

RESEARCH ARTICLE

New Pressures, Old Foodways: Governance and Access to Edible Mopane Caterpillars, *Imbrasia (=Gonimbrasia) Belina*, in the Context of Commercialization and Environmental Change in South Africa

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Urbanization and scarce income-earning opportunities have led to increasing commercialization of non-timber forest products in southern Africa, including the nutritious mopane worm *Imbrasia (=Gonimbrasia) belina*. The mopane worm contributes substantially to incomes and food security in households across the region, but little research has addressed its use within South Africa. Using semi-structured interviews with harvesters and resource managers, this paper compares the management of mopane worm resources under public, private, and communal governance systems to explore the ability of each to provide users with sustainable access to the resource. Results show that governance is weaker in the communal property regime compared to the public and private property regimes. Weak control over access and high demand for mopane worms in urban and rural centres may be leading to a concentration of harvesting pressures in communally managed areas, increasing competition for a resource already scarce after years of drought and land-use change.

Keywords: entomophagy; NTFPs; forest; livelihoods; rural; mopane

1. Introduction

Significant numbers of people around the world depend on woodland resources for their livelihoods, welfare, income, preservation of local cultures and spirituality (Heubach et al. 2011, Shackleton and Pandey 2014, Pandey et al. 2016). Indeed, harvesting woodland resources in southern Africa can garner rural households financial returns comparable to remuneration earned from local agriculture (Dovie et al. 2002), while urbanization and rising unemployment have led to the growing demand for low-cost forest products among the urban poor (Chidumayo and Marunda 2010).

Mopane worms are an important NTFP throughout their range in southern Africa and support an increasing rural and urban-based trade (Illgner and Nel 2000, Kozanayi and Frost 2002). They are an important source of protein, with consumption contributing significantly to food security for poor households (Dovie et al. 2002, Stack et al. 2003, Madibela et al. 2009). During the outbreak season, rural harvesters collect, clean and dry mopane worms for household consumption, trading and bartering (Illgner and Nel 2000, Gondo et al. 2010). As a key rural industry, mopane worm commercialization provides an important income source for households either through formal or informal trade (Kozanayi and Frost 2002), with harvesters and traders using profits for buying farm inputs, household provisions, paying school fees and health care (Stack et al. 2003; Thomas 2013).

Mopane worm harvesters presently trade over 80% of their yield, whereas it was once common for harvesters to collect mopane worms for home use and reciprocal bartering only (Stack et al. 2003, Gondo et al. 2010). In Botswana alone, the industry employs an estimated 10,000 people annually (Shackleton and

Gumbo 2010). Households attach importance to income from the mopane worm trade because the harvest occurs during the 'hungry season' - between agricultural harvests and just before the school year begins, when demand for cash to pay for school fees and uniforms is high (Stack et al. 2003). The regional trade of mopane worms has also flourished, with the cross-border trade between Botswana, South Africa and Zimbabwe valued between R422 million and R638 million per year (Makhado et al. 2014).

Despite the importance of mopane worms in regional livelihoods, little is known about their governance. Recent decades have seen a high and growing demand for the worms, and concerns about the possible decline of this resource underscore the importance of understanding the different governance regimes that may influence use (Thomas 2013). The centrality of governance is highlighted by cases throughout the world where NTFP use and trade is often characterised by poor management and over-regulation, with concomitant concerns linked to corruption, unsustainable use, and harvester exploitation (Belcher and Schreckenber 2007; Laird et al. 2010).

Through exploring the governance of mopane worms under three different property regimes in Limpopo Province, South Africa – public, private, and communal – and by comparing harvesting practices and access across these regimes, the paper aims to address this research gap and to explain the factors that increase the likelihood of successful resource management under different regimes (Cousins 1995, Ainslie 1999, Ostrom et al. 1999, Ostrom 2009). Within the context of increasing demand and trade and environmental change, the paper also aims to understand the possible impacts of increasing commercialization – both for the resource and for livelihoods. In doing so, the paper aims to provide evidence of the relative effectiveness of governance approaches within each of the regimes to sustainably manage the use of mopane worm resources.

1.1. Mopane worm life cycle

The caterpillars of the emperor moth, *Imbrasia* (= *Gonimbrasia*) *belina* (Lepidoptera: Saturniidae) are colloquially known as mopane worms (Makhado et al. 2009) because they feed almost exclusively on the mopane tree, *Colophospermum mopane*. At the commencement of the outbreak season, adult moths oviposit single clusters of between 30–300 or more eggs on the leaves and twigs of the mopane tree (Ditlhogo et al. 1996) (see **Figure 1**). A six-week larval stage follows the egg-laying period. The larvae will pass through five instars before harvesting in December/January and April/May, which is followed by pupation to mark the end of the season (Ditlhogo et al. 1996). The instar I to III larvae are known to forage together in combinations of about 20–200 individuals to counter predation pressure, regulate body temperature and reduce water loss (Frears et al. 1999, Klok and Chown 1999). The instar IV larvae become increasingly solitary and prepare for pupation underground (Klok and Chown 1999). Harvesting of mopane worms is more desirable during the instar V. This is due to the minimal effort needed for degutting as the caterpillars have little to no plant matter in their digestive tracts and have reached maximum growth (Stack et al. 2003). However, harvesters are increasingly targeting the instar III and IV caterpillars, due to increasing competition among harvesters and inexperience by novice harvesters (Gondo 2001, Lucas 2011, Thomas 2013). Mopane worms are bivoltine (producing two generations per rainy season), while in more arid regions such as Namibia they are univoltine (Ditlhogo et al. 1996, Thomas 2013). Nonetheless, rainfall and other climatic factors are known to play a critical role in triggering the emergence of the egg-laying moth and the survival of the caterpillar from hatching to pupation.

1.2. Overview of property regimes

Within the study area, *privately-owned land* takes many forms, but most of these areas are associated with livestock or game farms. In this property regime, individuals or families own land and can voluntarily transfer it through sale to another party. Property owners have the right to exclude others from the use of resources on their land.

Under a *public property regime*, the state manages land and its resources for specific purposes on behalf of its citizens. Administering authorities typically restrict the individual use of resources. For example, within state forests, provincial nature reserves, or national parks, some types of resource use, such as the collection of thatch, fruit, or medicinal plants, may be allowed on a limited basis and in restricted areas. Other resource uses, such as hunting, may be forbidden. Public lands in Limpopo Province primarily consist of state forests, provincial nature reserves, or national parks.

In *communal property regimes*, the state holds land in trust for specific tribal groups, and a chief or headman allocates this land for use by members of that group (Lahiff 2000). The chief acts as the

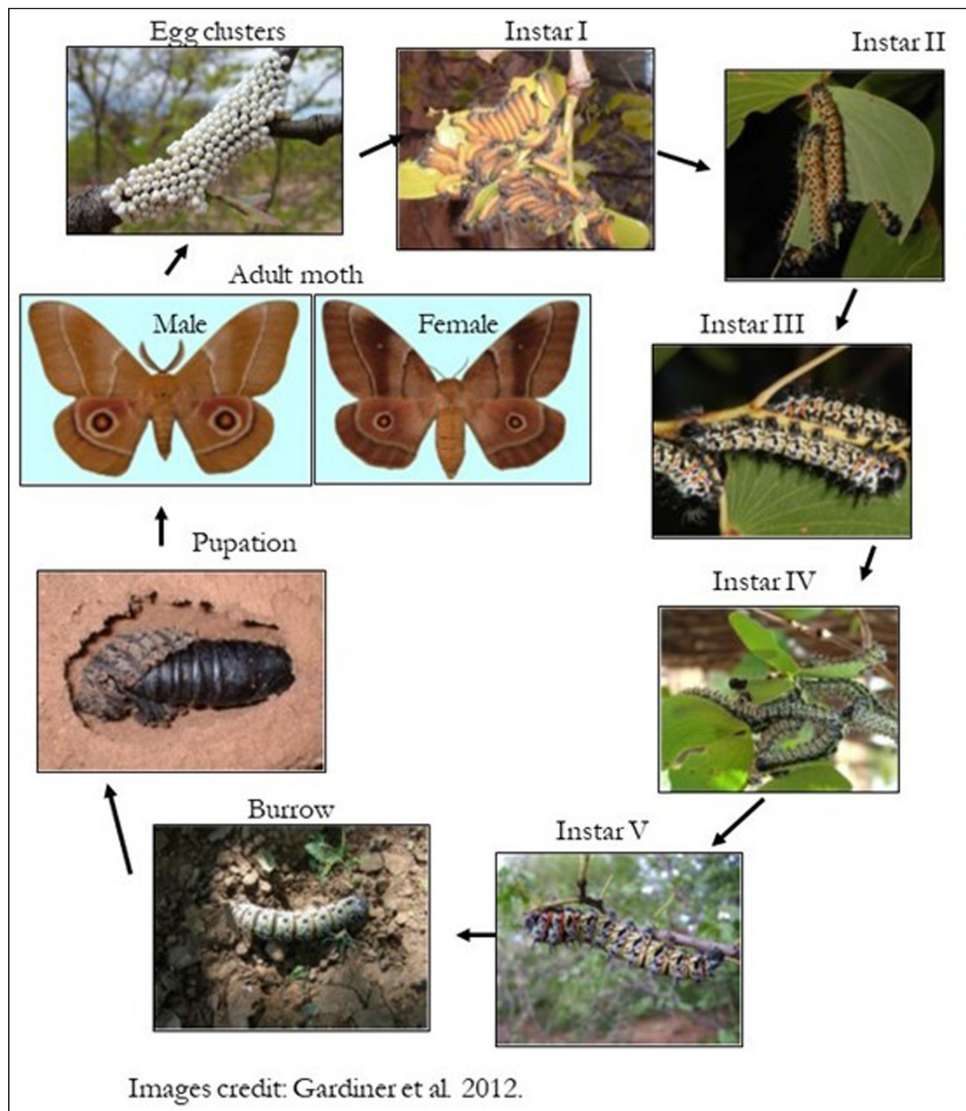


Figure 1: Mopane worm life cycle.

custodian of common resources for the communal area, and although many Chiefs will consult their communities on important matters, decision-making power rests with the tribal authority (Claassens 2001). Once allocated, land can be used by a household or transferred to another member of the household with permission from the tribal authority, but usually cannot be sold (Lahiff 2000). Customary law in southern Africa has historically played a role in regulating the use and management of communal resources such as grazing land and marula fruit harvesting, with varying degrees of success (Wynberg and Laird 2007). In this study, the communal areas were found primarily within the former homeland areas of South Africa and were administered at the local level by tribal authorities, e.g. a chief or VhaMusanda (headman).

2. Study Area

The study was conducted across nine sites in Limpopo Province – Dzumeri, Ha Gumbu, Makhuva, Masisi, Matiyani, Mopane, Mphambo, Nkomo, Zwigodini and Thohoyandou. **Figure 2** shows the location of the interview sites within the study area. These sites are located within Vhembe and Mopani districts in north-eastern Limpopo Province, South Africa. This area, which borders Zimbabwe in the north and Kruger National Park (KNP) in the east, contains one of South Africa's main mopane worm harvesting regions (Makhado et al. 2014). Research sites were selected based on the extent of mopane worm harvesting; this was determined through preliminary site visits in Thohoyandou, Malamulele and Giyani towns. Sites were selected to compare governance and access norms of the mopane worm harvest under private, public, and communal property rights regimes.

The existence of multiple types of governance in the study area and other parts of South Africa is directly linked to the apartheid era Bantu homeland system. This system was created under the auspices of the Bantu Authorities Act (1951) and the Promotion of Bantu Self-Government Act (1959) for self-regulation along tribal lines (Heffernan 2017). The study area includes part of the former Venda State and Gazankulu Homeland. Traditional leadership played a central role in the formation and governance of these homelands, effectively co-opted to police the citizens in their jurisdictions (see Mashele 2004, Khunou 2009). The Venda, Gazankulu homeland and others were later amalgamated into former Northern Transvaal province (later renamed Limpopo Province) in 1994. The collaboration of traditional leaders with the apartheid state in the oppression of black people has over time eroded the respect which the institution of traditional leadership had historically enjoyed (Mashele 2004). As a result of the decades-long policies of parallel development, these former homeland regions remain underdeveloped with limited economic activities and high dependence on NTFPs as a household coping strategy (Paumgarten and Shackleton 2011). Other socioeconomic dynamics, such as circular migration (rural to urban and urban to rural) provide an important coping strategy for households in these regions (Collinson et al. 2006).

3. Methods

Two sets of semi-structured interviews were conducted with harvesters and other key informants in 2016 and 2017. Over these periods, 45 harvesters and 8 land managers were interviewed (**Table 1**), including 33 harvesters and four community leaders (village heads and chiefs) in communal areas. Ten harvesters and three landowners were interviewed from privately owned areas. In the publicly owned areas of the Kruger National Park, two harvesters and one conservation official were interviewed. These areas and informants were identified using a nonprobability sampling approach.

Harvesters and other key informants were identified and selected through snowball sampling across the three property regimes, with each asked to suggest other potential informants for the study. This method

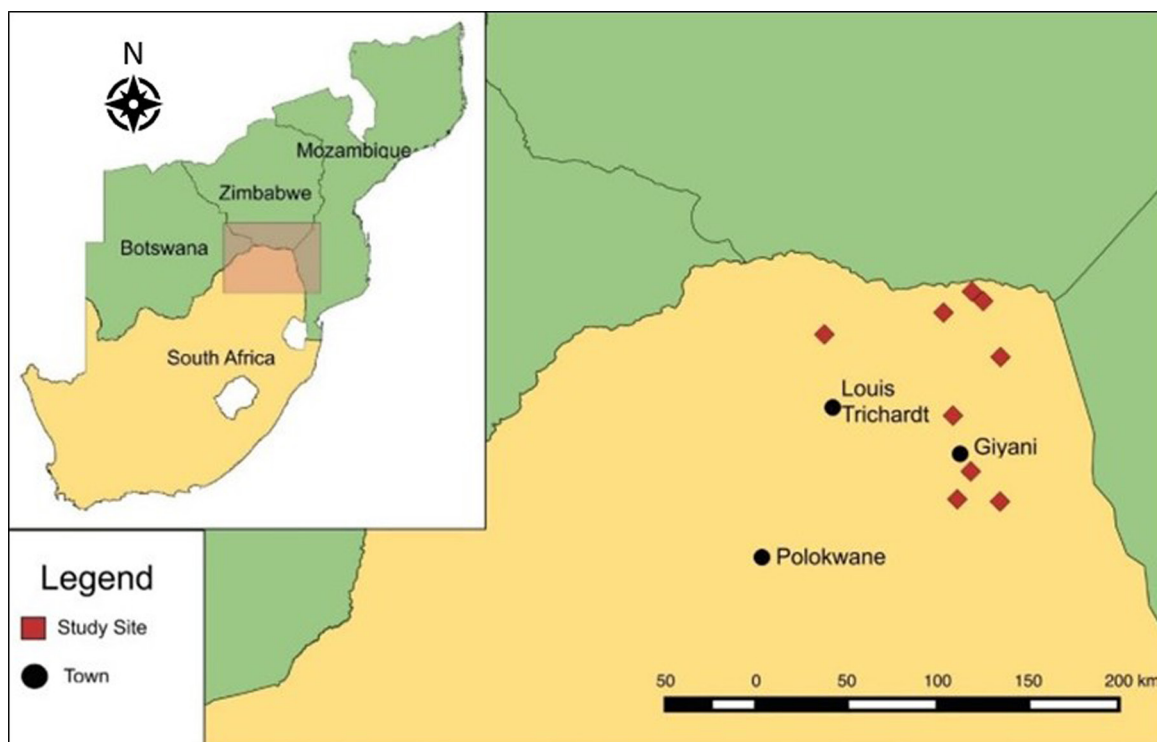


Figure 2: Location of study sites in Limpopo Province, South Africa.

Table 1: Surveyed participants in each property regime and the role they play in the mopane worm harvest.

	Public	Private	Communal	Total
Harvesters	2	10	33	45
Managers	1	3	4	8

is useful when working with remote or widely dispersed populations that would otherwise be unknown to the researcher. In most cases, authority figures at the village level assisted in identifying initial informants. The informants provided information on their livelihoods, harvesting practices and rules; perceptions of environmental change; governance and access to mopane worms; the impact of perceived changes on future outbreaks; and the availability of mopane worms. Interviews were conducted in Xitsonga, Tshivenda and English with the assistance of translators. These were transcribed and coded by hand. Thematic analysis was undertaken iteratively with data collection. Informed consent was obtained from all respondents prior to commencing the interviews, and the anonymity of all informants was strictly maintained. Ethics approval was obtained from the University of Cape Town prior to the research commencing.

4. Results

Across the three tenurial regimes, a plethora of rules, regulations and management objectives regulate the access, use and management of mopane worm resources. **Table 2** below presents an overview of the access and management rules across the three regimes in the study area.

4.1. Communal property regime

4.1.1. Customary rule subversion

Communal areas were located primarily within the former Venda and Gazankulu homeland areas and are administered locally by tribal authorities, usually led by VhaMusanda.¹ These authorities play a vital role in regulating the mopane worm harvest in communal areas. In general, there is little direct monitoring of the

Table 2: A breakdown of widely applied rules across three tenurial regimes.

	Communal	Private	State
Access Conditions	Access open for locals. Nonlocals require permission from the chief	An access fee of R300 charged per person per season	Access limited only to selected authorised harvesters
	Harvesters discouraged from camping	Camping only permitted in designated areas on the property	No overnight camping is allowed
Harvest Rules	No limitation on harvest quantities	There is no limit on harvest quantities	Harvesters are allowed to harvest as much mopane worms as they can in a four-hour window per day
	Harvesters discouraged from harvesting juvenile caterpillars. Digging pupae is a taboo	No harvesting of juvenile caterpillars or digging pupae allowed	No harvesting of juvenile caterpillars or digging pupae allowed
	No harvesting till chief declares the commencement of harvesting season	No harvesting till landowners declare the commencement	No harvesting till park managers declare the commencement
	No harvesting till mopane worm reaches maturity	Harvesting only permitted in instar V	Harvesting only permitted in instar V
	Harvesters encouraged to not to break branches or trees	No tree climbing or breaking branches allowed	Harvesters not allowed to break branches or climb trees
Management	Fires discouraged	Fires are only permitted at the camps or provided accommodation areas	All fires strictly prohibited
	Tribal police and ordinary villagers constantly monitor any unauthorised harvesting	Patrols conducted for security enforcement	Inspection of all harvesters on entering and exiting the park
Enforcement and fines	Fines and confiscation of harvest	Immediate confiscation of harvest. Expulsion and blacklisting	Immediate expulsion. In the case of poaching, prosecution

¹ Vhamusanda is a Tshivenda word for a village headman.

mopane worm harvest, but the chief calls a meeting of the tribal council and selects a date for the official start of the harvesting period. This usually takes place in the weeks following both Christmas and Easter, depending on the presence of an outbreak.

There appeared to be consensus regarding how the caterpillars should be harvested. Nearly all informants stated that caterpillars should not be harvested until they reach a particular size and that harvesters should not damage mopane trees. People harvesting in communal areas where they are not residents were expected to get permission from the traditional authorities before harvest commenced. However, harvesters did not uniformly follow these norms. In practice, people from outside the community rarely requested permission from tribal authorities. Reports from all communally managed areas surveyed suggested large numbers of outsiders coming from far away – Giyani, Polokwane, Thohoyandou, Johannesburg, or from villages nearby – parking their cars in the bush and beginning harvesting without making their presence known to VhaMusanda. One harvester commented:

“These other people who are not from here come in big numbers using buses and harvest the worms, sometimes without first going to the chief for permission. They break the trees when they harvest, and they do not follow any of our established harvesting practices.” Female harvester, 28

This view was shared by other local people, who felt that the influx of harvesters from the cities and other distant areas harmed mopane worm populations in their village. Most harvesters cited the failure by the non-local harvesters to observe certain local customary practices and established norms as the key drivers of population decline. One Chief commented:

“Nothing that is affecting the outbreak pattern is coming from the community. People from the outside harvest the small mopane worms and this might prevent the next outbreak. The community alone could not finish an outbreak.” Male Chief, 82

However, few harvesters followed the rules even within their communities. While the mopane worm harvest should begin after the chief has announced open season, only eight of the 33 harvesters in communal areas said they waited for the announcement, despite three of the four community leaders stating that harvesters waited for the announcement. This may be an indication of the covert rule-breaking by harvesters. Most harvesters said they either chose their starting day based on the size of the mopane worms or by coordinating with other harvesters or family members, whether or not the announcement had been made. Only ten out of 33 harvesters felt that harvesting norms were consistently followed. The view was that competition is fierce, and that those who follow the rules too closely may run the risk of finding the harvest finished before they arrive. The comment below illustrates the growing trend among harvesters to subvert their own communal rules due to the increasing competition for mopane worms:

“This year, people are harvesting before the announcement. They do this at their own risk. If you wait for the announcement, though, you might get nothing, and prices (for mopane worms) are remarkably high.” Female harvester, 28

4.1.2. Ineffective rule enforcement

Amidst this environment of pervasive rule-breaking, there was substantial ambiguity about who was responsible for enforcing harvesting norms, with harvesters suggesting that tribal authorities (18 out of 33), government rangers (seven out of 33) and harvesters themselves (six out of 33) were involved in enforcement. Almost a third of harvesters (ten out of 33) indicated that no one enforced the rules and that harvesting mostly took place in an open-access system. Many of the harvesters indicated that they did not feel empowered to participate in changing these rules. Despite the low levels of following rules and a lack of broad consensus on how harvesters might participate in shaping rules, all informants reported that they found the rules governing the harvest to be fair.

Changes to land cover due to vegetation clearing and the over-exploitation of mopane worms were common narratives in the communal regime. Settlement encroachment in communal areas was reported by eight of 33 harvesters. While 19 of 33 harvesters noted clearing to some degree, more than half of the informants reported moderate to substantial changes. The informants indicated a strong connection between the protection of mopane trees and future mopane worm harvest. The need for protection of mopane worms was particularly strong, where 24 out of 33 harvesters and all four community leaders

mentioned the importance of protecting mopane trees to secure future access to mopane worms. Some informants proposed an increase in the number of rangers to be deployed in the forests.

4.2. Private property regime

4.2.1. Access negotiation

Common land uses from the private property regime were associated with livestock or game farms. In general, farms were fenced, giving landowners and managers a high degree of control over resource access. Harvesters wishing to access mopane worms on private land required permission from the property owners and generally paid an access fee averaging R200–300 (US\$ 13–20²) per season; overnighting was typically permitted on the farms during the harvest only at designated areas. This allowed harvesters to avoid the costly daily commute between their homes and farms. Importantly, it was also an indication of the rapport and trust developed between private landowners and the harvesters.

Landowners have increasingly restricted access to mopane worm harvesters in recent years. The manager of one game farm, whose father had managed the same farm, remembered a time when 50–60 harvesters had been allowed to harvest each year, as opposed to the eight who currently harvest. He noted that in the past, landowners encouraged people to harvest mopane worms on their land to control the caterpillars. This was linked to a belief that caterpillars would reduce the available forage for their game animals. Commenting on motivations for access restrictions, and on how shifts in perceptions had shaped management approaches, the farm manager stated:

“The previous owner thought mopane worms would eat all the leaves and not leave any for the game, so he wanted harvesters to take the mopane worms. The new owner thinks that mopane worm harvesting is bad and harmful to the environment.” Male farm manager, 55

4.2.2. Adherence to access and harvest rules

Only harvesters that had successfully negotiated access could enter the private farms for harvesting. Such negotiation included a variable payment per person for a given number of days. Harvesters were permitted to stay on the farm for an agreed period and could harvest as many mopane worms as they wished. In rare cases, the harvested quantity was limited, ordinarily counted in a number of ‘maize meal’ bags or 20-litre containers. Nonconformity to these terms resulted in transgressors being expelled from the farms. In some instances, such transgressors were not granted future access. If possible, farm owners gave preference to harvesters with whom they had good relationships and had worked well in the past. Unauthorized access to the farms often resulted in a prosecution for trespassing.

The management approach adopted by the private landowners included the banning of mopane tree felling and close monitoring of the outbreaks and harvesting to ensure that only instar IV and V caterpillars were harvested. This aimed to maximize harvest quantities without compromising the subsequent years’ outbreaks by preserving habitat integrity. The effectiveness of these measures was evident as the harvesters preferred harvesting in the private and public lands as they were more likely to collect larger volumes. The landowners also determined the commencement and end of the season. This control feature was shared across the private and public tenure types. This management precaution prevented the harvesting of juvenile or burrowing worms and the digging out of pupae. This was done by closely monitoring the caterpillar development and the harvesting season as it progresses.

Harvesters reported no settlement encroachment and low levels of selective mopane tree cutting. Five out of ten harvesters interviewed believed that harvesting had a negligible impact on mopane worm populations, and that heat and drought were the main factors impacting outbreaks.

4.2.3. Balancing harvesting with management objectives

All informants within this regime believed that authority to make harvesting rules was vested entirely with landowners and that there was no scope for harvesters to participate in shaping these rules. All felt that landowners and their employees had the responsibility to enforce harvesting rules, and none believed that the government had any role to play in regulating the harvest on private land.

Linked to a shift from livestock to wildlife management over the past two decades, landowners now want mopane worms on their land, as they believe that defoliation of the mopane tree can increase the nutritional quality of the second flush of leaves, creating better forage for wildlife mammals.

² At the exchange rate 1 ZAR = US\$ 0.065.

“The white farmers do not let people harvest because they say the mopane worms must eat the old leaves so the game can eat the new leaves. The old leaves can make animals sick; they have some kind of poison in them.” Male farm employee, 55

However, for the wildlife game reserves, a fear of game poaching has also strengthened the desire of private landowners to maintain tight control over access to their land. Many harvesters reported that managers restricted men from harvesting mopane worms on private lands due to a fear of game theft. This view was echoed by one harvester who said:

“Only women can go into game farms because men might bring snares and steal game. Men are suspected of poaching in game farms, so they would have to harvest secretly there.” Female harvester, 61

Overall, only one harvester out of ten found the current system unfairly restrictive, whereas others accepted the conditions of access, provided the mopane worm outbreak was plentiful, and they were not given a limit to the amount they could harvest. All informants reported that in general, people followed the harvesting rules.

4.3. Public property regime

Extractive resource use in national parks is prohibited in South Africa. However, in 2010 KNP began piloting the Kruger Park Mopane Worm Harvesting Programme. KNP remains the only national park to sanction the harvest of mopane worms within its boundaries. As part of the KNP program, harvesting takes place under close monitoring and is only allowed in a four-hectare resource harvesting zone alongside the fence on the western edge of the park. Some of the harvesters hinted that limited harvesting also takes place at Letaba Ranch, a smaller provincially managed nature reserve. However, harvesting in this reserve was erratic and inconsistent, and as a result, none of the harvesters used Letaba Ranch reliably.

4.3.1. Access coordination

Each harvesting season, section rangers working in KNP evaluate the size of the outbreak to determine if it is sufficient to allow harvesting. If so, KNP staff hold a forum with community representatives bordering the park. The forum selects seven villages that will be allowed to participate in the harvest that season. Each participating village may send ten harvesters who are chosen internally by the village, often by the traditional authorities. South African National Parks (SANParks) recommends that those benefitting from the program should be the poorest in the community but is not involved in the decision-making process. The rules for the harvest are spelt out clearly in the forum: harvesters must take worms above a certain size, must provide their transportation that meets certain requirements, and must not damage or bend trees. Otherwise, they may collect as much as they like within their allotted time. Two armed rangers are always present to monitor harvesting activities and to protect harvesters from wild animals.

Two years after it began, KNP temporarily suspended the mopane worm harvest due to drought conditions in the park. Because of the program's short duration, only 140 harvesters had participated in the initiative up until December 2012, suggesting that in terms of broader patterns of resource access and use, harvesting on public lands is inconsequential.

4.3.2. Unambiguous access and harvesting rules

In many respects, governance of the mopane worm harvest in the public property regime resembled that of the private property regime. Harvesters found the system fair despite a lack of meaningful avenues for participating in the rule-making process. Managers and harvesters established a clear consensus around harvesting rules and how they were to be enforced. SANParks officials noted that rules were closely followed, most likely because if any individual broke the rules, the entire harvesting initiative would be terminated for all villages. Perceptions of environmental change were similar to the private property regime, with low levels of reported tree cutting and land-use change indicating robust compliance and resource governance in this system.

Access to the State-managed public land is strictly controlled. Currently, KNP is the only national park area to permit controlled harvesting of mopane worms under the following conditions: (a) Only authorised harvesters are allowed access. These are selected from the neighbouring communities, and poorer households get prioritised; (b) Harvesters are accompanied by a ranger for protection and monitoring; (c) No

overnight camping is allowed; (d) Harvesters are allowed to harvest as much mopane worms as they can within a four-hour window; (e) Any transgression results in immediate exclusion from the park. In the case of unauthorised access, transgressors face prosecution. Similarly, other smaller provincially-controlled nature reserves also permit mopane worm harvesting on terms which mirror that of KNP. Nonetheless, access and harvesting rules are monitored to ensure adherence to the rules and to detect any transgressors. One harvester mentioned:

“At Letaba Ranch they make people wait until mopane worms are big enough to harvest. They limit the harvesters to 7 people per vehicle and a maximum of 20 vehicles. Rangers check bags at the end of the day to make sure they are not taking the small ones.” Male harvester, unknown age

Some local villagers still managed to gain unsanctioned access to the nature reserves to harvest. One harvester remarked:

“The mopane worms in Letaba Ranch were more protected. Nevertheless people still jump the fence and take them. The electric fence was not working properly.” Male harvester, unknown age

5. Discussion

5.1. Resource access

Ribot and Peluso (2003) describe in their seminal work that the ability to access and benefit from a resource depends on a bundle of different power relationships, including among others access to knowledge, capital, authority, and identity. They further explain how governance systems privilege certain mechanisms of access over others through their institutions, rules, and norms. These analyses resonate with the findings of this study. The relative ease of access to mopane worm resources under the communal property regime means that a substantial proportion of mopane worm harvesting takes place in these areas as opposed to those under private and public management. For urban residents or migrant harvesters looking to make an income from mopane worms, harvesting without paying a fee and with negligible consequences associated with breaking the rules holds an obvious attraction. This in turn, also results in resource overexploitation. These findings resonate with similar studies in Botswana, Namibia and Zimbabwe revealing how vulnerable ‘outsider’ groups such as migrants or economic refugees would travel substantial distances to access mopane worms in communal areas with a loose regulatory climate (Stack et al. 2003, Lucas 2011, Thomas 2013). Similar trends were observed in communal tilapiine cichlids-based fisheries in Lake Liambezi of Namibia, where nonlocal businessmen hired Zambian fishers to fish for them for quick profits in complete disregard for locally agreed rules on resource sustainability and resident fishers (Tweddle et al. 2015). As an example of the export of wealth for the benefit of these businessmen and migrant fishers, the fish from Lake Liambezi were marketed in the Democratic Republic of Congo (DRC) via Zambia (Tweddle et al. 2015).

Of all three regimes, access to mopane worms in the communal areas was least controlled, with evidence suggesting that the enforcement of existing access mechanisms was ineffective to deter transgressors. The inefficiency of these measures was worsened by poor adherence to established customary norms due to unprecedented social change and urban influx. This is in part due to the tainted legacy of traditional leaders during apartheid which, together with their declining influence, continues to undermine their authority within communal areas (Mashele 2004). As a result, asserting customary control, setting rules and enforcing them over resources has increasingly become a challenge for traditional leaders. However, for resource users living in these areas, harvesting within the community is also more convenient and cost-effective than accessing mopane worms on private or public property. In this case, pressures such as uncontrolled access and habitat destruction from local and non-local harvesters could lead to resource degradation and reduced availability of the mopane worm. Such degradation may occur when common property systems break down (Cousins, 1995) or when resource use increases to the point that customary approaches are no longer appropriate for the level of commercialisation (Wynberg and Laird, 2007). The inability of tribal authorities to enforce existing resource management rules further indicates weak governance in communally managed areas (Ainslie 1999), which inadvertently creates an institutional control vacuum (Shackleton 2009). This breakdown in institutions extends beyond the village and communal area limits. As Bromley (2008) notes, it is crucial to go beyond the usual free riding, shirking, theft and resource degradation narratives that often dominate the commons literature. By focusing more carefully on the institutional isolation of the African commons, it becomes evident that external forces play a more significant role. Such structural issues may include the diminished ability of resource users to respond adequately to impending resource degradation;

disproportionate and skewed access to resources; unsuitable policy frameworks; and historical spatial patterns in communal regions (Beinart 2000, King 2011, Palmer and Bennett 2013, Vetter 2013).

In private and publicly managed areas, more effective access mechanisms such as strict sanctioning of harvesters; use of access fees; and, harvester patrols and inspections likely prevented damage to the mopane worm resource. Access under these regimes was costlier and less flexible; harvesters without the necessary capital, transportation and social relationships were unable to access this important source of cash income and nutritious food.

5.2. Resource degradation and perceptions of environmental change

Historically, traditional management systems based on traditional ecological knowledge likely ensured the sustainable use of mopane worms. In Zambia, for example, the knowledge of indigenous Bisa was crucial for the management and utilization of edible caterpillar species (Mbata et al. 2002). This involved monitoring the resource, protecting early life stages, conserving habitat, and applying harvesting restrictions through socially embedded customary practices, rules, and beliefs (Mbata et al. 2002). However, as revealed in this study, as customary systems have eroded, and commercialisation has increased, communal areas have seemingly become less controlled with associated resource degradation.

Evidence from this study suggests that existing regulatory mechanisms are ineffective to sufficiently deter transgressors and that tribal authorities are resorting to using 'tribal police' to patrol forests to monitor any premature harvesting, tree clearing and the presence of non-local harvesters. The inefficiency of these measures is worsened by poor adherence to established customary norms due to unprecedented social change and urban influx, poor access regulation and inadequate rule enforcement. In contrast, the governance of public and private lands has led to high levels of control over resource access, and seemingly more effective mopane conservation. Similar studies on mopane worm governance in communal areas in Namibia have demonstrated that institutional coordination and stricter controls on access and monitoring are critical for mopane worm population sustainability (Thomas 2013, Ndeinoma and Wiersum 2016). In Zimbabwe, diminished coordination, especially in communal areas, has led to widespread deforestation and habitat destruction in mopane woodlands (Ndlovu et al. 2019). Under such scenarios, coordination may be beneficial when led by the state, especially in communal areas in which traditional and customary rules have been eroded and remain weak. Exploring the governance of marula, Wynberg and Laird (2007) conclude that fit-for-purpose state interventions can be useful to address specific needs, in this case, strengthening adherence to traditional and customary rules. Ndeinoma and Wiersum (2016) observed that depending on the NTFP, legal protection of species may be necessary to ensure high adherence to statutory and customary rules.

Changes to land cover and the over-exploitation of mopane worms were common narratives across all tenurial regimes. However, perceptions of negative environmental change were more pronounced in communally managed areas, perhaps due to the multiple uses of mopane tree and pressures. This includes uses for energy, construction, medicinal uses, and settlement expansion in communal areas (Makhado et al. 2014). Similar observations were made in Cameroon and Democratic Republic of Congo (DRC) in which the decline in edible caterpillar harvest yields was found to be driven by high-value timber species logging driven by forestry concessions (Noutcheu et al. 2016, Muvatsi et al. 2018).

5.3. Resource management interventions

Several factors contribute to weak mopane worm governance on communally managed lands (Shackleton 2009, Thomas 2013). The high proportion of 'free riders' and the challenges of restricting access to the resource are likely to discourage local users from investing in expensive monitoring and enforcement activities (Cousins 1995, Ainslie 1999, Akpalu et al. 2009, Thomas 2013). Harvesters in communal areas see outsiders taking their resources without regard to customary norms and consequences. They are unlikely to incur the costs of self-organizing to protect their resources (or follow the rules themselves) when the problem seems intractable and they perceive little support from authorities. However, examples exist in other edible insect systems in which restrictive customary harvesting approaches have resulted in sustainable resource outcomes. In terms of customary norms, early instar harvesting was restricted in *Gynanisa maja* and *Imbrasia zambesina* in Zambia (Mbata et al. 2002), *Hemijana variegata* in South Africa (Egan 2013) and *Encosternum delegorguei* in Zimbabwe (Mawere 2014). Mawere (2014) concluded that local users in these systems restrict harvesting of juvenile instars and in some cases, avoid harvesting at particular times in the day. The ecological outcomes of these beliefs cannot be underestimated for resource conservation. Adhering to such customary beliefs inadvertently turned some users into activists who

protected their resources in communal areas. In the case of *Encosternum delegorguei* for example, Mawere (2014) observed that a strong bond between users and the resources was crucial for resource sustainability.

A lack of respect for local rules among outsiders has been commonly noted for mopane worm systems (Lucas 2011, Makhado et al. 2012, Sithole 2016), and other NTFPs (Twine et al. 2003). The unpredictability of the mopane worm harvest exacerbates this; since the size of the harvest varies greatly, the cost of managing the system to prevent 'outsiders' from extracting the resource may often be higher than the benefits received, further reducing the incentive to invest in management initiatives (Ostrom et al. 1999, Ostrom 2009).

Resource unpredictability does not have the same negative impact in private and public regimes because land managers have invested in access control systems such as fences and rangers for the protection of other, more valuable, and predictable resources, such as livestock or wildlife. These systems are repurposed for a few weeks of the year to provide income to land-owners or to build relationships through benefit-sharing programmes, and so mopane worm management is, in some sense, subsidized by other natural resource activities. Linked to a shift from livestock to wildlife management over the past decade (Cloete et al. 2007), landowners now want mopane worms on their land, as research has shown that defoliation of the mopane tree by herbivores can increase the nutritional quality of the second flush of leaves, creating better forage for wildlife mammals (Hartnett et al. 2012).

5.4. Overlapping mandates

As suggested by several authors (e.g. Shackleton 2009, Kozanayi et al., Makhado et al. 2012, Mwalukomo and Patel 2012) and confirmed in this study, overlapping mandates of tribal authorities and the provincial environmental department may cause confusion about who exactly is responsible for key resource management tasks. Often, the ambiguity which emanates from such institutional 'layering' tends to weaken local level resource management (Ainslie 1999, Makhado et al. 2012). In South Africa, this ambiguity, as well as a general weakening of common property systems in communally managed areas, stems in part from policies used by the apartheid regime to maintain social control over black communities in the former homelands by co-opting elites and chiefs. These policies served to dismantle rural people's capacity for independent organization and governance, while the institutional order that was created, operated mainly as a covert mechanism for purposes of control from above, instead of meeting community needs (Cousins 1995). For example, forced relocations that separated people from their traditional leaders and placed them under the rule of new leaders would have subverted the legitimacy of local institutions as tools for resource management. This led to the systematic dismantling of traditional governance systems, with implications for the communal area governance (Mwalukomo and Patel 2012). The effects of these historical geographies continue to have implications for natural resource use and governance in the modern day (Lahiff 2000, Claassens 2001, Twine et al. 2003, King 2007, Francis 2010). The growth of urban markets for mopane worms and the resulting high demand for the resource has added new pressures to the system, necessitating intensified systems of control where communal management systems once sufficed (Cousins 1995).

6. Conclusion

The findings provide evidence of the stark differences in governance systems and resource access across the three regimes. Overall, public, and private property regime managers demonstrated strong control over resource access, and the costs of controlling access to the mopane worm harvest were absorbed by pre-existing systems designed to manage other natural resources. In communally managed areas, there was an apparent breakdown in traditional governance systems, catalysed by significant social and political disruptions during apartheid, the legacy of which persists. Furthermore, the high costs of controlling access to unpredictable and wide-ranging mopane worm populations, increasing commercialization of the mopane worm resource and competing uses of the mopane tree undermine the effectiveness of this regime. Given the ongoing dysfunctionality of governance, the ability of the communal property regime in these areas to provide sustained access to mopane worm resources in the long term is thus doubtful. It may well be, however, that elsewhere in the region, communal areas provide a much higher level of control and functionality and thus provide a suitable governance regime for mopane worm regulation.

The degradation and decline of mopane worm resources pose a threat to the most marginalized harvesters, who lack the capital and social relationships necessary to maintain access through another system. Harvesters attempting to maintain access to mopane worm resources on tribal authority lands may increasingly be forced to negotiate access through other property rights regimes. A viable intervention could be to strengthen and invigorate traditional management systems and to develop an open dialogue between user groups, traditional authorities and local authorities. This could create a consensus regarding the customary rules that manage the

mopane worm harvest, and the roles each actor plays in supporting, monitoring and enforcing these rules as part of the local monitoring system. Such system could clarify who issues access permits, and harvest limits per household, and could maintain a register of permitted users and punishment for unauthorised access.

To increase the economic incentives for management, tribal authorities could co-manage land for both mopane wood and mopane worm resources. This might increase resource benefits while sharing management costs, providing an incentive to invest in management activities and strengthening local governance and participation of resource users. More research is needed to determine the impacts of harvesting and land cover change on populations of *I. belina*. The urgent need is to conduct systematic population surveys to corroborate or refute perceptions of resource users in this and other studies.

Competing Interests

The authors have no competing interests to declare.

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How to cite this article: Sekonya, J. G., McClure, N. J., & Wynberg, R. P. (2020). New Pressures, Old Foodways: Governance and Access to Edible Mopane Caterpillars, *Imbrasia* (= *Gonimbrasia*) *Belina*, in the Context of Commercialization and Environmental Change in South Africa. *International Journal of the Commons*, 14(1), pp. 139–153. DOI: <https://doi.org/10.5334/ijc.978>

Submitted: 22 May 2019

Accepted: 01 November 2019

Published: 18 February 2020

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