International Journal of Biodiversity and Conservation

Volume 8 Number 9, September 2016

ISSN 2141-243X

Academic Journals

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International Journal of Biodiversity and Conservation

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Vol. 8(8), pp. 196-205, September 2016
DOI: 10.5897/IJBC2014.0742
Article Number: CB34FD259912
ISSN 2141-243X

http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Conserving the caterpillar fungus [*Ophiocordyceps sinensis* (Berk.) G.H. Sung et al.]: A case study of habitat ecology and sustainability in district Pithoragarh, Western Himalaya, India

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Received 3 July, 2014; Accepted 6 May, 2016

The caterpillar fungus, Yartsa Gunbu (*Ophiocordyceps sinensis* (Berk.) G.H. Sung et al.), offers one prime example of the phenomenon, where a resource of immense economic value runs the risk of being over-exploited, more so when its exploitation remains a 'common property resource'. The ever-increasing demand of the commodity in the international markets and concomitantly its ever-increasing price, hovering at present at US$ 20,000 per kilogram locally, has resulted in not just its rampant exploitation but also the degradation of the very habitat, thus endangering its sustainability. The present study conducted across 9 broad study sites, across 110 villages and 2511 harvesters, within the Pithoragarh district, Central Himalaya delves into the following broad objectives; (i) quantity of the harvested lot from the region; (ii) effect of over-harvesting vis-a-vis the degradation of the prime habitat on the quantity harvested each year, as also (iii) its effect on the population size of the host larva (*Thitarodes*), and lastly, (iv) comparative study of the income generated out of the sale of Yartsa Gunbu, with the traditional sources of income. Field visits were made to each of the village; information was gathered through open-ended questionnaire. Host population size study was conducted in three selective sites through hand-sorting method. While over-all quantity of the harvested lot has shown an increase; habitat-wise the quality harvested has shown a perceptible decline in three broad study sites, a trend likely to be replicated by rest of the sites, which currently though is experiencing an increased yield.

Key words: Economy, ethnobotany, habitat ecology, *Ophiocordyceps sinensis,* sustainability, Yartsa Gunbu.

INTRODUCTION

The mushroom is also called the 'caterpillar fungus' on account of its origin, and, more frequently Yartsa Gunbu,

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Figure 1. Yartsa Gunbu or caterpillar fungus. The mature specimen can easily be differentiated with immature one, with the latter's stipe being rough and dark brownish or black in colour towards its end. Locating a fruiting body emerging out from the ground remains a frustrating experience, more so when a number of sprouting herbaceous species closely resemble the fruiting body, both in colour and shape.

which translates as 'winter worm, summer grass', or locally in Kumaun and Garhwal Himalaya as 'Keera ghas', referring to the Larva (syn. *keera*) and the emergent fruiting body that appears as sprouting grass (syn. *ghaas*). *Ophiocordyceps* is a genus of mostly entomophagous flask fungi (Pyrenomycetes, Ascomycotina) belonging to family Ophiocordycipitaceae. The British mycologist Berkeley (1843) first described it in 1843 as *Sphaeria sinensis* Berk. Later Saccardo (1878) renamed it as *Cordyceps sinensis*. Based on molecular phylogenetic study, Sung et al. (2007) separated the mega genus *Cordyceps* into four genera, viz. *Cordyceps* (40 spp.), *Ophiocordyceps* (146 spp.), *Metacordyceps* (6 spp.) and *Elaphocordyceps* (21 spp.), while the remaining 175 spp. were left in the *Cordyceps* group. As a result, *C. sinensis* was transferred to *Ophiocordyceps*, hence renamed as *O. sinensis*.

Ophiocordyceps sinensis parasitizes various grass root boring *Thitarodes* (previously *Hepialus*) caterpillars, which hatch as 'ghost moths' when not preempted by *Ophiocordyceps*. The infective cycle begins with the germination of the fungal spore on the thin integument of the host larva, presumably, during the period of molting, when the larva is most sensitive. The hyphae of the mycelium develop inside the body of the insect, first feeding on less vital parts before taking over the complete organism. Eventually the insect is completely mummified and emptied of nutrients, and all that remains is the exoskeleton filled and coated with *Ophiocordyceps* mycelium. In spring, the mushroom (the fruiting body) develops out of the head of the exoskeleton just above the eyes. The slender, brown, club-shaped fruiting body then emerges from the ground, reaching a total length of 8 to 15 cm (Figure 1). The fruiting season starts as early as mid-May on the eastern slopes of the Kumaun Himalaya, and consequently the harvesting season lasts locally about six weeks. However, the fruiting is delayed locally with increasing altitude, thus the fungus can be collected for nearly two months at different altitudes in some areas. By mid-June to mid-July the collection season is over, but mature fruit bodies with low value are reported to persist into August.

Ethnobotanical use

Traditionally, it has been found that most local folk/traditional healers use Yartsa Gunbu to treat 21 ailments, including erectile dysfunction, female aphrodisiac, malignant tumours, bronchial asthma, bronchitis, diabetes, cough and cold, jaundice, alcoholic hepatitis, among others. The traditional uses of Yartsa Gunbu among the Bai, Naxi, Lisu and Tibetan people living in the mountainous Northern Yunnan province include improving eyesight, in the treatment of calcium deficiency (specific to children), diabetes and associated nephropathy, and indigestion (specific to children), to speed up the labor or parturition, and to strengthen the immune system (Chen et al., 2010).

In some parts of Nepal, Yartsa Gunbu is powdered and combined with the rhizome of *Dactylorhiza hatagirea* for consumption (Adhikari, 2000); which along with honey and cow's milk is used as tonic and aphrodisiac (Lama et al., 2001; Prasad and Satyaal, 2006). As a tonic and for the purpose of sexual stimulant, people of both sexes normally use a daily combined dose of one dried Yartsa

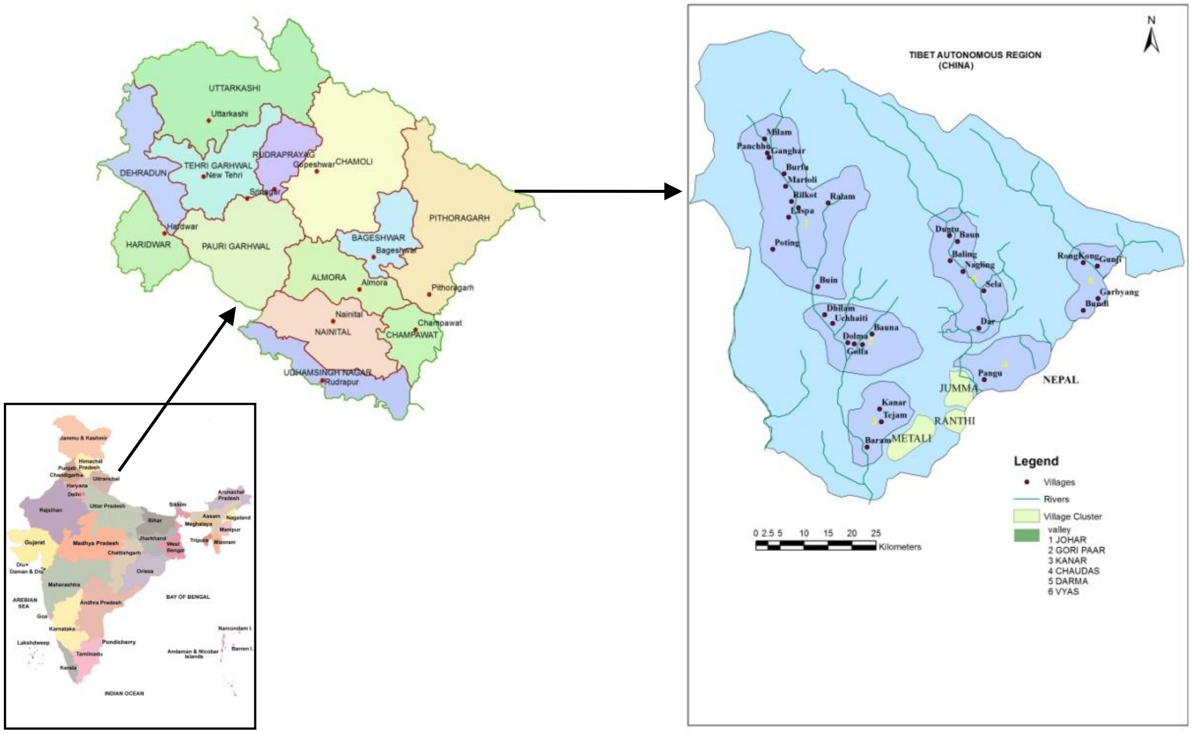

Figure 2. The landscape has been divided into 9 broad study sites.

Gunbu with half liter of milk and two teaspoons of ghee (clarified butter) for a week. Invariably, young or immature Yartsa Gunbu- golden-coloured larvae with short or insignificant fruiting body are recommended for the preparation of the sexual-stimulant (Prasad and Satyaal, 2006). As relates to the present area of study, it has been reported that in Dharchula, the locals consume *Ophiocordyceps* along with local brew, *Chakti.* The mode of intake is that *Ophiocordyceps* is left in the local drink for a period lasting for few days, and then consumed (Garbyal et al*.,* 2004).

Over the last two decades, invariably on account of the two pulling forces- ever-increasing demand of the commodity in the international markets and concomitantly its ever-increasing price, hovering astoundingly at present at US$ 20,000 kg^{-1} (1 US $= 60 rupees), has resulted in not just its rampant exploitation but also the degradation of the very habitat, thus endangering the future viability of the prized species. In the absence of real time data pertaining to the following; (i) over-all volume or the harvested lot from the district (that again is traded illegally across the border), (ii) environmental cost of the harvesting pressure; (a) on yield of Yartsa Gunbu, (b) on the population of the host insect (*Thitarodes*), and (iii) perceptible socio-economic changes in the lives of the harvesters, the present paper attempts to address the above-mentioned objectives with an aim to evolve sound management practices to safeguard the resource for future.

MATERIALS AND METHODS

Study area

The study was conducted in district Pithoragarh, Kumaun Himalaya. The study sites extend between 3200 to 4000 m above mean sea level and lie between 80°15′ to 81°5′ E longitude and 29°5′ to 30°32′ N latitude. Areas known for the availability of the Yartsa Gunbu, encompassing the villages involved in the harvesting, have been divided into 9 broad study sites (Figure 2). The three study sites- Naginidhura, Janthari and Marjhali, selected for intensive study of host insect population size, exhibit considerable variations in precipitation pattern, with the average rainfall ranging between 150 and 200 mm per annum, with the observed mean temperature between 10°C in shade and 15°C in open area, during the conduction of the study (mid-June- July-end).

Data collection

The study was conducted from 2012 to 2014, across the district in 110 villages, known for harvesting Yartsa Gunbu. The landscape was divided into 9 major study sites to make a comparative assessment of the salient aspects, primarily of quantity harvested over the last 5 year period, anthropogenic pressure, management practices (if any). Primary data was collected from a total of 2511 informants, across different age groups, even though efforts were made to elicit information from the family head. Qualitative data , viz., (i) collected lot per season over the last 5 year period, (ii) income earned, (iii) price of the commodity over the last 5 years, (iv) criteria for quality assessment of the sample harvested, and else, (v) the dilution of the traditional conservation practices and of the taboo systems, (vi) a comparative study of the income earned out of the sale of the produce (Yartsa Gunbu) versus the traditional

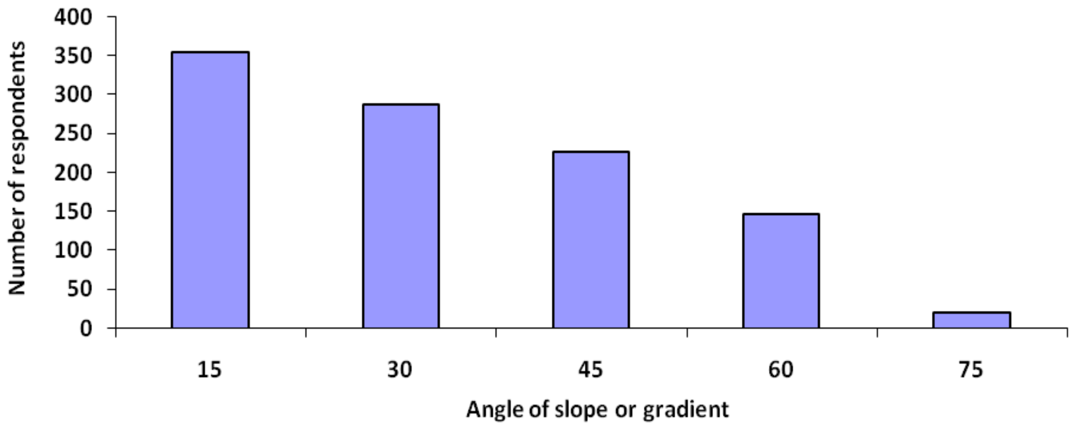

Figure 3. Correlation of the topography with the number of individuals of Yartsa Gunbu harvested (N=1039).

means of livelihood, viz., (a) income from agriculture, (b) medicinal and aromatic plants (MAPs) exploited from the wild and (c) the livestock population and the products derived from it. The information was elicited through an open-ended questionnaire. For population assessments of the host insect (*Thitarodes*), 1 x 1 x 1 feet pits were dug, 5 each within a quadrate of 5 X 5 meters, numbering a minimum of 10 in each study site, taking cognizance of the slope aspects (3), extending from 3200 to 4200 m amsl; the number of individuals of larva was assessed by hand sorting method.

RESULTS

Habitat ecology

Within the broad landscape of district Pithoragarh, Kumaun Himalaya, the most heavily exploited sites are the following: Chiplakot and adjoining Sumdum; Philam, Bon, Baling, Dugtu and Daantu in Darma Valley; Marjhali and Ralam Dhura in Ralam river watershed; Panchachuli (Balati glacier) in the River Mandakini watershed; Nagnidhura and the adjacent Jhanthari meadows lying above Gauri paar watershed; and finally Chhiyalekh and adjoining range in Vyas valley (Negi et al., 2006, 2014, 2015).

Within the study areas, it was observed that north-facing and gentle slopes, preferably little away from water body, but laden with above ground preferred herbaceous families including primarily Polygonaceae, Fabaceae, Cyperaceae, Poaceae and Liliaceae, harbour good population of host species (*Thitarodes*), and thus of Yartsa Gunbu. This fact was also substantiated by the harvesters, who, built on their experience, would frequent these spots, least oblivious of what constitutes north or south-slopes. The soil is sandy-loam, with pH always slightly acidic, usually around 5, in all the sites.

Even though the distribution of the *O. sinensis* in the landscape is confined within 3200 and 4800 m, a relatively wide niche one would believe, however since the topography within the alpine zone, show extreme variability in terms of the micro-habitats, the niche breadth eventually narrows down. Another bare fact to take note of is that lately, the lower reaches of the habitats, previously being harvested for Yartsa Gunbu, no longer harbour the same. This could be ascribed on account of the space being occupied by the harvesters during their interim stay during the harvesting season. Since the quantity harvested is inversely related with the gradient of slope, that is, with greater availability reported at 15° slope, and progressively declining with greater angle; the very ‘act of stay’ negatively impacts upon the yield of Yartsa Gunbu (Figure 3).

Habitat destruction brought about by the ever increasing harvesters remains the major cause of concern. This fact becomes obvious since the harvesters themselves have to procure the fuel wood from relatively greater distance (200 to 300 m) downhill in a number of sites visited. Lately however, the elderly folks have begun raising their concern as relates to the fast depletion of the woody species; more so when the local harvesters are out-numbered by the contract labourers from outside, who for obvious reasons, have least regard for the sacred landscape or its flora. Five years back, the present author had successfully implemented an effective mechanism to restrict the outsiders- not belonging to the said Van panchayat (forest council) by issuing permits to the local inhabitants of the village only. It was unfortunate to come across the fact that these passes (distributed even to infirm and elderly) are now auctioned to outsiders at unbelievable price (up to US$ 1,166 per pass). Yet another latest feature of exploitation (even though disliked by many) is hiring of labourers (mostly the proficient Nepalese) on contract basis by the local powerful villager, whose sole job is to make provisions for their lodging in the alpine meadows, in return for 50% of their harvested lot. Interview with the Nepali labourers was: ‘the population size in their meadows has declined (precipitously, and in fact, parting with 50% of their produce fetches more money that what they would earn

Table 1. Population density of the host species-*Thitarodes* sp.

Study period (confined to a duration of 2 weeks per month)	Population density of *Hepialus* sp. per hectare		
	2012	**2013**	**Percentage decline**
May	1144	976	14.68
June	1230	1078	12.36
July	1568	1366	12.88
August	988	798	19.23
September	1160	987	14.91
Average (rounded off)	**1218**	**1041**	**14.81**

in Nepal)'. The situation is greater number of harvesters, arriving too early in the habitat sites; competing among themselves to harvest his/her larger share, only lends credence to Hardin's 'Tragedy of the commons' (Hardin, 1968). The aftermath is a desolated landscape, bereft of the erstwhile woody species, and concomitant loss of the refuge of such wild species, such as Monal pheasant (*Lophophorus impejanus*) and muskdeer (*Moschus chrysogaster chrysogaster*).

Abundance of the host larva

The overall availability of the *O. sinensis* has to be seen vis-à-vis the population dynamics of the host insect, whose population again would be determined by the precise health as well as number of the host plant species. Reportedly, the normal reproductive cycle for *Thitarodes* (*Hepialus*) takes up to five years; most of the life cycle is lived as a caterpillar, the moth itself living for only a short time, 2 to 5 days in the case of *H. biruensis* (Chen et al., 2002). The host for *C. sinensis* most commonly reported is *Thitarodes armoricanus* (Oberthür) Ueda, Hepialidae, Lepidoptera. Other host larvae have been identified, such as *Hepialus oblifurcus* Chu & Wang (Gao et al., 1992), *H. baimaensis* Liang and *H. biruensis* Fu Huang & Chen (Chen et al., 2002). All in all, nearly 50 species of *Thitarodes* (*Hepialus*) moths are recognized, out of which 30 species are known to be infected by *Ophiocordyceps sinensis* (Chen et al., 2002). The genus *Thitarodes* was erected in 1968 to accommodate *H. armoricanus* and other related species placed originally in *Hepialus*, many of which are the host for *O. sinensis* (Nielsen et al., 2000).

During the study, the larval stages of the moth were encountered even at the depth of 2 feet or more, even though for the population study, the study was confined to 1 feet depth only. Early stage larva reportedly are confined to greater depth than those of, say the fourth or fifth instar larva, which normally is the developing stage of the host larva, usually encountered by the harvesters, hidden or just emerging out from the superficial upper layer of soil, that are infected by the spores of the *O. sinensis,* probably just before it undergoes molting (4th instar larva) or pupation (5th instar larva), since these stages are the only ones encountered, above ground. However, from the conservation point of view what is more important is the fact that a significant, 14.81% decline in the population of the host insect has occurred within just two years (Table 1). Even though, the perceptible decline cannot be taken as conclusive, the present preliminary study does re-enforce the belief that greater anthropogenic pressure invariably has negative effect upon the host larval population. However, conclusive results can only be drawn if (i) similar studies are conducted across multiple sites differing in intensity of harvest, (ii) undertaken over a relative longer time span, and (iii) environmental variables affecting the population size of the host larva are recorded.

Interestingly, the villagers have their own observation as relates to decline in population size (Figure 4), and infact lately have started raising concerns, as to the precise mode of uprooting the specimen by digging holes and not filling up the same post harvesting, since they have noticed that these sites do no harbour the worm, when they visit the site next year round.

Quality of specimen traded and ecological implications

Ophiocordyceps is traded in several categories; the main criteria defining the quality of the produce, in order of preference are the following: Lower water content (completely dried samples are preferred than the fresh ones), the state of processing (cleaned rather than uncleaned), and the size. Freshly harvested caterpillar encased in black topsoil layer is usually cleaned with a toothbrush and then dried under shade. The degree of dryness of Yartsa Gunbu is an important factor that controls weight, a price determining factor. Dealers assess the moisture content by the flexibility of the fungus; the less pliable the fungus, the dryer it is. Prices clearly fluctuate through the year, especially depending on the annual harvest.

Another very important quality besides larval size is the ratio of the size of the fruiting body, growing out of the head of the larva, versus the size of the insect larva.

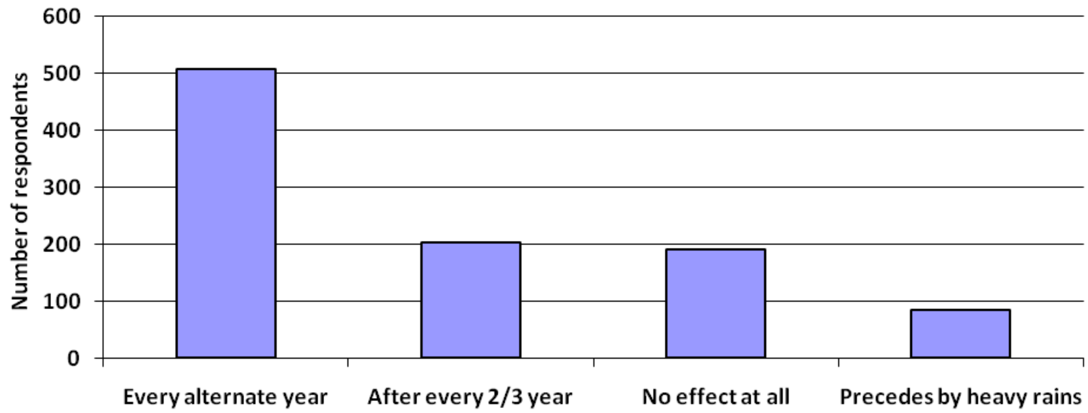

Figure 4. As per the responders, the availability of Yartsa Gunbu shows a decline every alternate year (N=984).

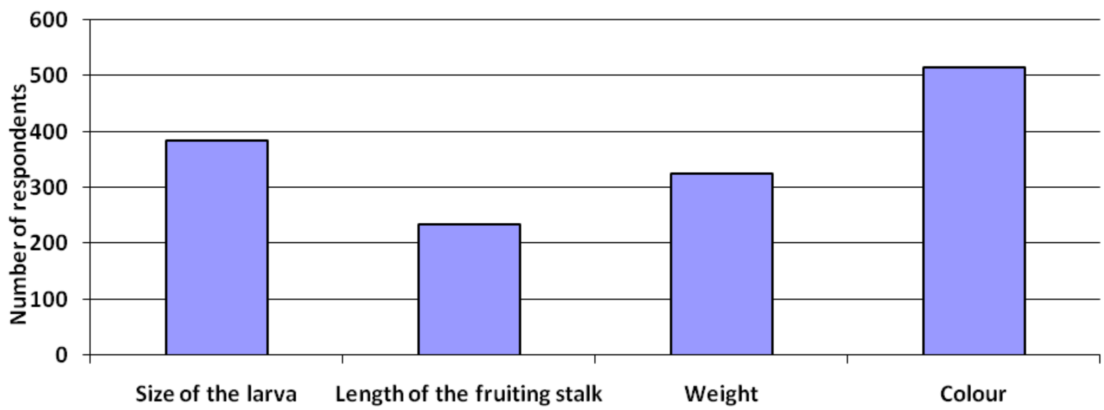

Figure 5. Gross parameters to assess the quality of the specimens (N=1460).

Highest value is for a Yartsa Gunbu, whose fruiting body is bit shorter than the larva or at least not much longer, since in general this ratio indicates the timing of the harvesting (Figure 5). The healing power of Yartsa Gunbu is in fact believed to be concentrated in the caterpillar, filled with *Ophiocordyceps* mycelium. Firmness of the larva is thus important in pricing. The harvesters are thus forced to collect caterpillar fungus early in the season. In fact, 70 to 80% of the harvested lot consists of immature specimens. This figure could be on higher side, but relates well with the finding of Shrestha and Bawa (2013), who reported 94.4% of the caterpillar fungi as reproductively immature from Dolpa district, Nepal.

Needless to emphasize, collection of such specimens will negatively impact reproduction and its future availability in the wild. The exorbitant price hike only makes the practice more detrimental. Educating the harvesters about the precise life cycle and the importance of the availability of the mature specimens for the completion of the infective cycle would go a long way in sustaining the future availability of the Yartsa Gunbu, or a mechanism is evolved whereby the duration of the harvesting is reduced, allowing a proportionately greater number of individuals to mature and disperse their spores. With perceptible decline in yield per unit space, and as observed by the harvesters, this remains the only alternative to safeguard or assure the availability of the resource for future.

Economics of Yartsa Gunbu

Anyone familiar with fungi is aware of the enormous fluctuations in yearly production of fruiting bodies, generally perceived as the result of fluctuations in weather conditions, which impacts on the life cycle of the host insect. Additionally, incongruities in data collected at the household level can appear, when collectors do not want to disclose how much they are actually collecting, more so, when the product is very valuable; also ambiguity remains as to its legality of exploitation. The results of the survey work show that while the quantity harvested collectively over the broader landscape has

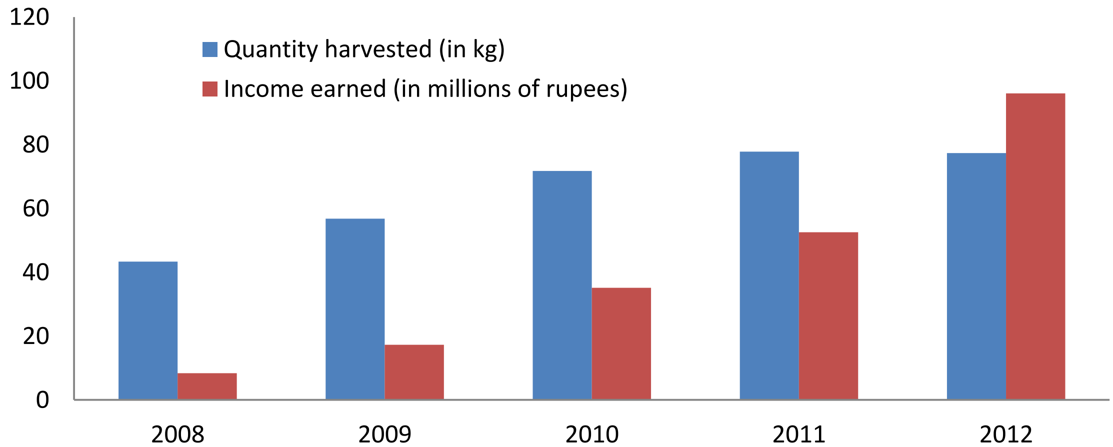

Figure 6. Quantity of Yartsa Gunbu harvested over the period (2008-12) and the income generated (figures confined to the stakeholders N= 2511; 1 US$= 60 INR).

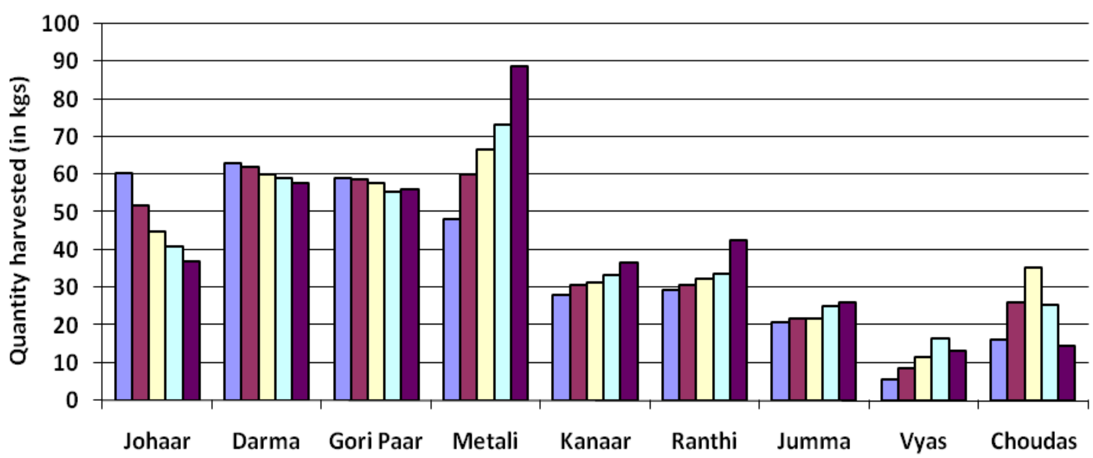

Figure 7. Quantity of Yartsa Gunbu harvested over the last five year period (2008-2012). A rough estimate of the total yield as per the informants (N=2511).

remained more or less steady over the last 5 years, the price of the commodity has increased many folds (Figure 6). In fact, the highest price offered during the penultimate year becomes the base-price for the next year. In other words, the price per kg of US$ 20,000 in the year 2012 becomes the base price for the year 2013. While the price of the commodity has only increased sharply, the quantity harvested is pattering off

Figure 7 brings out explicitly the decline in quantity harvested of Yartsa Gunbu in Johaar, Darma and Gori Paar valleys. One might ask what the reason is. These three landscapes are representative of habitat sites, which have been extensively explored for the presence of Yartsa Gunbu in the beginning, discovery of new sites only led to increase in the harvest. However, with no new sites left to be explored, concomitant to increased anthropogenic pressure, the yield eventually declined. The declining yields exhibited by these three valleys offer lesson that the future viability of the produce is intimately bound with the harvest pressure and the resultant denudation of the vegetation cover of the habitat sites.

Apart from Johaar (and to some extent the Darma) valley, the income earned from Yartsa Gunbu forms the only means of sustenance, presently (Figure 8). The problem is accentuated by the fact that most, if not all, have lately started showing indifference towards growing their traditional crops, or at the best leaving the same to the mercy of the wild animals, especially the monkey. While the yield has remained more or less stagnant over the last three years (2010-2012), the income earned has more than doubled over the same period! In fact, the income generated by the Yartsa Gunbu, restricted to a bare one and half months period far exceeds the traditional sources of income combined (Figure 8). This is a cause of concern, more so in the absence of any pro-active measures to manage the exploitation of Yartsa

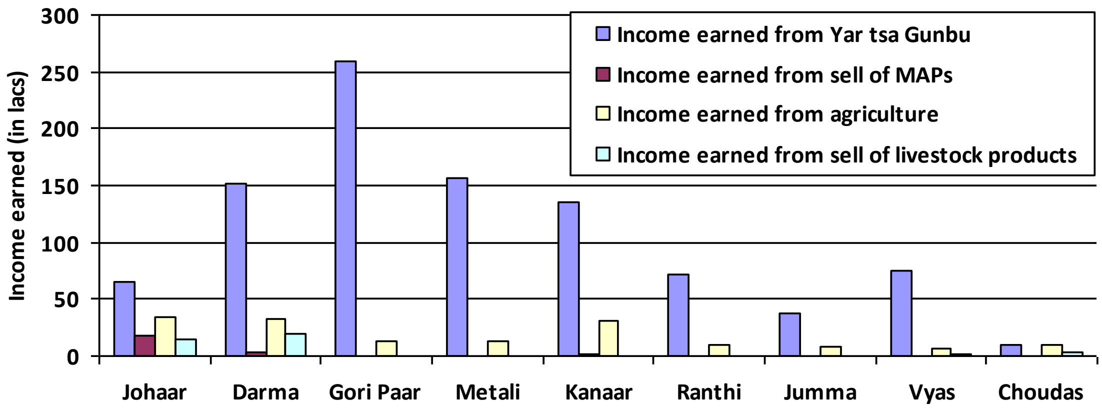

Figure 8. Income earned from the sale of Yartsa Gunbu offshoots the income earned collectively out from traditional crops, livestock or livestock products and sell of medicinal and aromatic plants (N=2511).

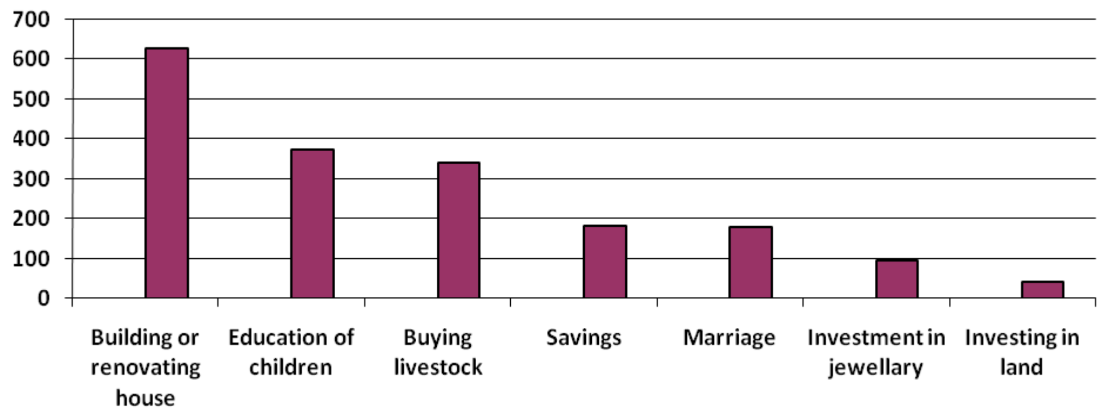

Figure 9. The income earned out of the sale of Yartsa Gunbu is principally invested in renovation of houses, education of the children and buying livestock (N=1732).

Gunbu, and the resultant (and very much conspicuous) deterioration of the habitats; the future availability of Yartsa Gunbu remains doubtful. What is warranted is to find ways whereby the pressure on Yartsa Gunbu is minimized.

The multiple effects of the Yartsa Gunbu harvest

When the price of the commodity hovers above US$ 20,000 kg^{-1} locally, it would seem that the harvesters are making a fortune. However, the truth remains that the yield per family averages between 150 and 300 specimens only. Considering the fact that around 3600 to 4200 Yartsa Gunbu pieces make up a kilogram; the family usually ends up earning between 1 and 2 lacs only. Considering the fact that the traditional means of sustenance- agriculture, livestock, and collection of medicinal herbs, is barely substantial, the extra income earned through sale of Yartsa Gunbu has just about enabled the poor to make secure investments, such as reconstruction of houses, education of children, else (Figure 9).

Yet another fortunate outcome of the Yartsa Gunbu phenomenon is that the bhotiya tribesmen, who had long lost touch with their villages, principally their summer homes, are now returning back to their roots. In fact, claimants are busy tracing their roots to a village with Van Panchayat harbouring Yartsa Gunbu. One could thus envision that the resultant longer duration of stay in summer homes will in turn encourage the villagers to go-in for cultivating the crop species, such as *Nappal* (durum wheat), erstwhile main crop of commerce traded with the Tibet. In zist, any effort on part of the policy makers or the enforcement agencies bent on prohibiting the exploitation of the Yartsa Gunbu, need to appreciate the above-mentioned facts; and thus endeavour not to bar the locals from harvesting of Yartsa Gunbu *per se*, but more importantly make them aware of the declining yields of the produce, and how best they can stop the trend.

Dilution of traditional conservation practices

i. The fact remains that until a few years back, the womenfolk were tabooed to enter into the alpine meadows (considered sacred), which obviously restricted the number of the harvesters. However, with the increase in the price of the commodity, the age-old taboo is now grossly discarded, and the womenfolk are actually encouraged to go for collection.

ii. Harvesting of the medicinal and aromatic plants (MAPs), such as *Kutki* (*Picrorhiza kurrooa*), *Salampanja* (*Dactylorhiza hatagirea*), *Jatamasi* (*Nardostachys jatamansi*), *Ginjari* (*Chaerophyllum villosum*), etc would only begin towards late-half of September, post the flowering and shedding of the seeds. However, presently exploitation of these species is carried out along-side Yartsa Gunbu.

DISCUSSION

Given the ever increasing demand in the international markets and the price of the commodity, it would be safe to presume that Yartsa Gunbu faces a very bleak future, not just because of harvesting alone, but more on account of the degradation of the very habitat and denuding vegetation cover, upon which its host thrives. Obviously, efforts of the policy makers as well as of enforcement agencies, both at the state level as well as village-level institutions have failed to stop the trend. The precarious situation is accentuated by the fact that the local inhabitants across the broad landscape in general, lack opportunities to raise their socio-economic profile via-a-vis other traditional means of livelihood.

Even though, a small segment of the locals have begun raising their voice, primarily as relates to the degradation of the habitats sites, more so since the same constitutes sacred sites, too; this is less likely to have any impact. Since the degradation is wreaked more by the outsiders, the contract labourers, issues are being aired in the village-level meetings against such practices. It is vital that local-specific awareness campaigns be launched to educate the stakeholders of the declining population size of not just the Yartsa Gunbu *per se,* but also of its host insect; and the close relationship between the availability of the Yartsa Gunbu with the population size of the host larva; or to extend it further, of the association between the host larva and the intactness of the above-ground vegetation.

The amount as well as frequency of harvests can be altered by evolving policies or through implementation of regulatory mechanisms (Olsen, 2005; Weckerle et al., 2010), or at times even through alternative economic incentives for not harvesting (Varghese and Ticktin, 2008). However, when the targeted species fetches more than US$ 20,000 kg^{-1} locally, the provision of incentive becomes impracticable. However, regulatory mechanism could bear fruit, if the villagers are convinced about the negative impact of their harvesting on the sustainability of the resource. Any other regulatory means would simply prove inadequate, on account of (i) lack of manpower to monitor the harvest, confounded by near inaccessibility of the mountain terrain, even though explored by the harvesters, and (ii) the sear financial gains accrued to the harvesters out of the exploitation of Yartsa Gunbu.

There is an urgent need to educate the villagers on (i) the need to restrict the numbers of the harvesters, say, restricting the number of members per household, (ii) shortening the length of their stay in the alpine meadows, to be enforced by a management body, which will check if any infringement to the established norms is flaunted. It is strongly believed that the local collectors can be the best stewards of their resources, if they are well informed and understand what is at stake. Under such circumstances they could accept certain regulations-crucially the stopping of collection once sporulation begins late in the season- as part of sustainable resource management, (iii) ensuring that degradation of the habitats, primarily on account of procuring the fuel wood, and thus species, do not take place, (iv) an effective mechanism be evolved at the village level to ascertain the quantity of the harvested lot vis-à-vis the extent and duration of the harvesting, and finally (v), a legal status to the harvesting of the species be rendered forth, so that the produce gets marketed and not trafficked across the borders.

Empowerment remains the key word. The village level institutions needs to be involved in the formulation and implementation of any policies that relates to conservation or development. Instead of multiplicity of institutions, already existing village level institution should be merged (for example Ecodevelopment Committee would infact be part and parcel), and with whom management concerns could be shared for implementation. As relates to Yartsa Gunbu, record of collections should be maintained by the village Van Panchayat (forest council). Also efforts should be made by the government to auction the produce to the international buyers directly, to get rid of the middlemen, and the loss to the exchequer. This will not just result in the transparency of the trade, but most importantly will garner maximum financial benefit to the harvester as well as generate revenue to not just the village council but also to the state, at large. More so, when the price of Yartsa Gunbu at the local level, US$ 20,000 per kg seems incredible, the price of the best quality Yartsa Gunbu fetches US$ 1,00,000 kg^{-1} in China, and US$ 1,30,000 kg^{-1} in Singapore (Shrestha and Bawa 2013).

Because local harvests are often guided by demand and price in regional and global markets (Weckerle et al., 2010), rising prices results not just in over-exploitation of the species (Nijman, 2010), but very often, the collected lot remains unsold in the vain belief that a far better price would be earned, if the sale is kept in abeyance. This phenomenon, very often leads to deterioration and thus quality of the harvest, and concomitantly its market value. In addition, the mystery that shrouds the very legality of the harvest, only accentuates the problem further. Hence the need for a transparent policy that governs the harvest, its recorded quantity, and its sale could only lead to extension of technology, in terms of better storage or processing, can be extended to the villagers.

Conflict of interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the financial help received from the Ministry of Environment, Forests and Climate Change (Government of India), Paryavaran Bhawan, CGO Complex, New Delhi. The study however, would not have been possible without the help of the village residents-the ultimate custodians of the biodiversity.

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academicJournals

Vol. 8(8), pp. 206-215, September 2016
DOI: 10.5897/IJBC2016.0969
Article Number: A4B7E9059914
ISSN 2141-243X

http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Structure and composition of the liana assemblage of Azagny National Park in the Southern Côte d'Ivoire

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Received 27 March, 2016; Accepted 14 June, 2016

The Azagny National Park represents one of the most important blocks of forest in Côte d'Ivoire, but its liana assemblage has never been characterized. Liana floristics, diversity, species composition and structure were evaluated. Fourteen plots of 1 ha (20 × 25 m) were established in different biotopes of the forest. All individual lianas of dbh ≥ 1 cm were identified, measured and marked. For each 1 ha plot, old growth forest from secondary forest was distinguished. In total, 5,436 lianas, representing 63 species, 47 genera, and 28 families were identified. The average number of species was 18.35, mean basal area was 0.21 m^2 and mean Fisher's alpha, Shannon index and Simpson diversity index values were 19, 2.81 and 0.72, respectively. Ten dominant plant families accounting for 83% of total species richness, 71% of liana abundance and 71% of basal area were also identified. Twiners, zoochorous, light-demanding and microphanerophyte species dominated. There were more large lianas in old growth forests than in secondary forests. The liana assemblage and species floristic composition is generally similar to that in other tropical African forests.

Key words: Lianas, old growth forest, secondary forest, species diversity, Azagny National Park, Côte d'Ivoire.

INTRODUCTION

Lianas (woody climbers) are notoriously abundant in the tropics, contributing up to 25% of the woody stem density (Gentry, 1991; Schnitzer and Bongers, 2002), and up to 12 to 40% of the overall species diversity of such forests (Gentry, 1991). Apart from their direct contribution to biodiversity, lianas help maintaining diversity through their effects on forest structure and dynamics (Putz, 1984; Schnitzer et al., 2012), and thus on species composition of both plants and animals.

A number of studies have documented the functional aspects of lianas in tropical forests. Indeed, lianas substantially contribute to canopy closure after tree fall, stabilizing the microclimate underneath, and contributing to whole-forest transpiration (Schnitzer and Bongers,

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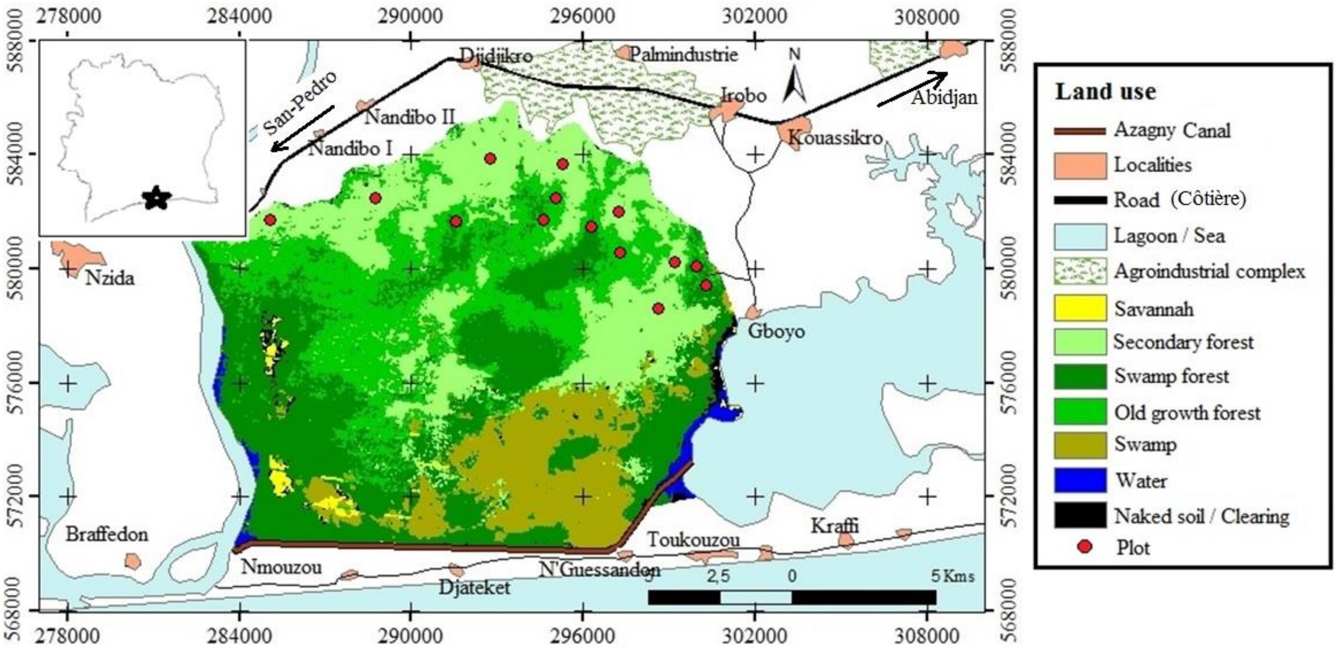

Figure 1. Location map of the Azagny National Park (ANP) in the South Cote d'Ivoire showing different types of biotopes.

2002). Lianas contribute also to the carbon budget of tropical forests (Lewis et al., 2009), representing as much as 10% of the fresh above-ground biomass (Putz, 1984), and accounting for up to 40% of the leaf productivity (Hegarty and Caballé, 1991). By colonizing trees, lianas create structural stress on their hosts, compete for light, water and soil nutrients, generally reducing tree growth (Dalling et al., 2012), and reproduction; while increasing rates of tree fall and limb breakage (Putz, 1984).

The varying species composition of lianas, in different forest types, demonstrates that there are large ecological and functional differences across species. Lianas have a similar growth form and are generally light demanding (Putz, 1984), but they do differ in, for example, climbing mechanisms (Putz and Holbrook, 1991) and light requirements (Kuzee and Bongers, 2005). Furthermore, dispersal type varies markedly across liana species (Cai et al., 2009), and are correlated with a wide range of pollinators and propagule distributers. All this enables lianas to occupy a wide range of habitat types (Nabe-Nielsen, 2001). The abundance, species diversity, and distribution of lianas depends on several abiotic factors, including total rainfall, seasonality (DeWalt et al., 2010), soil fertility (Toledo, 2010), landscape topography (Dalling et al., 2012), canopy structure (Ibarra-Manríquez and Martínez-Ramos, 2002) and disturbance regimes.

Although the importance of lianas is broadly recognized in the tropical world, in Ivorian forests, very few liana studies have been undertaken (Etien and Traoré, 2005; Kuzee and Bongers, 2005; Tra Bi et al., 2005; Kouassi, 2007). The present study could help redress this lack. It aims to evaluate the community structure of the liana assemblage in a national park in the South Côte d'Ivoire. Using data from 14 forest plots of 1 ha each, we (1) describe the floristics, diversity and structure of the liana assemblage in this park; (2) characterize liana functional traits (climbing mechanisms, regeneration guilds, stem size and dispersal syndromes); and (3) determine the effect of forest structure on liana species abundance.

Hypotheses were tested the that (1) the liana assemblage in the Azagny National Park (ANP) is similar in diversity and structure with rain forests elsewhere, but precisely similar other such assemblages in West Africa, and (2) there is a correlation between the number of species and of abundance between the two forest types.

MATERIALS AND METHODS

Study site

The Azagny National Park, located in the South of Côte d'Ivoire, between 5° 14' and 5° 31' north latitude, and 4° 76' and 5 ° 01' west longitude, covers an area of 21,850 ha (Kouamé et al., 2010) (Figure 1). It covers the Departments of Grand Lahou and Jacqueville, and is part of the phytogeographical region of "Upper Guinea", which stretches from Senegal to Togo.

Azagny National Park is a low lying and composed of vast swamp areas (about 9,000 ha), made of salt water, which does not show any sign of natural sinking (Kouamé et al., 2008). The water regime of the park gives its ecological specificity. Three quarters of its area are formed by the complex Bandama River, the Azagny

Canal and the Ebrié lagoon. Finally, the park is flooded to 45% throughout the year and 62% during the main rainy season. The climate of the region is sub-equatorial (Avenard et al., 1971). Few studies have been undertaken in this park concerning its diversity. In the same way, the history of the occupation of the park allows a variety of habitats to meet the objectives of this study.

Data collection

From September 2013 to December 2014, data was collected in the Azagny National Park. Fourteen plots of 1 ha, sub-divided into smaller plots (20 × 25 m), were surveyed. Seven different plots have been selected in old growth forests and seven in secondary forests, which are old fallows to allow comparisons.

In each 1 ha plot, a grid of 20 contiguous 20 × 25 m^2 quadrats was demarcated. All liana individuals of dbh ≥ 1 cm were identified and measured. Liana dbh was measured at 1.3 m distance along the stem from their rooting point. To facilitate comparison with other liana studies, true liana species was only included: woody climbing plants that germinate on the ground but lose their ability to support themselves as they grow, so they have to rely on external physical support to ascend to the canopy (Gerwing et al., 2006; Schnitzer et al., 2008).

All botanical identifications were based on both reproductive (flowers or fruits) and vegetative (leaves, bark and trunk) characteristics of specimens collected or observed in the field. In most cases, either fertile or sterile material was collected for identification at the reference Herbarium of the Botanic Garden in Félix Houphouët-Boigny University. Family and species nomenclatures follow Lebrun and Stork (1991–1997).

Data analysis

Liana floristic and structural components at three scales were characterized: fine (20 × 25 m quadrat), plot (7 ha) and community (14 ha). All analyses are based on identifications at three taxonomic ranks: species, genus, and family. Morphogroups not identified to a named taxon (10.31% of all recorded stems) were excluded from further analyses.

To describe the liana community structure, for each taxon, the Importance Value Index (IVI), was calculated, that is, the average percentage of relative density, its occurrence frequency (based on 20 × 25 m plots) and its basal area (Mueller-Dombois and Ellenberg, 1974). The total number of species, genera, and families were tallied for each plot (1 ha) and for the whole community (14 ha).

Three indices were used: Fisher's alpha, the Shannon index, and Simpson diversity (1/D, where D is the standard Simpson Dominance), to calculate liana diversity in the 14 ha community. These indices were selected based on their discriminant ability, sensitivity to sample size, and popularity. Estimate S 8.0 was used to compute the abundance-based coverage estimator (ACE) and Coleman non-parametric estimators of species richness (Chazdon et al., 1998).

In each 20 × 25 m quadrat, the lianas were categorized as small (dbh ≤ 5 cm) or large (dbh > 5 cm). The hypothesis that the number of liana species would affect the liana abundance and that the abundance of species, by diameter class, depends on the type biotope, was tested using Wilcolson test (R 2.15). Old growth forests and secondary forests subplots were compared for abundance of liana stems using t tests.

Functional traits/ecological characteristics (climbing mechanism, stem size, regeneration light requirements and primary dispersal syndrome) were assigned to each species, either by direct field observations and/or using data available in the primary literature (Aké-Assi, 2001, 2002; Adou Yao, 2005; Vroh, 2013). Climbing mechanisms for all liana species were categorized as (1) stem twiner, (2) hook climber, (3) root climber, and (4) tendril climber. Stem size was classified following Raunkiær (1934) as: mega-phanerophyte (> 30 m), meso-phanerophyte (8 to 29 m), micro-phanerophyte (2 to 7 m), and nano-phanerophyte (< 2 m). Regeneration light requirements were grouped into two classes: light demanding and shade tolerant. Three primary dispersal syndrome classes were used: anemochory, zoochory and barochory.

RESULTS

Floristic and taxonomic diversity

A total number of 5,436 stems were recorded in the fourteen 1 ha plots. Of these stems, 89.69% (4,876 stems) were identified to species level, and represented 63 species in 47 genera and 28 families. Secondary forest (41 species, 32 genera and 25 families) was slightly richer than old growth forest (39 species, 34 genera and 21 families). The ten most abundant species collectively accounted for 46.3% (2,258 stems) of all stems, and 57.6% (1.33 m²) of all basal area (Table 1). *Adenia lobata* (Passifloraceae) had the highest Importance Value Index (19.2%): it accounted for 6.9% of all liana stems and 5.4% of the total basal area, and was distributed in 6.9% of the quadrats. The ten most important genera included 16 species (25.4%), and contributed 54.7% of all stems and 58.3% to the basal area. *Adenia* (Passifloraceae) was the most abundant genus, but *Strophantus* (Apocynaceae) had the highest basal area (8.8%). *Cissus* (3 species) was the most speciose genus but contributed only 3.8% to abundance, and 2.5% to basal area. Ten of 28 families contained 27 genera, and contributed 71.0% to the number of stems, 70.9% to basal area, and 90.0% to total Importance Value Index. The most speciose families were Fabaceae (7 species), Apocynaceae (5 species), and Icacinaceae (5). *Calamus deerratus* (Arecaceae) was the only palm liana in the Azagny National Park liana assemblage.

Species richness and diversity

An average of 18.35 species, 13 genera and 11.28 families were recorded per hectare (Table 2). Fisher's α was 19.0 ± 2.7 ha^{-1}, Shannon index was 2.81 ± 0.25 ha^{-1}, and Simpson index was 0.72 ± 0.01 ha^{-1}. In the whole community (14 ha), we found that hectare-based species number estimates ranged from Coleman = 50.3 to ACE = 74.8. At the smaller scale of 20 × 25 m quadrats, all values were considerably lower.

Liana assemblage structure

Based on the fourteen 1 ha plots, mean stem density was

Table 1. The ten most abundant species, genera and families of lianas in the Azagny National Park (ANP). Abundance, basal area and importance value in 14 ha of forest. Values between parentheses represent percentages of abundance and basal area.

	Scientific name	Family	Stem abundance	Basal area (m^2/ha)	Importance value (%)
Species	*Adenia lobata*	Passifloraceae	376 (6.9)	0.16 (5.4)	19.2
	Tiliacora dinklagei	Menispermaceae	362 (6.7)	0.25 (8.3)	18.8
	Strophanthus gratus	Apocynaceae	292 (5.4)	0.26 (8.8)	18.2
	Alchornea cordifolia	Euphorbiaceae	246 (4.5)	0.11 (3.6)	13.3
	Piper guineense	Piperaceae	260 (4.8)	0.10 (3.4)	12.4
	Pararistolochia leonensis	Aristolochiaceae	186 (3.4)	0.11 (3.5)	9.9
	Calamus deerratus	Arecaceae	146 (2.7)	0.11 (3.7)	8.4
	Macaranga bellei	Euphorbiaceae	158 (2.9)	0.08 (2.8)	8.2
	Cnestis ferruginea	Connaraceae	148 (2.7)	0.04 (1.3)	7.0
	Secamone afzelii	Asclepiadaceae	84 (1.5)	0.11 (3.8)	6.9
	10 most abundant	-	2258 (46.3)	1.33 (57.6)	48.1
	All other	-	2618 (53.7)	0.98 (42.4)	51.9
	Total for identifed species	-	4876 (89.7)	2.31 (77.7)	84.8
	Total for non-identified morphogroups	-	560 (10.3)	0.66 (22.3)	15.2
	Total (14 ha)	-	5436 (100)	2.97 (100)	100
	Number of identified species	-	63	-	-
Genera	**Genus**	**# Species**			
	Adenia	2	474 (8.7)	0.2 (6.6)	23.71
	Tiliacora	1	362 (6.7)	0.2 (8.3)	19.1
	Strophanthus	1	292 (5.4)	0.3 (8.8)	18.6
	Clerodendrum	3	318 (5.8)	0.1 (3.8)	15.9
	Alchornea	1	246 (4.5)	0.1 (3.6)	13.7
	Piper	1	260 (4.8)	0.1 (3.4)	12.7
	Pararistolochia	1	186 (3.4)	0.1 (3.5)	10.2
	Cissus	3	206 (3.8)	0.1 (2.5)	10.1
	Macaranga	2	178 (3.3)	0.1 (3.1)	9.0
	Calamus	1	146 (2.7)	0.1 (3.8)	8.6
	10 most abundant	16 (25.4)	2668 (54.7)	1.4 (58.3)	54.8
	All other identified	47 (74.6)	2208 (45.3)	1.0 (41.7)	45.2
	Total for identifed genera	63 (100)	4876 (89.7)	2.4 (77.0)	86.2
	Total for non-identified genera	-	560 (10.3)	0.7 (33.0)	13.8
	Total (14 ha)	-	5436 (100)	3.1 (100)	100
Families	**Family**	**# Species**			
	Apocynaceae	5	470 (8.6)	0.34 (11.5)	27.8
	Passifloraceae	2	474 (8.7)	0.2 (6.6)	24.1
	Euphorbiaceae	4	436 (8.0)	0.2 (6.7)	23.0
	Fabaceae	7	512 (9.4)	0.3 (6.8)	22.8
	Menispermaceae	3	438 (8.1)	0.1 (9.1)	22.7
	Verbenaceae	3	318 (5.8)	0.1 (3.8)	16.2
	Piperaceae	1	260 (4.8)	0.1 (3.4)	13.0
	Aristolochiaceae	1	186 (3.4)	0.1 (3.5)	10.3
	Vitaceae	3	206 (3.8)	0.1 (2.5)	10.2
	Icacinaceae	5	160 (2.9)	0.1 (3.4)	9.3
	10 most abundant	34	3460 (71.0)	1.7 (70.9)	90.0
	All other identified	29	1416 (29.0)	0.7 (29.1)	10.0
	Total for identifed	63	4876 (89.7)	2.4 (77.0)	89.9
	Total for non-identified	-	560 (10.3)	0.7 (33.0)	10.1
	Total (14 ha)	-	5436 (100)	3.1 (100)	100

Table 2. Liana community floristic and structural attributes of Azagny National Park (ANP) (mean ± SD).

Site	Old growth forest		Secondary forest		Azagny	
Attribute	20x25 N=140	1ha N=7	20x25 N=140	1ha N=7	20x25 N=280	1ha N=14
Strutural and taxonomic recorded characteristics						
Abundance	19.6±7.02	392±133.8	19.22±9.23	384.6 ±173.5	19.41±8.2	388.3±143.9
Basal area (m^2)	0.01±0.01	0.30±0.12	0.006±0.005	0.12±0.09	0.01±0.009	0.21±0.13
Number of species	7.67±2.22	19.14 ±7.08	8.21±3.04	17.57±4.57	7.94±2.67	18.35±5.78
Number of genera	5.44±1.58	12.42±3.15	6.19±2.24	13.57±2.76	5.81±1.97	13±2.90
Number of families	5.2±1.55	10.57 ±2.93	5.86±2.18	12±2.16	5.53±2.02	11.28±2.58
Species richness non-parametric estimator						
ACE	19.48±10.77	74.88±11.34	15.84±5.12	66.22±3.26	17.66 ±7.95	70.58±7.27
Coleman	10.31±2.58	69.1±2.8	6.11±2.04	50.33±1.3	8.21±2.31	59.77±2.11
Species diversity						
Fisher's Alpha	9.27±2.2	22.17±4.2	6.68±2.45	15.8±0.9	7.97±2.32	19.0±2.57
Shannon	2.26±0.24	2.78±0.32	2.30±0.30	2.84±0.18	2.28±0.28	2.81±0.25
Simpson	0.77±0.8	0.72±0.01	0.73±0.7	0.73±0.006	0.75±0.07	0.72±0.01

388.3 ± 143.9 stems ha^{-1}, and mean basal area was 0.21 ± 0.13 m^2 ha^{-1}. Taxonomic abundances (Figure 2), at the 14 ha level, varied greatly. Six species (6%) were only known as two individuals; while 56% of all stems were represented by species with less than sexteen liana stems (Figure 2A). In contrast, genera and families exhibited lognormal-like distributions (Figure 2B and C), indicating that taxa vary markedly in their abundances. Most liana individuals were small: nearly 78% were smaller than 3 cm in diameter; while only 1% of stems had a dbh of more than 10 cm (Figure 2E). On average, stems measured between 2 and 3 cm in dbh. The largest stem measured was 17 cm dbh (*Leptoderris ledermannii*, Fabaceae). Species richness (Figure 2D), abundance (Figure 2E), and total basal area (Figure 2F) decreased with increasing stem size. Large lianas (> 11 cm dbh) contributed 8% to the total liana basal area and included 6 species.

The correlation test shows that the number of species is correlated positively with the abundance (N = 0.86, p < 0.0001). When the number of liana species increases, abundance also increases. There is no difference between the proportion of small lianas (dbh ≤ 5 cm) patches of old growth forest (average 17.67 ± 6.58), and those of the secondary forest (average 18.92 ± 9.01). By contrast, for large lianas (dbh > 5 cm), there is a difference between old growth forest (mean 1.92 ± 2.37) and secondary forest (average 0.30 ± 0.8). There are more large lianas in old growth forest than in secondary forest. Secondary forest plots had more liana stems (mean 8.59 ± 1.90) than old growth forest plots (mean 9.31 ± 2.19), possibly partly because the secondary forest fallows are recent and continue to be pressured.

Liana characteristics

The functional and ecological characteristics are summarized for the total species assemblage, as well as for the 10 most important families separately (Figure 3). Most liana species were stem twiners (63%): *Secamone afzelii* and *Baissea baillonii*, followed by hook climbers (18%): *Salacia debilis* and *Clerodendrum formicarum*, and tendril climbers (16%): *A. lobata* and *Cissus aralioides*. Liana species were predominantly micro-phanerophyte (84%) or nano-phanerophyte (10%), in stem size. Most species were light demanding (92%); only a few were either shade tolerant. The seeds of most species were animal dispersed (75%), followed by wind dispersed (22%). Only a few species were barochorous (3%). With few exceptions, individual families generally exhibited similar trends in functional characteristics to the complete liana assemblage. Notable exceptions are as follows: Fabaceae are mostly twiner-climbers and Vitaceae are only tendril climbers. Icacinaceae are only shade-tolerant. Icacinaceae, Menispermataceae, Araceae, Verbenaceae, Vitaceae and Rubiaceae species are entirely dispersed by animals; while all of the Apocynaceae and Dioscoreaceae lianas are wind-dispersed.

DISCUSSION

Floristic composition

Nearly all individuals (89.69% of all stems) were identified to family, genera, or species. The same result has been

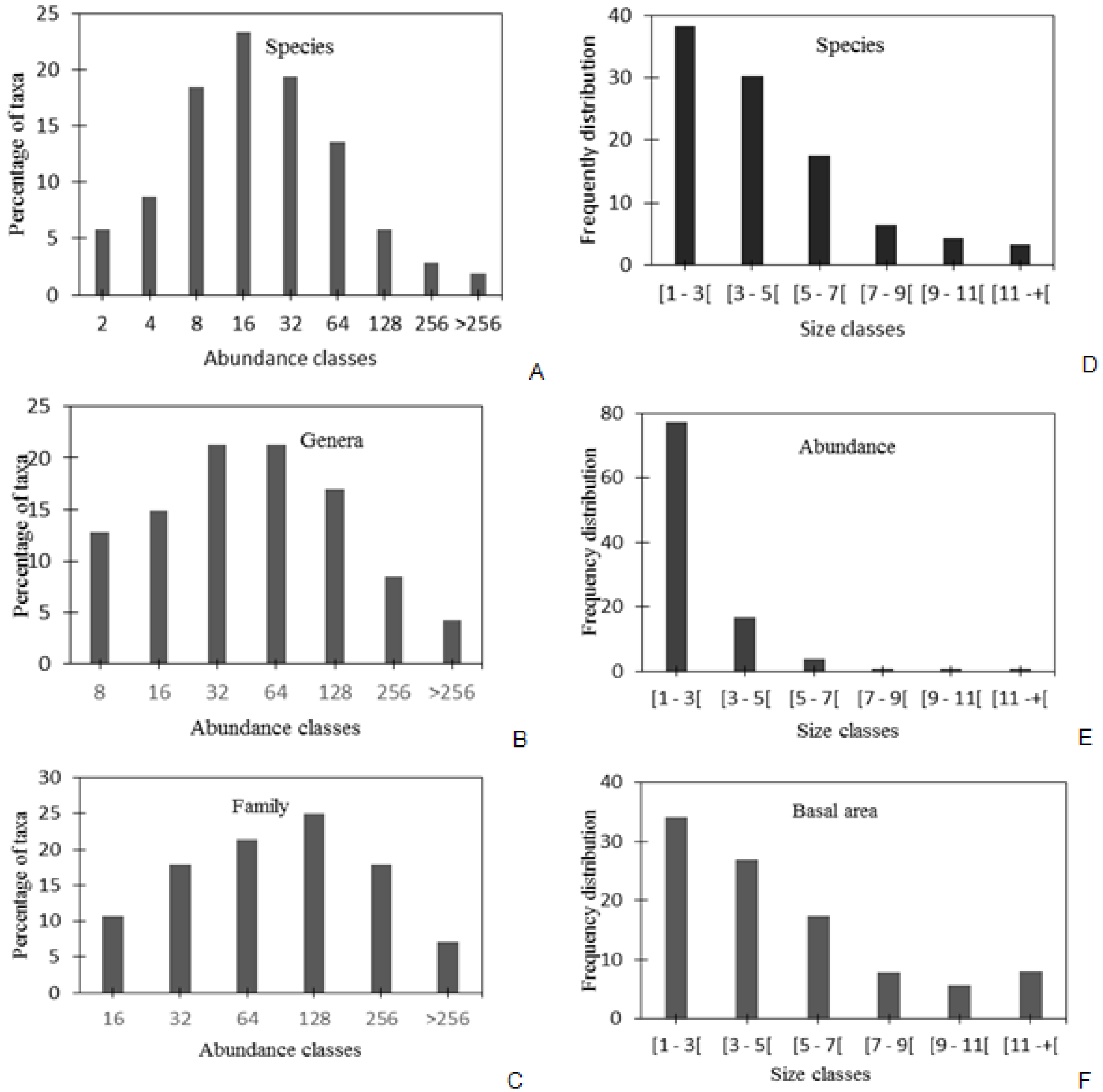

Figure 2. Percentage of: A, species (N = 63); B, genera (N = 47); and C, families (N = 28), in 14 ha of Azagny National Park (ANP) by abundance classes; and Frequency distribution of: D, total species number; E, stem abundance; F, basal area of lianas, of different size classes.

found by Ewango et al. (2015), who identified 90.2% of all individuals in a 20 ha plot in the Congo Basin. Our results are lower than those of Schnitzer et al. (2012), who identified 98.5% of all individuals in a 50 ha plot in Panama, and Kuzee and Bongers (2005), who identified 94% of their lianas in Côte d'Ivoire, but are generally well above the results reported in most other studies. The liana flora, in our study plots, was dominated by only a few widespread and more generalist species, among them, *A. lobata*. Such dominance may be the result of effective dispersal capacity, prolific vegetative sprouting, lack of specific habitat requirements, and low abundance of seed predators, or combinations of these. Although this species is generally thought to be light-demanding (pioneer), it was also observed in shady environments (Kouamé et al., 2005).

Species composition and family dominance of lianas in Azagny are largely the same as those found in most

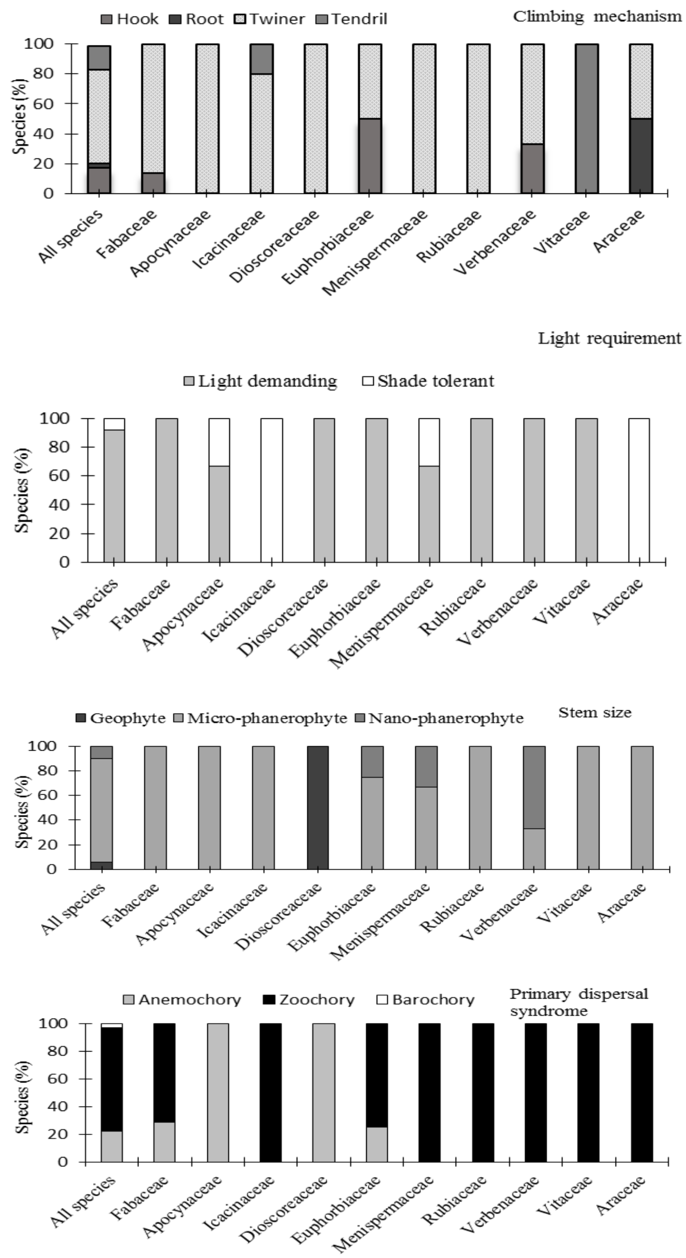

Figure 3. Proportion (%) of species with different: A, climbing mechanism; B, life light requirement; C, stem size, D, primary dispersal syndrome for all species (N = 63), and for the 10 most speciose families: Fabaceae (7 species), Apocynaceae (5), Icacinaceae (5), Dioscoreaceae (4), Euphorbiaceae (4), Menispermaceae (3), Rubiaceae (3), Verbenaceae (3), Vitaceae (3), and Araceae (2).

West African tropical forests Côte d'Ivoire (Etien and Traoré, 2005); Benin (Natta and Sinsin, 2005), and Togo (Kokou and Caballé, 2005). The most abundant families of Azagny (Apocynaceae, Passifloraceae, Euphorbiaceae, Fabaceae, Menispermaceae, Verbenaceae and Piperaceae) are widely distributed in West Africa (Kuzee and Bongers, 2005; Addo-Fordjour et al., 2008), even in Central Africa Cameroon (Parren, 2003) and Democratic Republic of Congo (Ewango et al., 2015), suggesting a strong similarity among West and Central African lowland forests. The speciose families Apocynaceae, Euphorbiaceae, and Fabaceae (which also include many non-lianas) and Vitaceae, Passifloraceae, Dioscoreaceae (only including climbers) are important liana families in both Old and New World floras (Gentry, 1991). The most common liana families in Asian forests are Menispermaceae, Fabaceae, Rubiaceae, Dilleniaceae and Icacinaceae (Appanah et al., 1993) suggesting a closer affinity to the Azagny Forest assemblage. However, the Azagny National Park is poor in palm lianas compared to the Neotropics and continental Asian forests.

Diversity and community structure

Species richness and species diversity (Shannon index and Fisher α) indices increased with sample sizes, as predicted. The Azagny National Park contains a few highly abundant lianas. *A. lobata* accounts for 7% of all liana stems, with 376 individuals, in 14 ha. These results are lower when compared with those of certain authors. *Strophanthus barteri* (Apocynaceae) represents 12% of stems in Ghana (Addo-Fordjour et al., 2008); while *Maripa panamensis* (Convolvulaceae) represents 11% of stems in both secondary and primary forests in Panama (DeWalt et al., 2000).

Family dominance, however, was in accord with other studies in Africa (Gentry, 1991; Bongers et al., 2005), with Apocynaceae, Passifloraceae, Euphorbiaceae, Fabaceae, Menispermaceae, Verbenaceae, Piperaceae, Aristolochiaceae, Vitaceae and Icacinaceae being the most important families. The 10 most abundant liana species (of 63) represent 71% of the stems, which may be characteristic of the Azagny National Park.

Small lianas account for the highest species richness, abundance, and basal area (Figure 2D to F) and, compared to other tropical forests, the Azagny National Park is particularly poor in large liana stems. Again, it was speculated that this is the result of disturbances in the recent past (Konan, 2008). Alternatively, its high liana density may be related to the climate seasonality (DeWalt et al., 2010) under which large-diameter lianas are few (nutrient-poor soils have fewer lianas (Gentry, 1991).

Within the Azagny National Park, liana density (388.3 ± 143.9 stems ha^{-1}) is lower compared to other African forests (Parren, 2003; Ewango et al., 2015). Some Bolivian Amazonian forests showed exceptionally high liana density (mean of 2,471 lianas ha^{-1} ≥ 2 cm dbh), and lianas accounted for as much as 44% of the total woody species (Pérez-Salicrup et al., 2001).

As predicted, the abundance of lianas was positively correlated with the number of species, which means that the number of species increases with abundance. The proportion of small vines (dbh ≤ 5 cm) is the same in both habitats. By contrast, there is a big difference in terms of large lianas (dbh > 5 cm) in both habitats. Forest disturbance (Hegarty and Caballé, 1991) and seasonality (Gentry, 1991; DeWalt et al., 2010) are factors most strongly controlling the abundance, species richness, and distribution of lianas in other forests. Abundance was higher in secondary forests plots than in old growth forests plots. This is caused by the human activities that take place in secondary forests. These activities include agriculture, hunting and gathering of plant species (Konan, 2008).

Functional characteristics of the liana community

In Azagny, twining is the dominant climbing mode (63% of the species, Figure 3A). Our findings corroborate that of many other studies in tropical forests: Laurance et al. (2001) in Brazil; Sridhar Reddy and Parthasarathy (2003) in India; and Addo-Fordjour et al. (2008) in Ghana. Because of their ability to ascend trees directly, twining species indiscriminately colonize a wide range of trees and species. There seems to be an association between stem mechanical architecture and climbing mechanism; some families with heavy stems are exclusively twining (e.g. Fabaceae, Asclepiadaceae, Menispermaceae, and Apocynaceae) or hook-climbing (e.g. Verbenaceae); while other families that tend to have flexible stems, also rely on tendrils (e.g. Passifloraceae, like some *Adenia* and most Vitaceae species, *Cissus*).

Herbaceous climbers are generally light-demanding, since they establish and grow particularly well in large clearings (Putz, 1984). In contrast, woody lianas often occur in very heterogeneous light habitats such as in old gaps, forest margins, and under irregular and broken forest canopies (Putz, 1984; Hegarty and Caballé, 1991). Most liana species can start their life as a seedling in the understorey, and wait for a long time until they find support and get access to the canopy. Liana abundance in old-growth forest is, therefore, not so much determined by light availability, but rather by trellis availability. Eight per cent of the Azagny National Park liana species were classified as being shade tolerant. These species have the ability to remain self-supporting for a longer period, and can grow several meters tall before they have to rely on trees for support, for instance *Piper guineense, Cercestis afzelii, Flagellaria guineensis* and *Xylopia acutiflora*.

The prevalence of zoochory shows the importance of animals in the liana's dissemination (Figure 3). The same result has been found by some authors as Bullock (1995) and Addo-Fordjour et al. (2008). This is important for conservation: most lianas rely on animals for their seed dispersal and/or pollination, whilst animals rely on them for food and habitat (Ødegaard, 2000; Schnitzer and Bongers, 2002).

Conclusion

It was found that, in terms of structure and family composition, the liana community in Azagny National Park is congruent with other Guineo-Congolian forests, with prominent liana taxa being Apocynaceae, Fabaceae, Vitaceae, Rubiaceae and Euphorbiaceae. The most important taxa at Azagny National Park are also important in other African forests, and we conclude that the Azagny National Park liana composition accords with other tropical forest elsewhere. However, the Azagny National Park differs from other Guineo-Congolian forests, because it has a high liana abundance and species richness, especially in small size classes, but a low basal area. In the Azagny National Park, the most important determinants of variations in liana abundance, species richness, and distribution are forest structure and habitat. The secondary forest had greater liana abundance than the more closed canopy of the old growth forest. Human activity plays an important role in the liana abundance. However, further research on the use of lianas by the local populations is required.

Conflict of interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors would like to thank the population around the ANP and Ivorian Office of Parks and Reserves for the authorizations and the agents of that office for their help on field. They would like to thank PASRES for helping in the funding of this study.

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academicJournals

Vol. 8(8), pp. 216-223, September 2016
DOI: 10.5897/IJBC2016.0956
Article Number: 16CEAEC59916
ISSN 2141-243X

http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Species composition, relative abundance and habitat association of rodents in Yekoche Forest, East Gojjam, Ethiopia

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Received 9 February, 2016; Accepted 6 April, 2016

A study on species composition, relative abundance and habitat association of rodents in Yekoche Forest was carried out from September, 2014 to April, 2015 during both wet and dry seasons. Data were collected using live trap and snap trap. A total of 841 individual of rodents were trapped using both live trap and snap trap. Rodent species such as yellow spotted brush-furred rate (*Lophuromys flavopunctatus)* (24.5%), African grass rat (*Arvicanthis niloticus)*, (23.5%), Broad beaked dolphins (*Pelomys harringtoni*) (19.1%), Ethiopian narrow headed rat (*Stenocephalemys albicaudata)* (20.7%) and house mouse (*Mus musculus)* (12.1%) were recorded. Most of the rodent species prefer Acacia grassland habitats and agricultural farmland. Bushland and riverine vegetation provided less number of rodent individuals. Highest numbers of rodents were recorded during the wet season (56.8%) than the dry season (43.2%). All age groups were represented in the population of the captured species. Abundance of rodents was significantly differed between dry and wet seasons. The study area was highly affected by human activity, as a result rodents species were reduced. Therefore, community based conservation need to be implemented in the study area.

Key words: Habitat association, relative abundance, rodents, species diversity, Yekoche Forest.

INTRODUCTION

Rodents are the most successful mammals. They show great diversity in their ecology, morphology, physiology, behavior and life history strategies. The order Rodentia comprises the largest in mammalian species (Kingdon, 1997). Of the total rodent species of the country, 21% are endemic. Muridae family covers 57 species (84%) of the overall species (Afework and ZCorti, 1997). Rodents are adapted to wide range of environments (Nowak, 1999). They are highly successful mammals in different environments all over the world. Their success is probably due to their smaller size, having short breeding cycle and wide variety of food items. The way rodents select their habitats mainly depend on the vegetation type and life history strategies (Fitzherbert et al., 2007).

The distribution and abundance of rodents are influenced by environmental factors such as nature and

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density of vegetation, climatic conditions, disease, predication and habitat utilization by humans (Johnson and Horn, 2008). Absence of sufficient food and ground cover largely determine the number of individual rodents in a certain area. The loss of ground vegetation leads to decreasing rodents diversity but increasing predation risk (Hoffmann and Zeller, 2005).

Rodents live in different micro habitats. Some rodents spend their entire life in the underground tunnel systems. Others such as the ground squirrels dig extensive burrow systems used for resting and caring for their young, whereas few are arboreal. Some are gliders and others are adapted for semi-aquatic life (Nowak, 1999; Wright et al., 2002).

Rodents often respond rapidly to changes in habitat structures such as plant composition and ground cover (Leis et al., 2008). Their diversity tends to be lower in open habitats; this is due to reduction of habitats and food resources (Silva et al., 2005).

Habitats with increased structural heterogeneity have a positive influence on rodents abundance and richness (Ecke et al., 2002). Even though, habitat disturbance is associated with decreased rodent species richness (Avenant and Cavallini, 2007). Habitat selection provide that a useful way to determine how different species respond to environmental heterogeneity (Nowak, 1999). Habitat selection of rodents has an adaptive basis, this is due to individuals choosing high quality habitat have a reproductive advantage over in low quality habitats. This eventually would lead to particular species being more abundant in some habitats than others (Cramer and Willig, 2002).

Therefore, the present study aimed to assess species composition, relative abundance and habitat association of rodents in Yekoche Forest east Gojjam, Ethiopia.

MATERIALS AND METHODS

Description of the study area

Yekoche Forest is found in East Gojjam Zone, Amhara National Regional State and located at about 304 km northwest of Addis Ababa and 5 km northwest of Debre Markos town. It is located in between 10°21'52'' N latitude and 37°42'23'' E longitudes, minimum altitude of the area is 2355 m. a. s. l. and maximum altitude 2482 m.a.s.l (Figure 1). The study area represents one of the most beautiful natural areas in Gozamen woreda. Originally, the area of Yekoche Forest was large but recently it is reduced from 160 to 100 ha, this is due to agricultural encroachment (GWAO, 2010). Currently, the wildlife found in this area decreasing from time to time due to poaching and loss of habitat by human activities (EGZAO, 2010) (Figure 1).

Trapping

A permanent 4900 m^2 live trapping grid was established in each selected habitat types for three consecutive days and nights. The selection of different habitats was based on vegetation composition of the study area. The selected habitats were agricultural farmland, riverine vegetation, bush land and Acacia grassland. In each trapping site, standard square (seven rows by seven columns) trapping grids were established during wet and dry seasons (Linzey and Kesner, 1997). A total of 49 live traps were set per grid at every 10 m interval between points during both dry and wet seasons. Peanut butter was used as bait. To prevent the trap from cold weather and damage by other wild animals, the traps were covered with leaves and grasses. The traps were checked twice per a day early morning (between 06: 00 and 07:00 h) and late afternoon (between 17:00 and 18:00 h). Rodents caught from 06:00 to 18:00 h were recorded as a day trappings and those caught from 18:00 to 06:00 h as night trappings. Each trapped rodent was, identified, marked by toe clipping and released back to the site from where it was trapped (Linzey and Kenser, 1997).

Snap traps were also set during both wet and dry seasons, the skin and skull voucher of representative snap-trapped rodents were prepared and brought to the Zoological National History Museum of Addis Ababa University for identification purpose. Snap traps were shifted randomly during each trapping sessions in order to assess rodent species that might exist in the habitats. Trapped rodents were dissected and the number of embryos in the left and right uterine horns of pregnant females was counted. Grids in the study area contained 25 snap traps in a 5×5 alignment. Each snap trap was spaced at about 10 m interval along five transect lines in all habitat types. Snap traps were also baited with peanut butter and checked twice a day. The traps were labeled with consecutive numbers. Trapping was done for three consecutive days and nights during both wet and dry seasons.

Data analysis

The collected data were analyzed using SPSS statistical software version 20 and Microsoft Excel. Chi-square test was used to test the variation between sex of individuals. One-way ANOVA was used to test the significant variation among rodents caught across different season and habitats. Species richness and diversity were computed by using Shannon-Weaver Diversity Index (Shannon and Weaver, 1949). The species diversity is important to know which species is highly distributed and can be calculated by using the formula $H' = \Sigma$ (Pi) ln (pi).

RESULTS

Species composition

A total of 841 individuals rodents were trapped during in both wet and dry seasons. They belong to five different species. The species were Ethiopian narrow headed rat (*Stenocephalemys albicaudata),* broad beaked dolphins *(Pelomys harringtoni),* African grass rat *(Arvicanthis niloticus),* yellow- spotted bush-furred rat *(Lophuromys flavopunctatus)* and house mouse (*Mus musculus). L. flavopunctatus* had (24.5%) the highest relative abundance whereas *M. musculus* had the least (12.1%) (Table 1).

Habitat association

Most species were trapped from Acacia grassland (47.5%) habitat, whereas the least number of species were recorded from riverine vegetation (5.1%). There

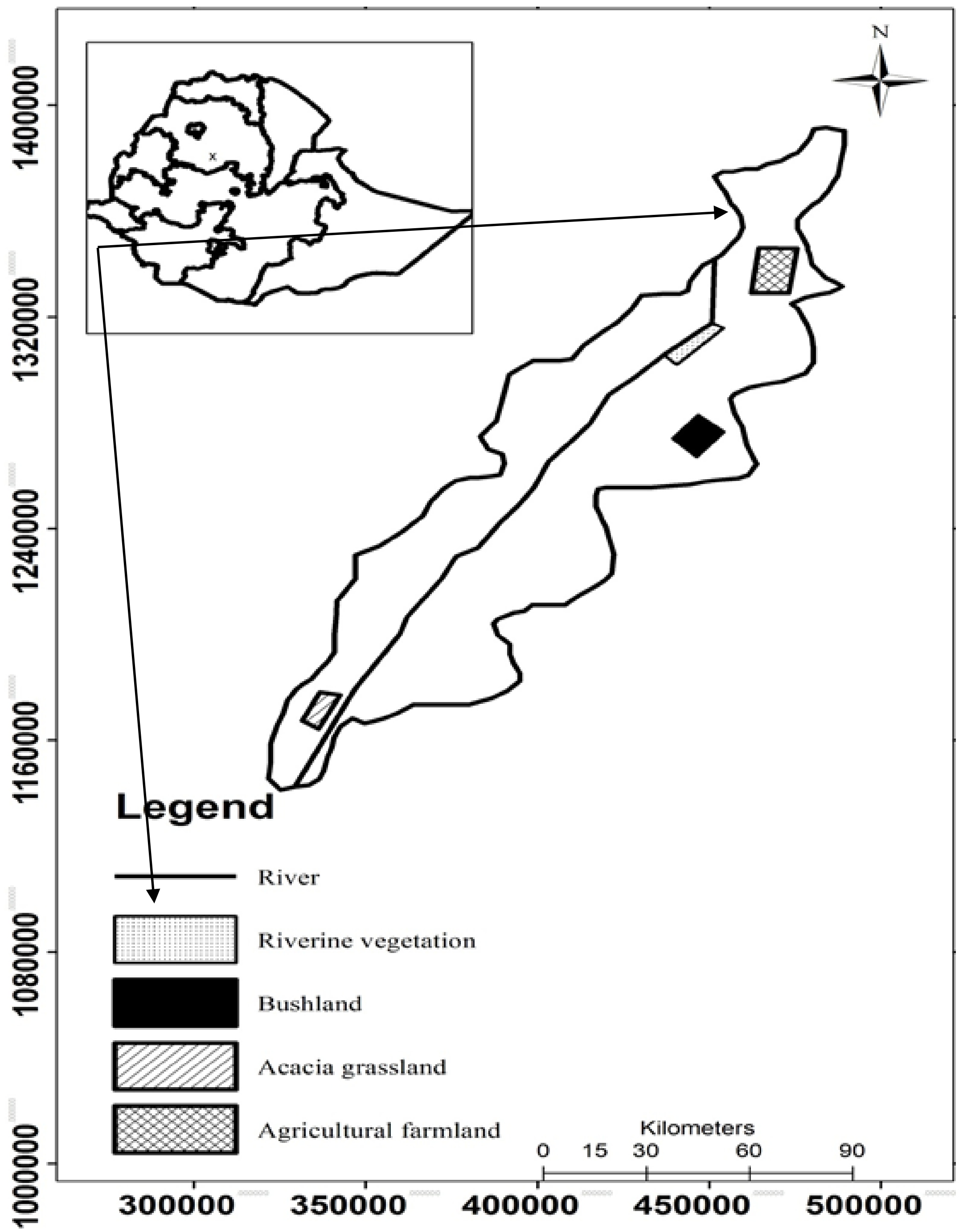

Figure 1. Map of the study area.

were was significant difference of rodents species in difference habitat (F= 7017.7 ,P < 0.05) (Figure 2).

Seasonal variation

In wet season L. flavopunctatus (14.2%) was highly recorded where as M. musculus had the least proportion (7.3%). In dry season A. niloticus (12.2%) was highly recorded whereas M. musculus was the least recorded (4.8%). There was significant difference among species across different seasons (F= 0.124, P < 0.05) (Figure 3). At day time the number of rodents species were varied, *L. flavopunctatus* (15.8%) was highly recorded whereas *Mus musculus* was the least (7.6%). During the night time the numbers of captured rodents were varied. The

Table 1. Rodent species and their relative abundance in the study area.

Species	Total number of individual	Relative abundance (%)
Lophuromys flavopunctatus	206	24.5
Arvicanthis niloticus	198	23.5
Pelomys harringtoni	161	19.2
Stenocephalemys albicaudata	174	20.7
Mus musculus	102	12.1

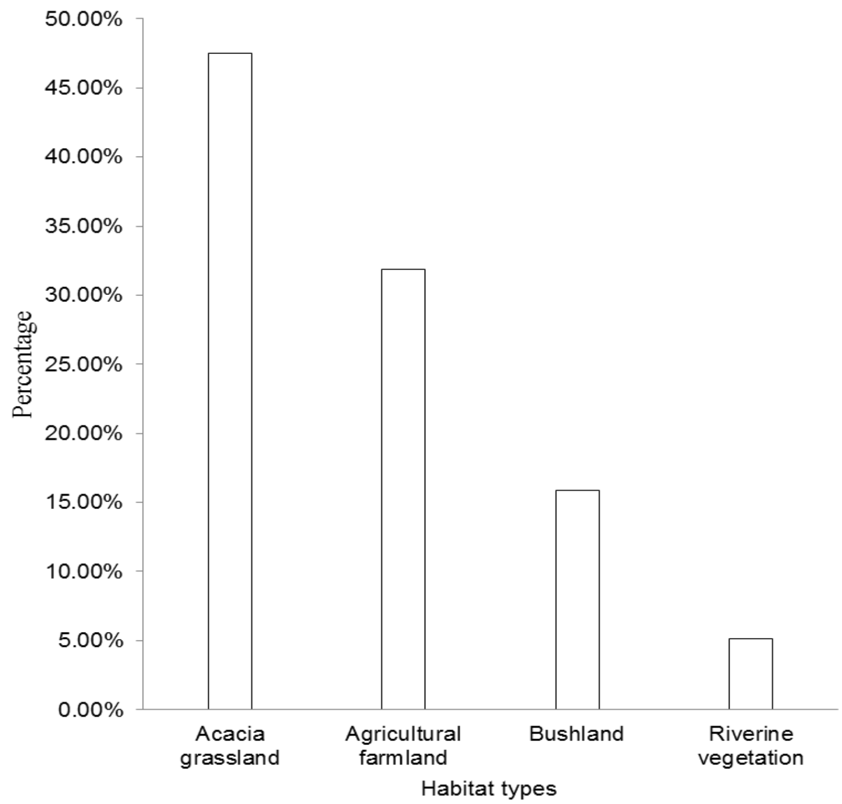

Figure 2. Percentage of species trapped in difference habitats.

numbers of L*. flavopunctatus (*15.8%) were higher than others, whereas *M. musculus* (4.5%) were the least abundant species. There was significant difference of rodents species across difference time (F= 1605.5, $P < 0.05$) (Figure 4).

Sex ratio and age structure

The numbers of captured female rodents were 54.5% and the remaining 45.5% were males. In both seasons the sex ratio of females was higher than males. There was variation; the variation was statistically significant among different sex (χ^2= 41.3, df = 1, $P< 0.05$). In both wet and dry seasons sub adult had 46.7% highly captured where as juveniles had the least value (17.5%). The majority of them were captured during the wet session (56.8%) and the remaining (43.2%) were captured during the dry season. There was significant difference among difference age groups (χ 2 = 88.1, df = 2, $P < 0.05$) (Figure 5).

DISCUSSION

Relative abundance of rodents

A total of 5 species of rodents were recorded during this

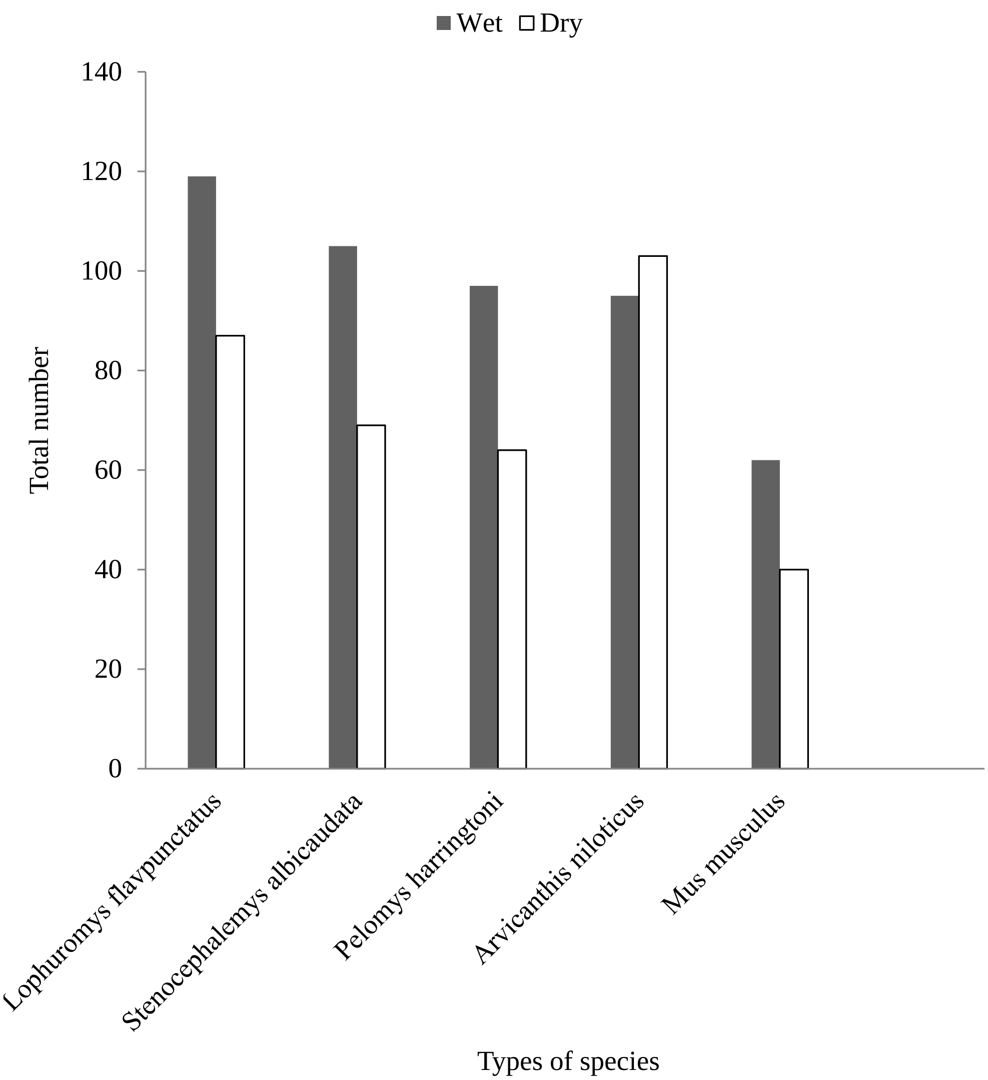

Figure 3. Total number of rodents species caught during wet and dry seasons across all habitats.

investigation. The number of *M. musculus (*12.1%) from the present investigation was the least interims of number and diversity. But the result was unexpected, as it is the most widespread rodent species in Ethiopia (Yalden, 1988). Demeke et al. (2007) described that the species was more abundant in agricultural farmland than bush habitats. Similarly, this species was abundant in the Acacia grassland than bush land habitat in the present study. The reduction of *M. musculus* might be food and other factors such as the nature and density of vegetation, climatic conditions, disease, predication and habitat utilization by humans, those factors were not comfortable for them.

During the present study *L. flavopunctatus* 24.5% was the first most abundant and widely occurring species of the total captured rodents. This agrees with the findings of Yalden (1988) in the Harena Forest, Bale Mountains National Park and in the Wondo Genet, Ethiopia, by Dawit and Afework (2008). *L. flavopunctatus* is the most widespread and numerous rodents in the moist area of East Africa. The species lives in different habitat types having dense vegetation (Clausnitzer et al., 2003). Yalden and Largen (1992) reported that the species was widely distributed in Ethiopia inhabiting both scrub and forest habitats. In the present study, the species has generalized distribution encountering in all habitats. The findings of earlier studies have shown similar pattern of generalization throughout different habitats, especially in the moist massive forest (Delany, 1971; Juch, 2000). This might be attributed to the diverse feeding habit of the species (Hanney, 1964).

*Arvicanthis niloticus (*23.5%) was the second most abundant rodent species in the study area. Similarly a study conducted in Gambela and lower Omo Valley

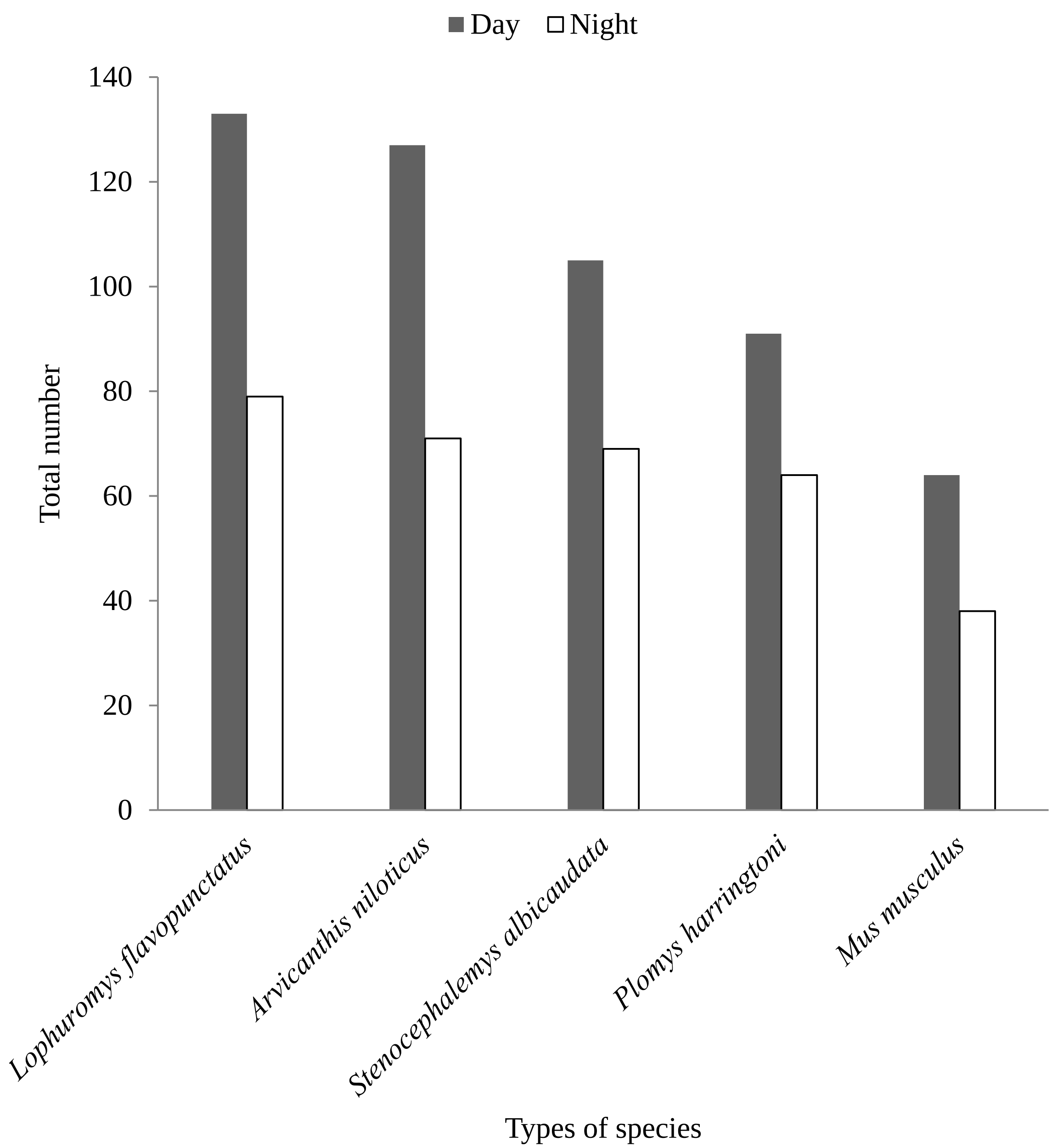

Figure 4. Number of rodents species caught during day and night time.

indicated that *A. niloticus* is a common species (Bulatova et al., 2002). In the present study, the species was recorded from all habitat types. They were also captured by both live and snap traps.

*Stenocephalemys albicaudata (*20.7%) was the third abundant species in the study area. Yalden and Largen (1992) described the species as one of the most common and abundant endemic rodent species in Ethiopia. In the present study this species was the most abundant in the Acacia grassland. The absence or reduction of *S. albicaudata* can serve as an indicator for reduction of Acacia grassland.

*Pelomys harringtoni (*19.2%) was the fourth abundant species in the present study area. This species practices arboreal and frequented forest habitats (Yalden and Largen, 1992). In the present study, the species was captured from all habitats. Like *S. albicaudata* the species was abundant in Acacia grassland. This might be due to the presence of enough food found in Acacia grassland. However, the number of *P. harringtoni* in the riverine vegetation was highly reduced; this might be due to the presence of enough food was not found in this study sites. The presence of *P. harringtoni* was reported by Afework (1996) from Menagesha State Forest, Ejigu

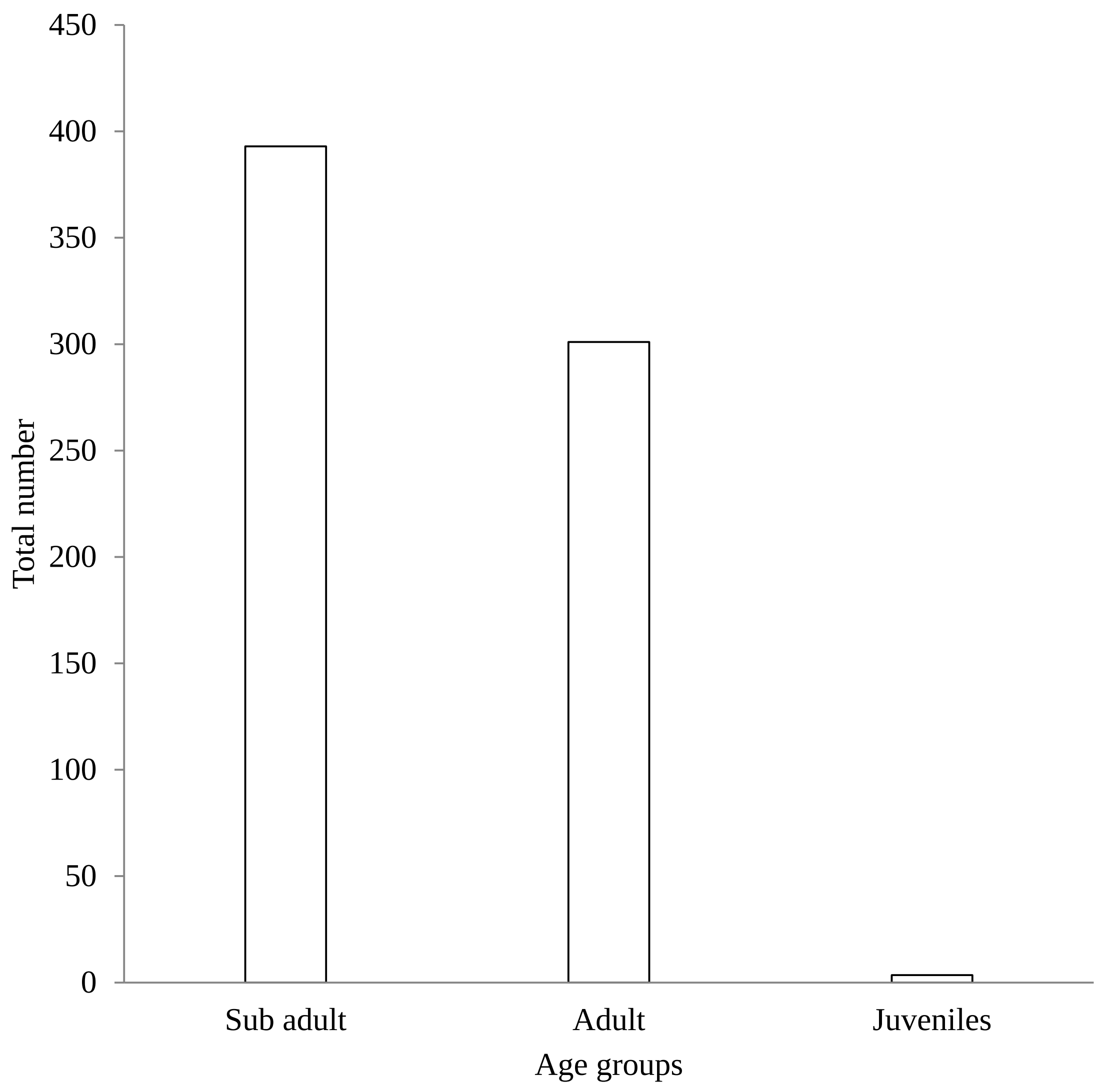

Figure 5. Age distribution of trapped rodents in all habitats.

(2008) from Birsheleko and nearby natural habitats and Eshetu (2008) from Donkoro Forest.

Seasonal variation

In both live and snap trap the numbers of rodents during wet season were higher than dry season. At the beginning of the wet season, newly regenerated grasses after harvest attracted rodent species because fresh grasses might be nutritionally high and easily edible. As noted by Mahlaba and Perrin (2003) rodents are known to respond to habitat quality such as food, vegetation cover and rainfall. Rainfall had a significant role for the occurrence of high population of rodents during the wet season. As noted by Mahlaba and Perrin (2003) rodents are known to respond to habitat quality such as food, vegetation cover and rainfall. Therefore, rainfall had a significant role for the occurrence of high population of rodents during the wet season.

Age structure and sex ratio

In both methods the numbers of sub adults were higher than juveniles and adults respectively. This might be due to factors that affect the distribution of rodents do not affect sub adults. Out of the 841 trapped rodents by both live and snap trap during all trapping sessions, males and females comprised 383 and 458 respectively. From this the numbers of females were higher than males. This might be the factors that affect rodents distribution like food, predication, climate and others comfortable for females than males. Most of the rodent species respond differently to different habitats during the wet and dry seasons. Habitat favorite and distribution of rodents in the study area determined by the degree of ground cover, habitat structure and availability of food, plant species composition and other physical and biological variables. Yekoche Forest is one of the remnant forest priority areas in Gozamen woreda that is affected by humans due to agricultural expansion and fire wood production. Therefore, it is better to take responsibility of Gozamen worda agricultural office and Wonka Kebele people to practices restoration of the Forest through aforestation. Wonka Kebele administration and local people should take responsibility to reduce livestock grazing especially during the dry season.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

We are grateful to Debere Markos University for helping us to conduct this study.

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