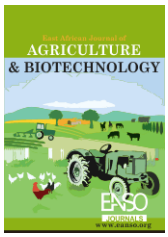

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Original Article

Promoting Ecosystem Conservation and Food Security through Sustainable Harvesting of Edible Caterpillars in Kanchibiya District, Zambia

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ABSTRACT

Insects play a vital role in enhancing food security and improving the livelihoods of rural communities. This study focused on the identification of caterpillar harvesting practices in Zambia, particularly in Chief Kopa's village, Kanchibiya District, Muchinga Province, where the caterpillars of Gynisa maja and Gonimbrasia belina play a crucial role in food security. A mixed-methods approach was employed, utilizing face-to-face interviews and self-administered questionnaires to capture both qualitative and quantitative insights. Quantitative data, including caterpillar harvesting amounts and correlations with tree destruction, underwent statistical analyses, including ANOVA and post-hoc Tukey's HSD tests. The Chi-square test explored gender distribution across research sites. Qualitative data from open-ended questions during interviews underwent thematic analysis. The study sampled 100 respondents from six areas, and the results revealed significant differences in caterpillar harvesting amounts among villages. Post-hoc tests identified specific pairwise differences. The findings indicated that traditional harvesting methods persisted, with limited adherence to rules. A significant positive correlation was observed between caterpillar harvesting practices and evolving trends such as increased harvesting intensity, changes in harvesting methods, and environmental impact and tree destruction ($p=0.001$, $r=0.917$). The study contributed valuable insights into past caterpillar harvesting practices, proposing conservation strategies for enhanced food security and sustainability. The study proposes a multifaceted approach to balance ecosystem conservation with food security in Kanhaiya District, emphasizing the importance of sustainable caterpillar harvesting. Recommendations include developing community-based sustainable harvesting guidelines, such as rotational zones and harvest limits, alongside education programs to raise ecological awareness. It advocates for diversifying livelihoods and food sources to lessen dependence on caterpillars, ensuring gender-inclusive participation in these initiatives. Monitoring and further research are essential to adapt strategies effectively. These measures aim to preserve the ecosystem, ensuring the caterpillar's role in food security and offering socioeconomic benefits by fostering community resilience and reducing food insecurity vulnerabilities.

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INTRODUCTION

Edible insects are a significant part of the diet for at least two billion people globally, with over 1900 species consumed for food and feed. Entomophagy, the practice of eating insects, has a long history and is especially prevalent in Africa, which boasts the richest diversity of edible insects, including caterpillars, termites, locusts, grasshoppers, crickets, ants, bees, bugs, and beetles (Ivanišová et al, 2022). These insects, often seasonal and dependent on host plants, are vital components of cultural diets. They offer high-quality protein, fats, vitamins, and minerals, are enjoyed for their taste by those familiar with them and have considerable economic benefits.

In regions where insect consumption is customary, gathering them from natural habitats like bushes, forests, and agricultural fields is the primary acquisition method. This practice contributes to household food security, as insects are either consumed within the family or sold for income (Gahukar, 2016. In Zambia, for instance, several insect species, including caterpillars of *Gonimbrasia belina* and *Gynanisa maja*, termites *Macrotermes falciger*, and grasshoppers *Ruspolia differens*, are popular in diets. These insects, which emerge with the short rains in late October, are consumed both as emergency food during shortages and as a regular part of diets throughout the year when preserved or available seasonally

Caterpillars, locally known as "Vinkubala" or "Ifishimu", are the larval stages of the moths' *G. belina*, and *G. maja*, known locally as Mumpa and Chipumi, respectively, are a delicacy for many Zambians (Siulapwa et al., 2014). Until recently, edible caterpillars were a seemingly inexhaustible resource in Zambia (Schabel, 2006). Yet like most other natural resources, the caterpillars are in peril, mainly due to a number of anthropogenic factors, which are imposing threats on their populations (Van Huis et al., 2013). Human collection is, in itself, resulting in direct competition with other predators, undermining population viability (Choo, 2008). Increased deforestation, agricultural intensification and environmental pollution are a threat to butterfly habitats, while higher demand due to commercialization is leading to overexploitation (Ramos-Elorduy, 2006).

In Northern Zambia, overexploitation of these edible caterpillars poses a serious threat to both the current and future practice of entomophagy (Morris, 2004; Schabel, 2006) particularly if the number of collected individuals (mature and immature) exceeds regeneration capacity (Cerritos, 2009). Matters are further complicated by the fact that Indigenous knowledge, which often includes the sustainable use of edible insects and their habitats, is gradually dissipating (Kenis et al., 2006) and inexperienced collectors sometimes resort to unsustainable collection

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methods (Ramos Elorduy, 2006; Choo, 2008). In the forests, when caterpillars cannot be reached, desperate livelihood-seekers will often cut the trees, a practice traditionally frowned at, as the loss of host trees is detrimental to the survival of future insect populations (Latham, 2003; Morris, 2004; Toms & Thagwana, 2005). Host trees are often cut down to increase and facilitate the collection of caterpillars with obvious consequences that invariably influence their abundance and distribution for future harvests (FAO, 2011; Vantomme et al., 2004). Habitat loss due to deforestation, forest degradation and pollution (e.g., through insecticides), has placed further strain on the edible caterpillar populations (Morris, 2004; Ramos Elorduy, 2006; Schabel, 2006).

Unpredictable weather patterns are affecting the life cycle of the caterpillars, due to loss of synchrony between the breeding cycle of the insects and the phenology of host plant species (Toms & Thagwana, 2005). Extreme temperatures and increased drought frequencies and intensities are drying up large numbers of host tree, thus denying the butterflies their breeding grounds. Equally, rainfall patterns are changing and negatively influencing the emerging cycle of caterpillars.

Sustainable harvesting of edible caterpillars in Kopa area will ensure conservation of *G. maja* and *G. belina* and contribute significantly to the Zambia's food security and livelihoods of its poor population, especially women and children. The caterpillars offer alternative protein source to conventional products such as meat, which is beyond reach for the poor and requires more agricultural land and water to produce but release more greenhouse gases into the atmosphere. Yet entomophagy is more environmentally friendly, requires less space and feed and are quite nutritious (FAO, 2013). Thus, this study aims to document traditional harvesting methods and rules that have governed harvesting of caterpillars in the past 10 years while promoting sustainable practices that balance resource utilization and conservation to benefit the environment and the local community.

MATERIALS AND METHODS

Study Area

The study was conducted in Senior Chief Kopa's Chiefdom, between latitudes 11 ^{0} 25' and 12^{0} 20' South and longitudes 30^{0} 22' and 31 ^{0} 08' East with WGS 84. The area is found in Mpika District of Muchinga Province of Zambia and covers about 1,400 sq. km (*Figure 1*)

Description of The Study Sites

The study area spreads on a plateau lying between 1200 m to 1300 m above mean sea level, except in its western portion where the land slopes to the Bangweulu floodplain at 1000 m to 1200 m above mean sea level. This western portion of the area is grassland while the rest of the area is woodland. Three major rivers drain the area. The Munikashi drains the northern part while the Lwitikila drains the southern part and its main tributary- the Kanchibiya drains the eastern and central part of the area (Five vegetation types characterize the study area, namely: miombo woodland, chipya, termitaria and riparian forests and grassland. The most widespread of these vegetation types is Miombo woodland, dominated by legume tree species belonging to Brachstegia, Julbernardia and Isobelinia (Mbata & Chidumayo, 2003). The climate of the area is tropical. The area experiences seasonal rainfall from November to March with mean annual rainfall of 1110 mm and a long dry season from April to October. Seasonal temperature variations are pronounced, such that three distinct seasons are recognized: cool dry season from April to July, hot dry season from August to October and hot wet season from November to March (Mbata et al., 2002: Ingram, & Schure, 2010).

Kopa Chiefdom is inhabited by the Bisa people whose major sources of livelihood include chitemene subsistence farming of millet, cassava and sweet potatoes, edible caterpillar collection and hunting of game (Mbata et al. 2002). Chitemene is a form of shifting cultivation which involves the cutting of trees or lopping branches in a given area and when adequately dry, piled in a portion of the tree cut area and burnt to create an

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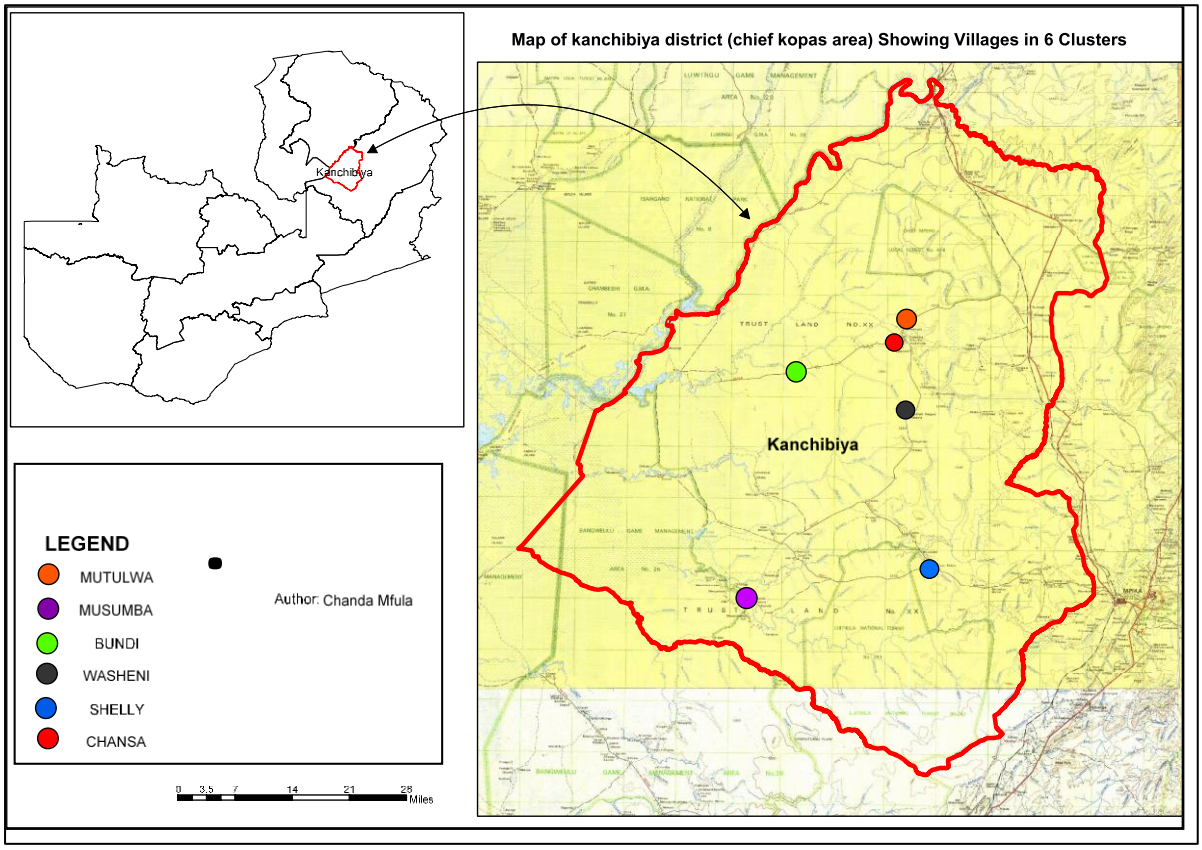
ash-field also known as an infield that is cropped for several years before abandonment as a result of loss of soil fertility (Thompson, 1954). The cut area which is not part of the infield is known as the outfield. Chitemene is practiced for food crop production and results in large areas being cleared of tree cover. Edible caterpillars are found in many areas throughout Zambia, but the epicentre of production is Kanchibiya and Mpika districts in Muchinga Province.

Figure 1: map of the study site



Source author (2020)

Choice of Study Area

The selection of Kanchibiya and Mpika districts in Muchinga Province, Zambia, as the focal area for this study was influenced by several key factors. Notably, these districts are pivotal in the production of edible caterpillars, serving as a major hub where large quantities are harvested and distributed throughout Zambia. This high concentration of edible caterpillar activity offers a unique opportunity to explore the sustainability of current harvesting practices and their wider impacts in a context that is both significant and representative of the broader region. Additionally, there is already a body of documented information on edible caterpillars in this area, providing a valuable baseline of knowledge. This includes historical harvesting practices, ecological data, and trends in caterpillar populations, which can greatly enhance the research by offering a richer, more accurate picture of the situation. The strategic combination of the area's central role in caterpillar production and the existence of prior studies underscores its relevance and potential to yield insightful findings regarding the dynamics of edible caterpillar consumption and conservation in Kanchibiya and Mpika districts.

Research Design

The research design employed for this study was a mixed method approach with a focus on capturing both qualitative and quantitative insights. Through the utilization of face-to-face interviews and self-administered questionnaires, the structured questionnaire allowed for a systematic exploration of individuals' knowledge

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regarding caterpillar harvesting methods. This approach facilitated a nuanced understanding of traditional and contemporary practices and enabled the collection of socio-demographic information from participants, providing a holistic context to the study.

Data Collection

The data collection methodology for this study was multifaceted, employing a combination of survey techniques and quantitative measurements. The core of the data collection process involved the use of a structured questionnaire administered through face-to-face interviews and self-administered questionnaires. This instrument focused on eliciting information about the respondents' knowledge of caterpillar harvesting methods, encompassing both traditional and contemporary practices. Additionally, the survey delved into socio-demographic aspects, capturing details such as age, gender, marital status, location, level of education, and employment status to provide a comprehensive understanding of the participating households.

Quantitative data related to caterpillar harvesting was a pivotal component of the study. Participants were requested to quantify the amounts of caterpillars harvested in kilograms from identified areas. This quantitative information aimed to discern any potential trends or variations in caterpillar quantities, offering insights into the sustainability of current harvesting practices. Furthermore, the study sought to establish a correlation between the quantities of harvested caterpillars and the destruction of trees in the specified areas, shedding light on the environmental impact of these harvesting practices on the local ecosystem.

The survey also assessed conservation and reforestation efforts. Participants were asked about any ongoing initiatives related to tree planting or broader conservation strategies. This exploration aimed to understand whether the communities involved in caterpillar harvesting were proactively engaged in sustainable practices to counterbalance potential environmental repercussions. Additionally, the study sought to identify any affiliations with conservation institutions such as the Forestry Department of Agriculture, providing a broader context and potential insights into collaborations with organizations focused on environmental preservation.

Sample Size

The initial calculation of the sample size was determined using the formula below;

$$n=\frac{z^2.p.(1-p)}{d^2}$$

Considering a 95% confidence interval, an estimated proportion of 50% in the population, and a desired precision level of ±5%. The calculated sample size was 384.16, and after adjustment based on the sample frame (estimated to be 150 harvesters), the final sample size (nf) was approximately 108. However, the study sampled 100 respondents from six areas due to discarding eight questionnaires with unclear answers.

where: n is the sample size needed, Z is the Z-score, which corresponds to the desired confidence level (e.g., 1.96 for 95% confidence interval), p is the estimated proportion of the attribute in the population,

d is the margin of error, also known as the desired precision level (e.g., 0.05 for ±5%).

Sampling Procedure

The sampling procedure involved using a simple random sampling technique to select adults above the age of 20 years who have experience in harvesting, assuming a decade of experience. Harvesters from Chief Kopa's village were selected based on accessibility and availability with the total sample size of 108 respondents and distributed this evenly across the six areas—Mutulwa farm block, Musumba, Bundi, Washeni, Shelly, and Chansa—which resulted in an allocation of approximately 18 respondents per area. This distribution, based on the specified total sample size, also fell within the initial range of 5

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to 30 respondents per area and ensured a more uniform representation of each area's perspectives on the research topic, influenced by factors such as the population size of each area, the density of experienced harvesters, and logistical considerations like accessibility and availability of respondents The sampling process aimed to provide accurate and useful opinions on the research topic.

Reliability Assessment

To gauge the reliability of the data obtained in the field, Cronbach's alpha was employed. A satisfaction survey, comprising 5 items, was distributed to 108 harvesters, and the resulting Cronbach's Alpha value was calculated to be $\alpha = 0.820$. According to established benchmarks by Lavrakas (2008) and Salkind (2015), the obtained value, while falling below the threshold of 0.9, was within the range of 0.8, indicating a high level of consistency and reliability in the instrument (Questionnaire) utilized for data collection. The reliability test results are summarized i*n Table 1*, showcasing a Cronbach's Alpha of 0.820 for the set of 5 items in the survey. This analysis reinforces the confidence in the reliability of the data gathered through the questionnaire, affirming the consistency of responses and the robustness of the instrument in capturing meaningful insights from the participants.

Table 1: Cronbach test for reliability

Cronbach's Alpha	Number of items
0.820	5

Validity in Research

Internal validity was maintained by designing a well-structured questionnaire and interview schedule, ensuring that questions accurately captured the intended information. The inclusion of open-ended questions during face-to-face interviews allowed participants to elaborate on their experiences, minimizing the risk of misinterpretation. External validity was addressed through carefully selecting the sample frame, encompassing adults above 20 years with a presumed decade of harvesting experience. This demographic choice aimed to enhance the generalizability of the findings to individuals with substantial knowledge of the subject matter.

Analysis Conducted

Quantitative data, specifically caterpillar harvesting amounts in kilograms, underwent statistical analyses to discern trends, variations, and potential correlations. An analysis of variance (ANOVA) was applied to examine differences in caterpillar harvesting amounts across multiple villages. The post-hoc Tukey's Honestly Significant Difference (HSD) test was used to determine which specific groups or treatment conditions differ significantly from each other. The Chi-square test was used to examine whether there was a significant difference in the distribution of gender across the research sites. Qualitative data from open-ended questions during interviews underwent thematic analysis, facilitating the identification of recurring patterns and nuanced insights. The integration of both quantitative and qualitative analyses provided a comprehensive understanding of caterpillar harvesting methods, their environmental implications, and the broader socio-demographic context within the studied communities.

RESULTS

Table 2 illustrates the distribution of respondents from each selected village within the Kopa chiefdom. This distribution includes 30 respondents from Musumba, 25 from Bundi, 20 from Mutulwa farm block, 10 from Washeni, 10 from Shelly, and 5 respondents from Chansa (see *Table 2*).

The distribution of gender in the villages where the research was conducted showed that Mutulwa farm block, Bundi and Washeni had the highest number of females who are involved in harvesting edible caterpillars. Musumba village had equal distribution of male and female respondents involved in the harvesting. Shelly and Chansa had male dominance involved in the harvesting than female. Records of respondents based on the gender distribution of harvesters from Mutulwa farm block, Musumba, Bundi, Washeni, Shelly

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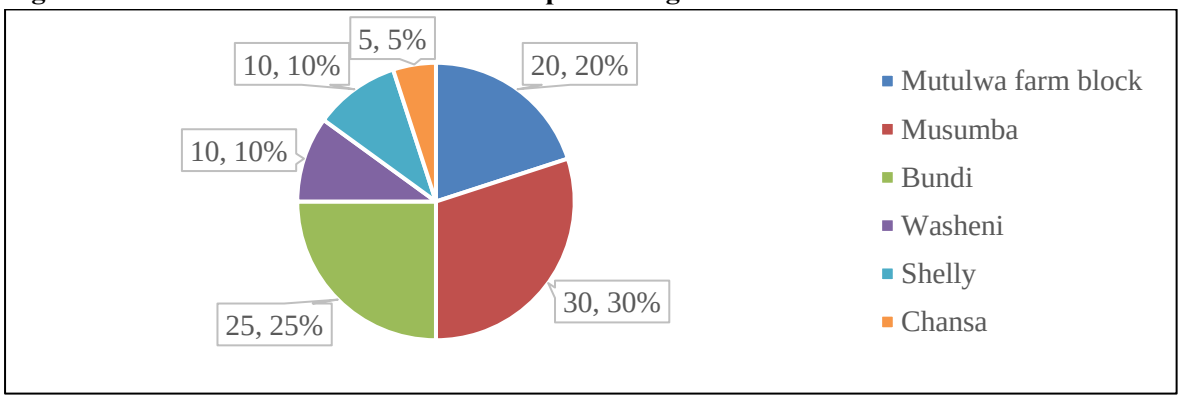
and Chansa village are shown in *Table 2*. The Chi-square test indicated a significant difference in gender distribution across the research sites ($\chi 2$ = 12.5, df = 5, p < 0.05). Therefore, a significant association between gender and the research sites, with a greater number of females involved in harvesting edible caterpillars in certain villages compared to males.

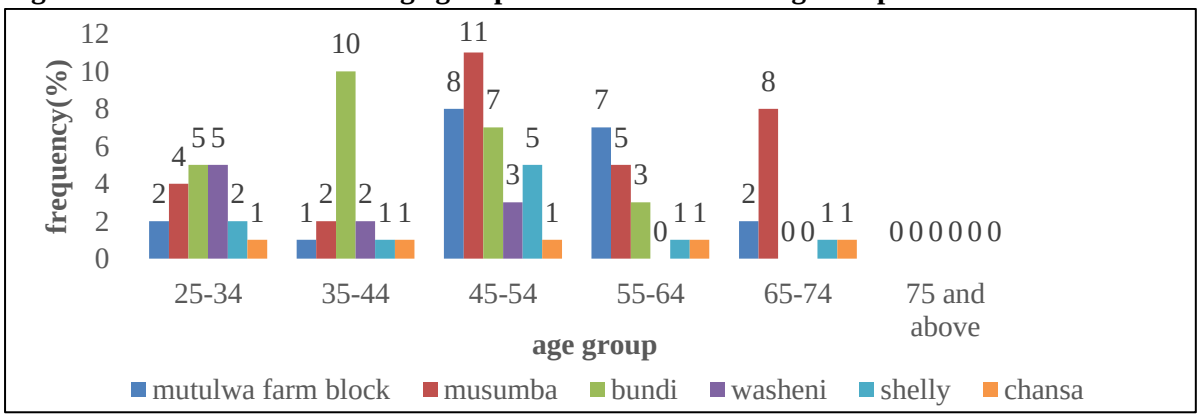
Figure 2: Selected areas in Senior Chief Kopa's Village



Gender distribution

The age distribution among respondents in the described study indicated varying demographic characteristics across the villages, highlighting different stages of life and possibly reflecting distinct social, economic, and cultural dynamics within each village. Chansa and Shelly shared a notable characteristic: they had the oldest average age group of respondents, specifically those aged between 65-74 years, suggesting that these villages might have had a higher proportion of older residents, indicating a stable or aging population. The absence of respondents over 75 could reflect the upper limit of life expectancy in the area, or possibly migration patterns of the very old. Musumba stood out for having a broad age range among its respondents but was particularly distinguished by having the highest concentration of individuals in both the 45-54 and 65-74 age brackets, implying a relatively balanced age distribution but with a notable presence of older adults. Bundi was characterized by having a significant number of middle-aged respondents, those between 35-44 years, indicating a potentially active, working-age population that could be contributing significantly to the village's economy and social fabric. Both Bundi and Washeni were identified to have a comparable number of young adults, aged 25-34, referred to as the youth, suggesting both villages were experiencing similar dynamics in terms of young adult populations, essential for the regeneration of the population and community development. Overall, the past demographic profiles indicated diverse needs and potentials across the villages, each with its implications for community planning, resource allocation, and policy-making, emphasizing the importance of understanding these age dynamics for targeted interventions.

Figure 3: Records of different age groups involved in harvesting caterpillars.



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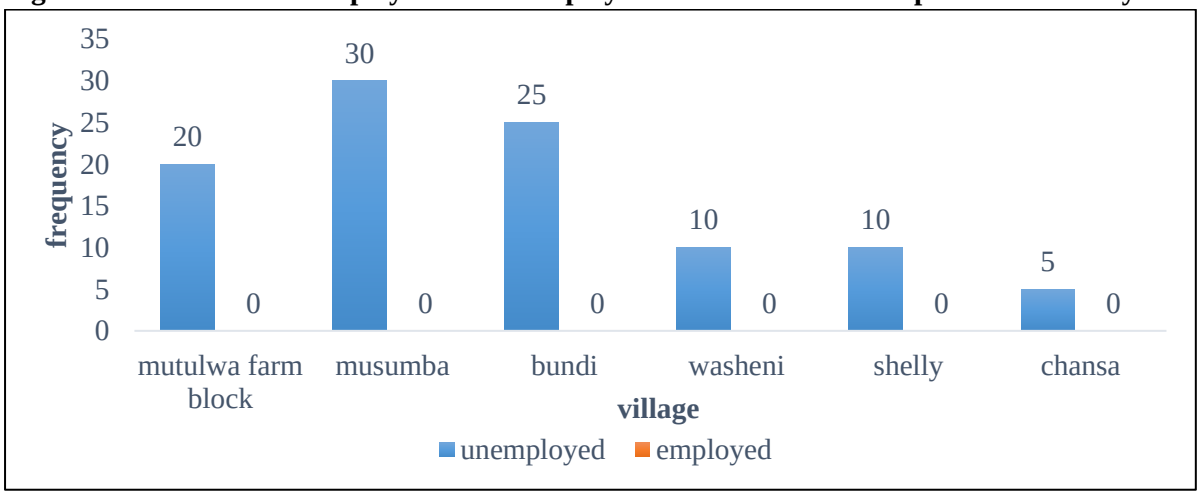
Data on the level of education attained by the respondents who were involved in harvesting caterpillars indicated that most of the people had reached the level of primary education (Grade 7) in all the villages. Musumba had the highest number, respondents (11) with secondary level of education (see *Table 2*). Chansa and shelly had 3 people each who had secondary education. Of the one hundred respondents, a good number either attained primary or secondary levels of education, but none had attained tertiary education.

The village that had the highest number of married respondents was Bundi, having 20 respondents followed by Musumba 17, Mutulwa farm block 15 Shelly 10, Washeni 6 and Chansa had the least with 4 respectively (see *Table 2*). Musumba had the highest number of respondents who were widowed while Shelly, Chansa and Washeni had zero widowed respondents. Washeni had the highest number of single respondents in the entire village. There were no divorced respondents across the villages that was involved in the research.

Figure 4: the number of employed and unemployed harvesters that took part in the survey



The employment status of the respondents involved in harvesting of caterpillars the villages showed that none of them was deployed with a sustaining paying job (see *Table 2*). They were all unemployed, hence harvesting and selling of the caterpillars was one way of self-sustaining themselves and their families.

In addition, the most predominant source of income activity across the villages was farming. They grew crops such as Maize (Zambia's staple food), cassava, millet and sorghum, among others. In Mutulwa farm block a good number (14) of respondents were involved in farming as a source of income while 6 were involved in both farming and business for income generation (see *Table 2*). In Musumba 8 were involved in a mixture of farming and business while respondents who were involved in farming alone were 16. Six respondents were involved in business alone as a source of income. Mutulwa farming block had only two income generation activities: farming and a mixture of farming and business. In Bundi, Washeni and Shelly, at least every respondent was involved in farming, business and both farming and business. While in Chansa 3 were in farming, and 2 were engaged in business but none of them were involved in both farming and business. None of the respondents was on a salary because none was employed. The participants (100%) in the survey said the employed the same methods that have been used by their ancestors.

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Table 2: Statistical analysis summary of frequency and cumulative percentage obtained on the variables; gender, age, marital status, level of education, employment status and source of income.

Variables		Musumba	Bundi	Shelly	Mutulwa	Washeni	Chansa	Total frequency	Cumulative percentage
Gender	Male	15	11	6	8	3	3	46	46
	Female	15	14	4	12	7	2	54	54
	Total	30	25	10	20	10	5	100	100
Age	25-34	4	5	2	2	5	0	18	18
	35-44	2	10	1	1	2	0	16	16
	45-54	11	7	5	8	3	0	34	34
	55-64	5	3	1	7	0	2	18	18
	65-74	8	0	1	2	0	3	14	14
	75 and above	0	0	0	0	0	0	0	0
	Total	30	25	10	20	10	5	100	100
Marital status	Single	4	3	0	3	6	1	17	17
	Married	17	20	10	15	4	4	70	70
	Divorced	3	0	0	0	0	0	3	3
	Widowed	6	2	0	2	0	0	10	10
	Total	30	25	10	20	10	5	100	100
Level of education	None	0	1	0	0	1	0	2	2
	Primary	19	16	7	5	4	2	53	53
	Secondary	11	8	3	15	5	3	45	45
	Tertiary	0	0	0	0	0	0	0	0
	Total	30	25	10	20	10	5	100	100
Employment status	Unemployed	30	25	10	20	10	5	100	100
	Employed	0	0	0	0	0	0	0	0
	Total	30	25	10	20	10	5	100	100
Source of income	Farming	16	16	7	14	5	3	61	61
	Business	6	3	2	0	2	2	15	15
	Farming and business	18	6	1	6	3	0		34
	total	30	25	10	20	10	5	100	100

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Harvesting Amounts in Kilograms

An Analysis of Variance (ANOVA) was conducted to examine the differences in caterpillar harvesting amounts across various villages.

The table below presents the means and standard deviations of the data distribution.

Table 3: Harvesting amounts in kilograms

Research sites	Means	Std. Dev.
Mutulwe Farm block	7.80	1.87
Bundi	8.00	1.41
Washeni	4.6	0.84
Musumbu	10.4	1.40
Shelly	5.60	0.80
Chansa	2.80	0.84

In analyzing the caterpillar harvesting amounts across multiple villages, a one-way Analysis of Variance (ANOVA) revealed a significant difference in means ($F(5, 24) = 15.49$, $p < 0.0001$). This indicates that there are statistically significant variations in caterpillar harvesting amounts among the villages and the Post-hoc Tests- Tukey's Honestly Significant Difference (HSD) test, revealed significant differences between Mutulwe farm block and Washeni ($p < 0.05$), as well as between Musumba and Chansa ($p < 0.05$). Thus, the ANOVA results suggest that there are significant differences in caterpillar harvesting amounts between at least two villages. Post-hoc tests indicate specific pairwise differences. These findings contribute to a better understanding of the variations in harvesting practices across the studied villages.

Table 4: Past and present harvesting methods that have been employed by harvesters in Kanchibiya District

Past methods	Current methods
Bend tree branches	Bend tree branches and climb
Collect from shorter trees	Collect from shorter tree
Shake trees	Shake trees
Use sticks to pull the caterpillars down	Use sticks to pull the caterpillars down
Collect crawling caterpillars from the ground	Collect crawling caterpillars from the ground
Cut the tree down to collect caterpillars	Cut the tree down to collect caterpillars

Plate 1: The harvester picking and shows off the caterpillars from the tree

Source author (2020)

The researcher observed that the past methods in the picking of edible caterpillars in chief Kopa's area do not differ from the current methods. The harvesters employed more than one method of

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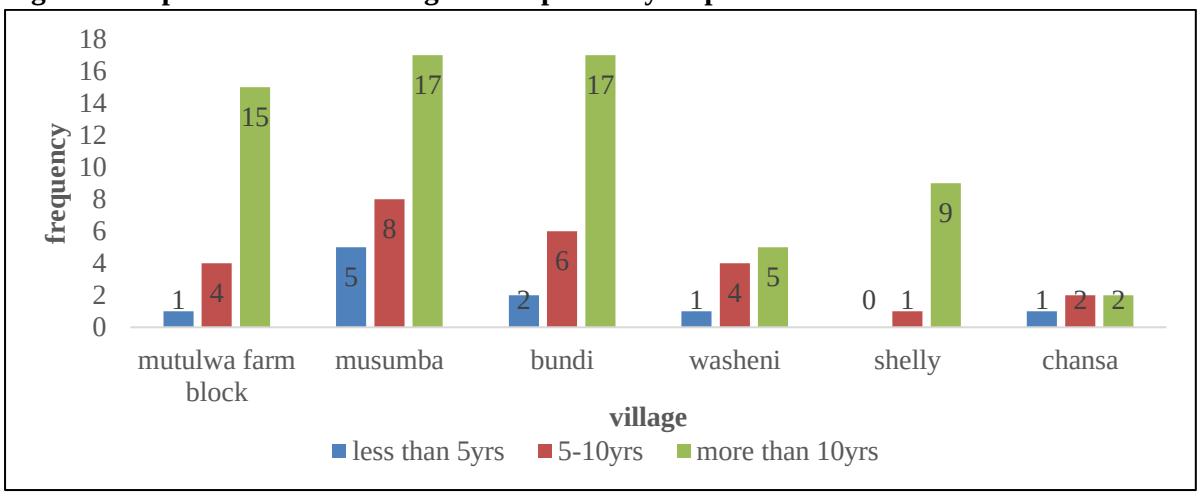
harvesting, they engage in practices such as shaking trees or climbing the trees, bending infested tree branches, 'plucking' the edible caterpillars from short trees, and collecting the ones crawling on the ground which were common among present harvesters.

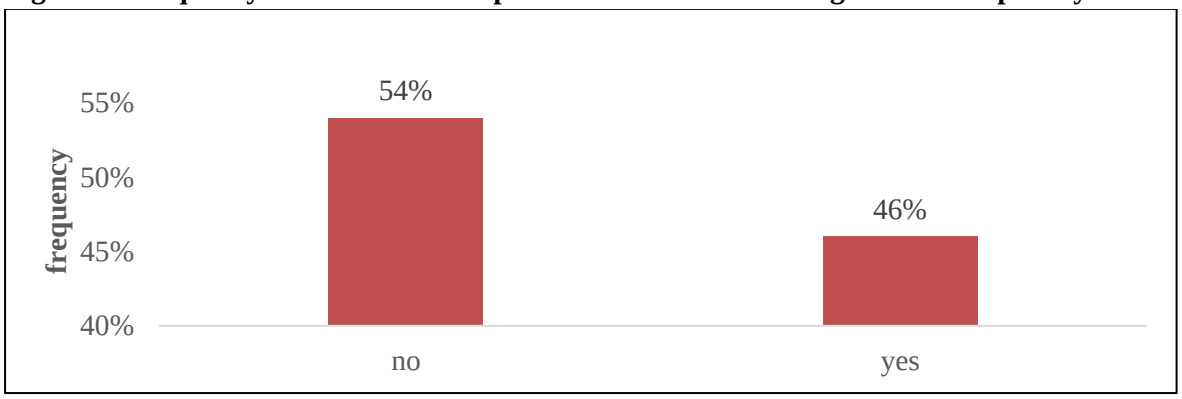
The harvesters highlighted that these were the easiest and quickest ways of harvesting the edible caterpillars. Harvesters sometimes cut tree branches or the entire tree to have access to the caterpillar despite being aware of the subsequent adverse impacts such as the lessening or even disappearance of the edible caterpillars.

Figure 5: Experience in harvesting of caterpillars by respondents



The number of years' respondents have been involved in harvesting edible caterpillar in Kopa area was another important aspect. All the villages had respondents with more than 10 years in the field of harvesting caterpillars in which they gave significant information about how they harvested caterpillars in the past years. Bundi and Musumba had the highest number of respondents with over 10 years of experience followed by Mutulwa farm block, Shelly, Washeni and Chansa having the least experienced respondents. Chansa had the highest number of respondents with less than 5 years of experience in caterpillar harvesting.

Figure 6: Frequency distribution of responses on methods affecting edible caterpillar yields



When the respondents were asked as to whether the harvesting of caterpillars with the methods, they used to be affecting the caterpillar yields, 54% of the respondents felt that the habitats were not being threatened with destruction while 46% felt otherwise the methods used were causing harm to the habitats. The respondent confessed,

> *"The yields are reduced because of destruction caused to vegetations"*

While the other respondent indicated,

> *"I am sure these methods are destroying the environments as you can see they are reducing in sizes"*

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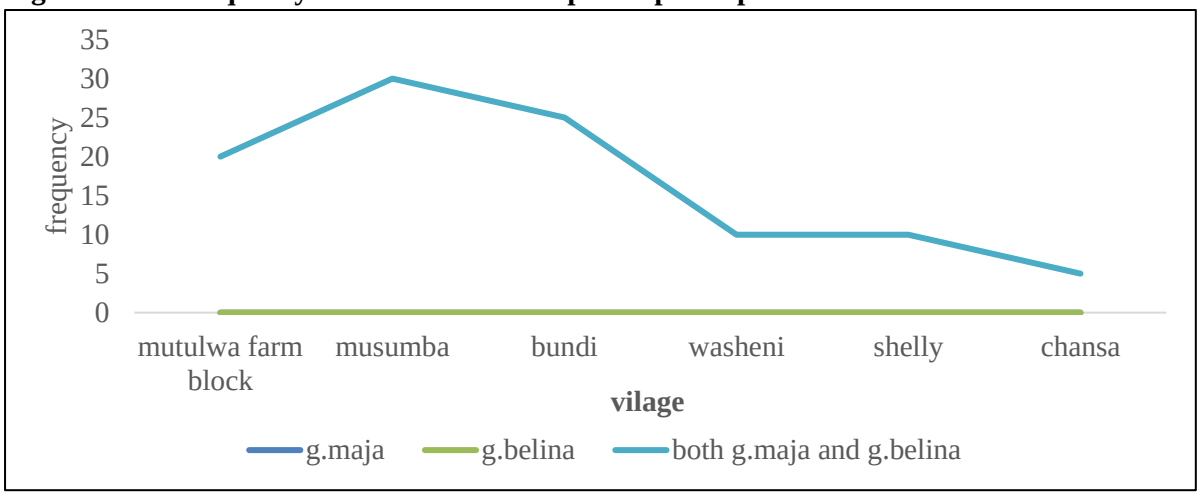
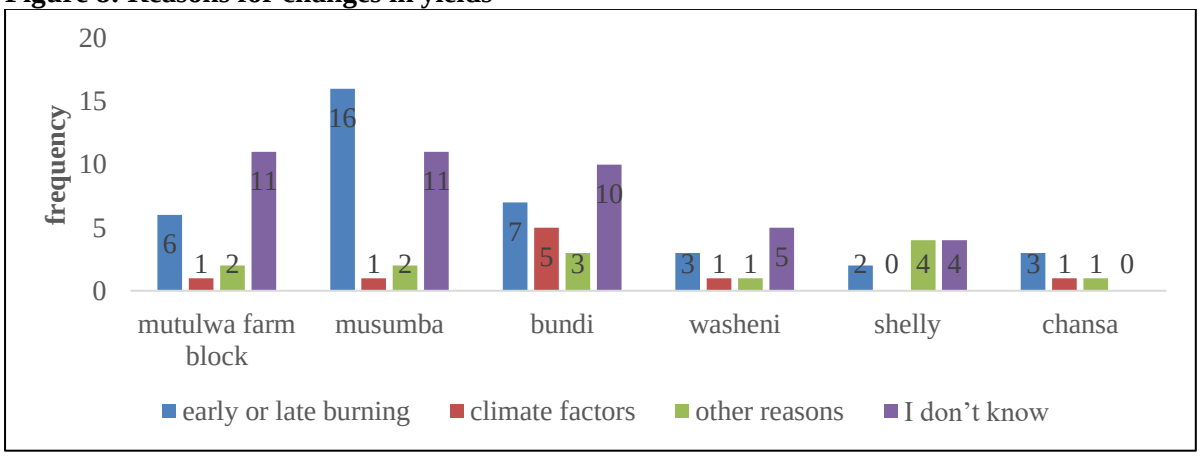
Species Distribution

Figure 7: The frequency distribution of caterpillar species per area



The distribution of caterpillar species in Kanchibiya District indicate that both species of *G. belina* and *G. maja* are common and are evenly distributed across the villages and when respondents were asked some of the reasons why there were changes in the yields of the caterpillars every year, their responses varied according to ones' opinion as the table below shows.

Figure 8: Reasons for changes in yields



Majority (40%) of the respondents claimed that early or late burning (chitemene i.e. clearing the forest canopy) caused the changes in yields of caterpillars. A respondent confessed,

> *"I believe that early or late burning practices have significantly impacted caterpillar yields. It's clear that these practices alter the environment in ways that affect the caterpillars' life cycle"*

Despite this fact, the local people strongly feel that chitemene has a positive impact on the abundance of edible caterpillars since it is in these areas where *G. maja* and *G. belina* tend to be more abundant. On the other hand, 38% said they did not know the reasons for the changes while 9% said changes were due to climate change. They further elaborated that in September temperatures of about 28 degrees are favourable for hatching eggs and that when temperatures are high about 30.5 degree the young caterpillars are killed. Thus, favourable temperatures result in a high number of eggs hatching and unfavourable temperatures result in low number of eggs hatching. Two respondents said,

> *"I'm not really sure what's causing these changes in caterpillar populations. It's hard*

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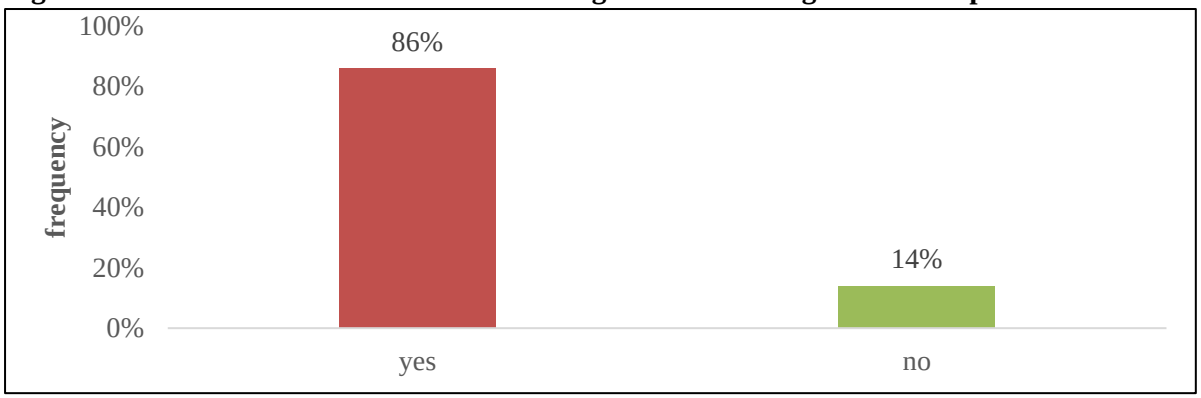
to pinpoint a specific reason without more information."

"From what I've observed, climate change appears to be a significant influence. The particular warmth levels in September, are essential for the successful hatching of caterpillar eggs. When warmth levels exceed, it can be harmful to the young caterpillars"

The other respondent indicated,

"Moderate wind speeds in August and particularly September are beneficial as they assist in the unearthing of moths. However, strong winds in early October can be detrimental, causing young caterpillars to fall to the ground where they perish, scorched by the intense heat of the earth."

Figure 9: Present rules and conservation strategies on harvesting edible caterpillars.

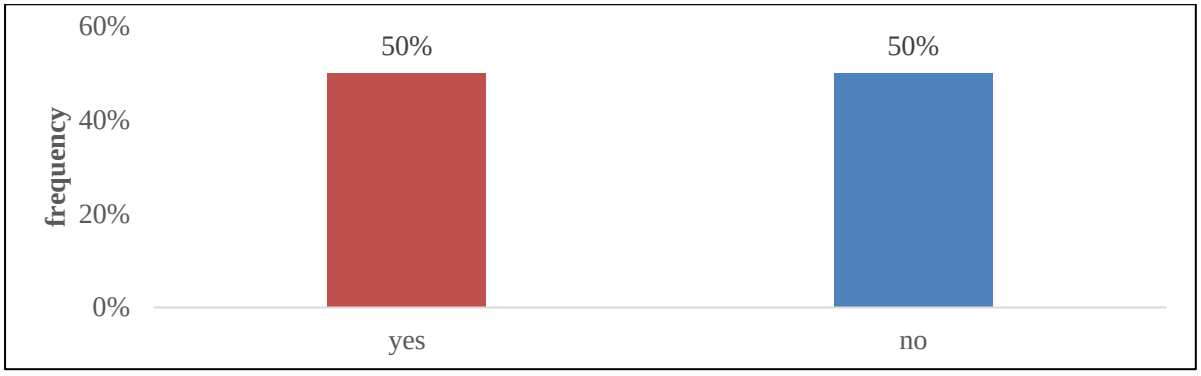


Respondents were asked if there were any rules that had been put up to guide the harvesting of the caterpillars. 86% agreed that there were rules. Rules had been put up by the chief and starts before the harvesting of the caterpillars. A respondent said,

"The golden rule is that no one is supposed to collect the Caterpillar from the woodlands before the chief performs certain rituals, failure to this, local people have been believed that there are certain taboos that occur upon disobeying the orders. e.g. It is believed that people go insane when they consume very young caterpillars"

Therefore, before any harvest is done monitoring by the members of neighbourhood watch units and those of the so-called bush police, of the chiefdom walk through the woodlands daily throughout the chiefdom, to locate areas of the woodlands where moth eggs occur in high densities on host plant foliage. Monitors continue to follow the development of the eggs in the woodlands and look out for the appearance of the first developmental stage (1st instar) caterpillars. Once eggs hatch and 1st instar caterpillars are spotted on foliage, two representatives first instar caterpillars of each species of caterpillars exploited in the area whose eggs hatch at the time, are collected from the foliage and presented to the Senior Chief through the Senior Chief's advisors.

Figure 10: Responses on the conservation strategies present in the area



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Upon receiving the first stage of caterpillars, the wife to the chief offers the tiny caterpillars to the ancestral spirits of the Bisa people. This offering (locally known as "ukuposela") is to thank the Bisa ancestral spirits for the caterpillar harvest that is anticipated for that year and to seek for the protection of all members of local communities of the chiefdom against all dangers in the woodlands, during the expected harvesting period (FAO, 2011). Meanwhile the monitors continue to closely follow the development of caterpillars in the woodlands. They look for the first appearance of well-grown, harvestable stages of the caterpillars (5th and 6th instars). When these emerge and are spotted on host plant foliage several samples involving different caterpillar species that are exploited in the area are collected and taken to the senior chief's palace. A meeting is convened, and the senior wife is commissioned to offer the mature caterpillars to the ancestral spirits at the palace shrin (DeFoliart, 1999). e. The senior chief later sets up the date for the start of the caterpillar-harvesting period for the year. The information is spread to the community by the village headmen who also enforce the stoppage directive for the harvest once received from the senior chief. When the respondents were asked if there were any conservation strategies of caterpillars and their host plants that had been put up in the area, 50% of the respondents agreed that they were there while the other 50% disagreed of not knowing any. the 50% respondents who agreed to having conservation strategies said the forest department sensitizes people not to be cutting the trees in the area for this has been a common trend and is threating the caterpillar species.

Table 5: Rules and regulations on Caterpillar harvesting

Rules	Respondents in (%)
The primary rule is that no one should collect caterpillars from the woodlands before the chief performs certain rituals	86%
No harvesting before ritual offering of tiny caterpillar to ancestral Spirits by the chief's wife.	86%
No harvesting before monitoring and collection of mature caterpillars are done.	86%
Ritual Offering of mature caterpillars at the senior chief's palace must be done to precede harvesting.	86%
Setting harvest date by the senior chief sets harvesting season	86%
There are regulated harvesting seasons and quotas to be followed.	50%
The forest department advises against cutting trees in the area to protect caterpillar species.	50%
There are education and community engagement programs on tree conservation.	50%

Respondents were asked about the evolving trends of caterpillar yields in the village as to whether there have been changes over the years. Musumba had the highest number of people that claimed that yields in caterpillars varied per year followed by Bundi, Mutulwa farm block, Washeni and Shelly had the same number of respondents and lastly Chansa with the least. Other harvesters admitted to having witnessed the decrease in caterpillars that they are decrease unlike the other years. Mutulwa farm block and Musumba had the same number of people that said there was a decrease in caterpillars.

Pearson Correlation was tested determine the relationship between caterpillar harvesting methods and the evolving trends in caterpillar yields and the *Table 4* below shows values denoting the relationships between predictor variables and the dependent variable. The p- value for each relationship has been included to show the level of significance. The Caterpillar harvesting methods had a p-value of 0.001 and r=0.917, Caterpillar harvesting methods on evolving trends of caterpillar yields p=0.003 and r= 0.891, respectively these values are significant because they are below the alpha value of 0.05. Therefore, significant relationship between

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caterpillar harvesting methods and the evolving trends in edible caterpillars' yields exist strongly.

As shown in the *Table 4* above 64% of the respondents had more than 10 years of experience in harvesting edible caterpillars *G. maja* and *G. belina* while 11% had less than 5years of experience. According to respondents, both species of caterpillars were distributed evenly throughout the area. Many respondents 86% agreed that rules were present in harvesting caterpillars while 14% disagreed. 73% of respondents disagreed that methods of harvesting caterpillars used in the area did not affect the yields while 27% agreed to the methods affecting the yield per year. In addition, reasons for the changes in yields varied with many reasons. 37% of respondents claimed that early and late burning caused the variations in numbers while 37% did not the reasons for the changes. 13% said it was due to climate change while 3% had other reasons. Conservation strategies have been employed in the area (50% agreed) while 50% disagreed.

Figure 8: Evolving trends of caterpillars over the past years

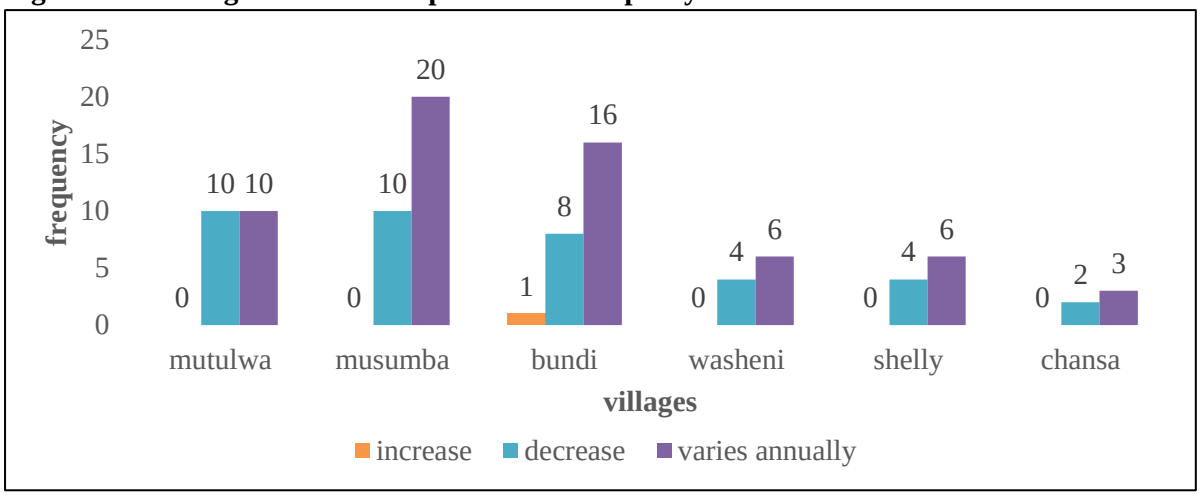

Table 3: The relationship between the harvesting method and the evolving trends in caterpillar yields

		Caterpillar harvesting practices	Caterpillar harvesting practices on evolving trends
Pearson Correlation	Caterpillar harvesting practices	1.000	0.917
	Caterpillar harvesting practices on evolving trends	0.891	1.000
Sig. (2-tailed)	Caterpillar harvesting practices	.	0.004
	Caterpillar harvesting practices on evolving trends	0.003	.

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Table 4: Summary of information on harvesting of caterpillars show the total frequency and cumulative percentage.

Variable		Mutulwa	Musumba	Bundi	Washeni	Shelly	Chansa	Total frequency	Cumulative frequency
Years of experience	≤ 5years	1	5	3	1	0	1	11	11
	5-10 years	4	8	6	4	1	2	25	25
	≥ 10 years	15	17	16	5	9	2	64	64
	Total	20	30	25	10	10	5	100	100
Harvesting methods affect caterpillar yields	No	17	22	14	8	8	4	73	73
	Yes	3	8	11	2	2	1	27	27
	Total	20	30	25	10	10	5	100	100
Distribution of caterpillar species	*G. belina*	0	0	0	0	0	0	0	0
	G. maja	0	0	0	0	0	0	0	0
	Both species are present	20	30	25	10	10	5	100	100
	Total	20	30	25	10	10	5	100	100
Reasons for changes in yields	Early or late burning	6	16	7	3	2	3	37	37
	Climate change	1	1	5	1	4	1	13	13
	Other reasons	2	2	3	1	4	1	13	13
	I don’t know	11	11	10	5	0	0	37	37
	Total	20	30	25	10	10	5	100	100
Rules present	No	1	13	0	0	0	0	14	14
	Yes	19	17	25	10	10	5	86	86
	Total	20	30	25	10	10	5	100	100
Conservation strategies present	No	5	24	4	10	4	3	50	50
	Yes	15	6	21	0	6	2	50	50
	Total	20	30	25	10	10	5	100	100
Caterpillar yields from 2010	Increase	0	0	1	0	0	0	1	1
	Decrease	10	10	8	4	4	2	38	38
	Varies annually	10	20	16	6	6	3	61	61
	Total	20	30	25	10	10	5	100	100

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DISCUSSION

The survey findings conducted in senior chief Kopa's area revealed that more females than males were involved in harvesting and processing of caterpillars across the village. Corresponding to these findings (Chanda et al., 2020), pregnant and old women obtain nutrients from the caterpillars to alleviate malnutrition and hunger, hence the dominance of harvesting. Over the years, it has been shown that there has been an increase in the number of male participants being involved in the harvesting, this is in response to the changing circumstances such as commercialization. Urbanization and scarce income-earning opportunities have led to increasing commercialization (Sekonya et al., 2020). The predominant age group involved in the harvesting of caterpillars were the middle-aged group with 34% predominance. Unemployment (no formal jobs with monthly salary) has led to the growing demand for low-cost forest resources (Unkown author, 2014). This shows that lack of employment in the villages is causing most villagers to turn to caterpillar harvesting as a source of livelihood. This is causing overharvesting of caterpillars.

According to FAO, 2014, during the harvesting season, all members of the household shift in woodlands to gather caterpillars. Most harvesters attained primary education, but a handful had reached secondary school without obtaining school certificates. This shows that's most respondents have no stable jobs but entirely depend on caterpillars as a source of income. To support this finding, Author unknown, 2014 said school children drop out of school to gather caterpillars in the wild and never return to continue with school. The highest number (70%) of respondents in the survey were married and claimed harvesting caterpillars and preserving them sustained their families for consumption and some were sold, and money earned was used for other basic needs. Mbata (2001) further adds that the caterpillars are also bartered with other items by the local community members. In addition, participants were completely dependent on farming crops such as maize for mealie-meal, cassava, vegetables and livestock like goats and cattle for their livelihood.

The harvesting methods that have been used in the past are still currently being used in the present to harvest caterpillars. These include bending the tree branches, collecting from shorter trees, shaking of trees for the caterpillars to fall off, use of sticks to pull the caterpillars down from the tree, collecting crawling caterpillars from the ground and cutting down of big trees in order to collect the caterpillars. In spite of a higher density of cut stems during caterpillar harvesting in young re-growth miombo woodland, the trees appear to recover fairly quickly through coppicing and tree mortality is negligible. The impact of harvesting caterpillars by cutting small trees is therefore temporary and does not seriously affect the capacity of the regrowth habitat to support edible caterpillars in the study area (Mbata et al., 2001). Handpicking the worms by bending infested tree branches, collecting from short trees where the worms are easily accessible, and collecting from the ground when the caterpillars fall in readiness to pupate. Although generally the amount of illegal tree cutting done during caterpillar harvesting is negligible and does not often amount to what could be regarded as deforestation (Mbata & Chidumayo, 2001), the threat of deforestation due to this practice among the local people is real. Among the reasons put forward by the respondents as to why people were increasingly cutting down caterpillar host plants in their area were population pressure, poverty among members of local communities, and high demand for caterpillars from outside buyers. Consequently, they indicated that the traditional caterpillar harvesting regulations that had been put up within the village such as not harvesting immature and other regulations were weakening.

Regarding experience harvesting the edible caterpillars, 64% of harvesters interviewed had been involved in harvesting for more than 10 years. This was an accomplishment to this research because the respondents gave out key information in relation to this topic. Among the

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information given they added that during the period of harvesting, families relocate to areas where the caterpillars have been reported to be abundant. They camped and settled in the bush for weeks collecting and processing caterpillars by degutting burying them under huge flames of fire to avoid moisture (DeFoliart,1999; Lucas, 2010). This process is important in the preservation of the caterpillars. They further added that previously, harvesters collected enough for consumption and trading but of now, what can be termed as “heavy harvesting” is taking place to supply the needs of both the buyers and the harvesters. When asked if the methods used directly or indirectly affected the caterpillar population, 73% disagreed. Respondents stated that some of the reasons that affect the yields of caterpillars each year either early burning or late burning of fields. Early burning destroyed the eggs while late burning scotched the first instars of larvae, 13% of the responders’ alluded to climate change factors such as rains temperatures and wind. Heavy rainfall swept away the eggs laid on host leaves and branches while temperatures above 30 degrees scotched the larva that fell to the ground to pupate. Observation by the researcher indicated that strong winds on the other hand blew away the eggs from the host trees. This can be supported by a study done by Hara (2012) while the temperature in October kill the young caterpillars when they fall to the ground because they get scotched by the hot ground thus reducing the abundance. In addition, the effects of rain also claim the abundance of caterpillars such that if it rains in September, before the eggs hatch, the eggs are destroyed, while when it rained moderately in October the caterpillars would grow fast and heavy rainfall in October would wash away and kill young caterpillars.

Based on local knowledge from the respondents, it seems that; temperature and rainfall impact the egg and larva stages while wind speed impacts the larva and pupa stages. Thus the abundance of *G. maja* and *G. belina* is affected in two ways which include; through the direct effect of climatic factors namely temperature, rainfall and wind speed on the larva stage and indirectly through the impact of climatic factors, namely temperature and rainfall on the egg stage and wind speed on the pupa stage.

The traditional rules and cultural practices governing the harvesting of edible caterpillars within certain communities, such as the ritual of "ukuposela," play a crucial role in ensuring the sustainability of this resource. The "ukuposela" ritual, for instance, involves a ceremonial offering to the ancestral spirits, symbolizing gratitude and seeking protection during the harvesting period (Chidumayo & Mbata 2002; Van Huis A. (2003). This practice is not only a cultural cornerstone but also serves a practical purpose: it allows the caterpillars time to mature before they are harvested for consumption fully. Moreover, the community adheres to certain taboos, such as the belief that entering the fields without the chief's permission can lead to serious consequences, like being bitten by deadly snakes. These rules and beliefs underscore a deep respect for the natural cycle of caterpillar development and a commitment to harvesting them responsibly.

However, there are concerns regarding modern conservation strategies' effectiveness and impact on caterpillar yields. While the forestry department has implemented measures like prohibiting tree cutting during caterpillar harvesting, these rules are not always strictly enforced due to a lack of inspections. This lax implementation could potentially threaten both the caterpillars and their habitat. Additionally, the trends in caterpillar yields appear to fluctuate, with some noting a cyclical pattern of increase and decrease over several years, while a significant portion of the survey respondents observed a general decline in numbers compared to past years. Only a small fraction reported an increase in yields. The Pearson correlation test suggested that the methods used in harvesting and managing the caterpillars significantly affect their abundance. This evidence highlights the need for more effective conservation strategies and adherence to traditional practices that have historically maintained a balance between human needs and ecological sustainability.

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CONCLUSION

The collection of G. belina and G. maja caterpillars is a key activity for the rural population, offering significant benefits in terms of food security and income. Traditional harvesting techniques are still prevalent in the area, involving methods like bending branches, gathering caterpillars from lower trees, using sticks to knock them down, and even cutting trees to access higher branches. However, these practices, particularly the bending and felling of trees, contribute to a decline in caterpillar yields. This study also highlighted the role of environmental factors such as extreme temperatures, unpredictable winds, and heavy rainfall in causing annual variations in caterpillar populations. A decrease in caterpillar harvest affects the local diet by reducing a vital protein source and impacts household income and the ability to purchase other essential goods and services.

The people of Kanchibiya District adhere to established rules for caterpillar harvesting, but conservation efforts are often half-hearted, underscoring the necessity for more robust and actively enforced conservation measures. These should aim to secure the future of both the caterpillars and their tree habitats for coming generations. Effective conservation might include comprehensive management and monitoring of caterpillar populations, safeguarding specific habitats, and adhering to designated harvesting times. Additionally, planting more trees that serve as hosts for caterpillars, both before and after the harvesting season, could be another effective strategy to ensure the preservation of these vital species.

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Ethical Approval

This study was ethically reviewed and permitted by the Ethical Review Committee and Board of Postgraduate Studies of JOOUST. Permission to collect data from the study county was obtained from Board of Graduate Studies. Consumers who took part in the study completed consent forms and were assured of anonymity.

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