on issues of resource management and income generation through rural community enterprises, SAFIRE is ideally placed to utilise the outputs of the project.

Revision and refinement of the manuals that have already been produced are planned pending additional resources are made available. These manuals have proved highly successful with considerable interest expressed by members of all communities to which they have been disseminated. It is not yet clear whether the concepts and methods the manuals describe will be taken up by the local communities, but the discussion they have already engendered is expected to raise awareness of alternative strategies for producing and marketing mopane worms.

Scientific publications describing the technical outputs of the research are in preparation and will be published in due course. However, this is likely to be hampered in at least the short term by an unfavourable environment in Zimbabwe where most of the authors reside.

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