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Regulated access to wild climbers has enhanced food security and minimized use of plastics by frontline households at a premier African protected area

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Abstract

The amount of food harvested, processed and stored by households determines food availability—a key dimension to food security. In developing countries, frontline households around protected areas harvest wild climbers for making food security products. When access to the wild climbers is denied, households adapt by using other available alternatives such as plastics with potential consequences to biodiversity. The relationships between harvesting wild climbers and: (a) food availability, (b) plastic use, and (c) wild climber populations have rarely been investigated. We interviewed 119 frontline households adjacent to Bwindi Impenetrable National Park, Uganda to evaluate the relationships between household access to wild climbers and: (a) plastic use and (b) food security. We used forest surveys to assess the impact of harvest on population structure of three mostly utilized wild climbers. The frontline households used more wild climber products (65.02%) than plastics (34.97%). Fifteen wild climbers were harvested for food security products. Two of these; *Dracaena laxissima* and *Smilax anceps* depicted size class distributions similar to those of healthy sustainable plant populations, while *Monanthotaxis littoralis* depicted a size class distribution of unsustainably harvested plant populations. We recommend increased access to wild climbers for enhancing food security and minimizing use of plastics.

KEYWORDS

biodiversity conservation, food security, frontline households, plastics, protected areas, wild climbers

1 | INTRODUCTION

Food security exists when all its four dimensions are in place; i.e., (a) food availability, (b) access to sufficient and nutritious food (in terms of quantity, quality and variety), (c) utilization (use based on knowledge of basic nutrition), and (d) stability (of all the dimensions over time) (FAO, 2004; 2012; World Food Summit, 1996). Physical availability of food is one key dimension of food security because it addresses the "supply side" of food security (Bashir & Schilizzi, 2013; Manditsera, Lakemond, Fogliano, Zvidzai, & Luning, 2018; Matsumura, 2001;

Morris, Neuhauser, & Campbell, 1992; Porkka, Kummu, Siebert, & Varis, 2013). In rural communities particularly those in developing countries, adequate food availability is often hampered by lack of suitable food harvesting, processing and storage facilities (Cunningham, 2001; Kumar & Kalita, 2017; Muhwezi, Cunningham, & Bukenya-Ziraba, 2009; Nukenine, 2010), with direct consequences on household food security. As a solution, rural households especially those living adjacent to tropical forested protected areas (PAs) often harvest wild climbers (vines and lianas) as raw materials for food harvesting, processing and storage products (Cooper et al., 2018; Muhwezi et al., 2009; Poppy et al., 2014).

The increasing dependence on wild climbers for food harvesting, processing and storage products by rural local people has resulted into their increased extraction raising concerns of over-exploitation (Bitariho, Sheil, & Eilu, 2016; Ghazoul & Sheil, 2010; Ticktin, 2004). On the other hand, where access to forest wild climbers is prohibited, like it is the case at most tropical forested PAs, local households resort to using readily available products such as plastics for harvesting, processing, and storing food (Geyer, Jambeck, & Law, 2017; Marsh & Bugusu, 2007; Qi et al., 2018). Plastic products are commonly used by rural people particularly in developing countries because plastic products are versatile, ubiquitous, cheap and are of lightweight.

The use of plastic products around PAs is a global biodiversity conservation concern and a major environmental pollutant (Geyer et al., 2017; Qi et al., 2018). Plastics littered in and outside PAs undoubtedly pose a great risk to biological communities, with impacts on organisms and ecological processes stemming from a myriad of mechanisms (Windsor et al., 2019). Microplastics (measuring between 0.0001 and 5 mm) that are formed from the degradation and fragmentation processes of plastics litter, for instance, alter the geochemical and physical environment of terrestrial biota (De Souza Machado, Kloas, Zarfl, Hempel, & Rillig, 2018). Plastics release chemicals which disrupt invertebrate and vertebrate hormonal systems and hence toxic to wildlife. Plastic litter which accumulates in surface soils are ingested by soil-dwelling organisms (Rillig, 2012). Microplastics (measuring >25 mm) and large plastic items for example bags and drinking straws which remain on ground surface are ingested by wildlife, with plastic materials observed in animal feces sometimes (Badru Mugerwa personal communication). The ingestion of plastics has severe effects on wildlife ranging from blockages in the digestive tracts to reduced growth and mortality (Derraik, 2002).

Protected area management authorities now recognize, not only the dangers plastic use poses to biodiversity, but also the impacts caused by the overharvests and use of wild climbers as raw materials for making food harvesting, processing and storage products (Muhwezi et al., 2009). For these reasons, some PAs have put in place mechanisms of allowing regulated and cautious exploitation of wild climbers by local people adjacent the PAs (Bitariho et al., 2016). These mechanisms have also had an added advantage of facilitating the integration of the use and conservation of tropical forests and improving local people—PA relations (Bitariho et al., 2016; Ndangalasi, Bitariho, & Dovie, 2007; Ticktin, 2005). Furthermore, the use of wild climbers may potentially alleviate the use of plastics for purposes of food harvesting, processing and storage, with beneficial outcomes for enhancing household food security and minimizing the impacts of plastics on biodiversity.

While the dependence on forest wild climbers by households living around tropical forest PAs, and their potential to minimize the impacts of plastics on biodiversity is clearly understood, the relationships between harvesting wild climbers and: (a) food availability (harvesting, processing, and storage), (b) plastic use, and (b) wild climber populations remains poorly studied. For the latter, the overharvesting of wild climbers has indeed received resistance from ecologists who suggest that overharvesting the wild climbers may impact the ecological functions of forests (Ticktin, 2004). Overharvesting wild climbers can affect ecological processes at many levels, from individuals and population to community and ecosystem levels (Bitariho, McNeilage, Babaasa, & Barigyira, 2006; Moegenburg & Levey, 2002; Stewart, 2003; Ticktin, 2004). The exact magnitude of the impact is mainly dependent on the nature and intensity of harvesting and the particular species being extracted (Arnold & Perez, 2001; Hall & Bawa, 1993; Robinson, 2016), although the effects of life history and the part of plant that is harvested have also been reported (Ticktin, 2005).

Bwindi Impenetrable National Park (hereafter after "Bwindi") is a premier African PA in Uganda where mechanisms for regulated harvesting of wild climbers and other Non-timber Forest Products (NTFPs) by local communities have been in place since 1994. In 1994, Bwindi management devised strategies to link conservation to local livelihoods by introducing the Multiple Use Program (MUP) that allow authorized members of the local community access to the park and harvest selected wild climbers (Bitariho et al., 2006, 2016; Ndangalasi et al., 2007). Since then, local communities at Bwindi have harvested wild climbers as raw materials for food harvesting, processing, and storage products that include granaries, mats, trays, and baskets (Bitariho & Akampurira, 2019; Muhwezi et al., 2009).

In this paper, we evaluate the contribution of wild climbers to food availability (harvesting, processing and storage) for local people around Bwindi, and whether the use of wild climbers alleviates the use of plastics or not. The objectives of the study were therefore to (a) quantify the use of wild climber and plastic products by households for harvesting, processing and storing food/cash crops; (b) identify the factors associated with the use of the wild climber products vs. plastic products; and (c) assess the impacts of harvests on the population structure of the three mostly harvested wild climbers. Here we concentrate on food availability to mean food security, while fully recognizing the importance of the other three dimensions for a food secure food household.

2 | MATERIALS AND METHODS

2.1 | Study area

Bwindi is located in Southwestern Uganda at 0°53′–1°08′S and 29°35′–29°50′E and occupies an area of

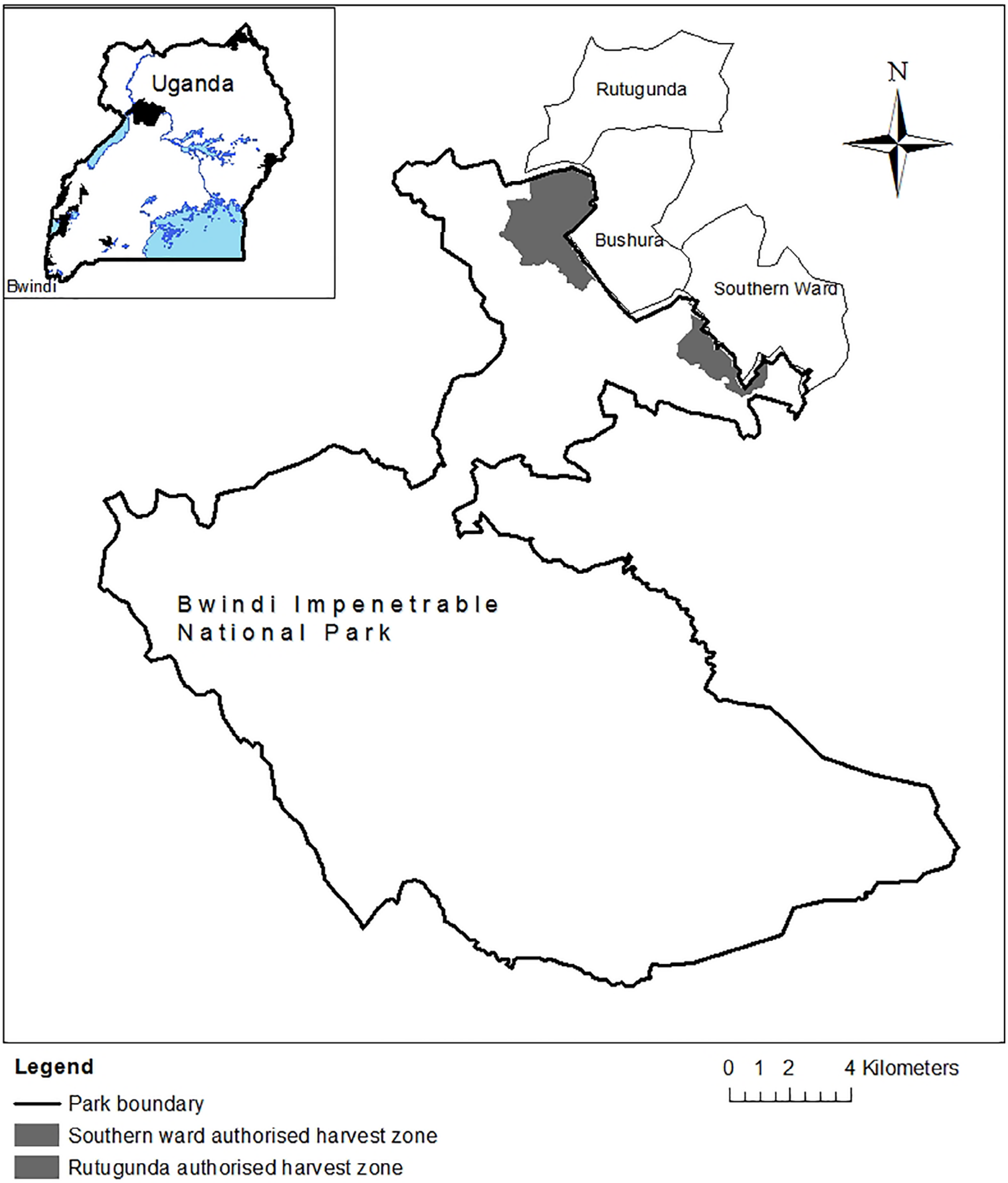

FIGURE 1 Map of the study area parishes and authorized harvest zones for the wild climbers in Bwindi Impenetrable National park, S.W. Uganda

331 km^2 (Figure 1). It arguably ranks topmost as an important PA for conservation in the Albertine Rift biodiversity hotspot (Plumptre et al., 2007 and is home to over 20 species of medium to large sized mammals (Mugerwa, Sheil, Ssekiranda, van Heist, & Ezuma, 2013; Plumptre et al., 2007). Bwindi is one of the most important forests in Uganda for biodiversity conservation as it contains half of the world's remaining 1,000 mountain gorillas (*Gorilla beringei beringei* (Hickey et al., 2018). The other important fauna in Bwindi include the chimpanzees (*Pan troglodytes scweinfurthii*), the African elephant (*Loxodonta africana*) and the vulnerable African golden cat (*Caracal aurata*)—Africa's least studied feline (Brodie, 2009). Bwindi is also home to over 381 species of birds (Plumptre et al., 2007), of which 24 are restricted range species (Stattersfield, Crosby, Long, & Wege, 1998). The vegetation is a combination of medium-altitude moist evergreen forest and high altitude sub-montane forest consisting of 223 trees species (Kakuru, 1993). Bwindi's terrain is rugged with undulating hills, steep slopes, ridges and narrow valleys. The elevation of Bwindi ranges from 1,190 to 2,607 m above sea level. Bwindi is immediately surrounded by 25 adjacent community administrative parishes, occupied by a human population density of up to 300 people per km^2, 95% of whom rely on subsistence farming for livelihood (Plumptre et al., 2004). A parish is the second smallest administrative unit in Uganda's local government administrative structures comprising of a range of between 8 and 12 villages, while a village is the smallest administrative unit that constitute several households (Bitariho et al., 2006). The common types of crops cultivated include; beans, peas, maize, wheat, sorghum, millet, potatoes and tea (Bitariho & Akampurira, 2019). Because of Bwindi's terrain, local communities tend to erect houses on hill ridges sometimes leading to scattered households in the parishes/villages. This can be a dauting task for researchers while carrying out household surveys.

2.2 | Data collection

We conducted household and forest surveys for 5 and 3 months, respectively, between January and August 2018. Using household interviews, we collected data on the types and use of food harvesting, processing and storage products by households adjacent Bwindi. We then used forest survey plots in the Bwindi forest interior to collect data on the population structure of the wild climbers mostly harvested as raw materials for food harvesting, processing and storage products.

2.2.1 | Sampling strategy for household surveys

Firstly, we stratified the study parishes into two groups; those that are legally authorized to harvest wild climbers (MUP parishes) and one that is adjacent the MUP parishes but not legally authorized to harvest the wild climbers (Non-MUP parish). We purposively selected two MUP parishes (Rutugunda and Southern ward parishes), and one Non-MUP parish (Bushura) as Figure 1 shows. All the study parishes are located in Kanungu district adjacent Bwindi. The parish stratification was done in order to cater for precision, study costs and effectiveness of our sampling method especially noting the difficult terrain and household locations (Bennett, Woods, Liyanage, & Smith, 1991; Clark & Steel, 2007). The objective of our stratification was to choose a limited number of smaller units (villages and later households) in which a simple random sampling would be conducted (Bennett et al., 1991). Therefore, secondly, we considered all the villages within a 1–2 km radius from the Bwindi park boundary (also called frontline villages) spread all over the three study parishes for sampling with households being the basic sampling units (Bennett et al., 1991; Bitariho et al., 2016; Clark & Steel, 2007). In total, Rutugunda has two frontline villages, Southern ward five and Bushura six frontline villages (total 13 frontline villages). Thirdly, in order to identify households for interviews from the frontline villages, we used a simple random sampling technique from a list of households obtained from the Uganda National Population Census and Electoral Household Manifests kept by local council officials of the three study parishes. As such, from the total household list of 1,619 households (i.e., 462 from Rutugunda, 503 from Southern ward and 654 from Bushura), and considering the labor, time, and costs involved, we randomly sampled 119 households spread all over the three parishes for interviews. These were all from the 13 frontline villages spread all over the three study parishes. Thirty-nine of these households (8.4% of 462) were from Rutugunda, 40 (7.9% of 503) from Southern ward and 40 (6.1% of 654) from Bushura. Indeed, our number of sampled households were comparably similar to those previously done by Muhwezi et al. (2009) who sampled 50 households per parish with an average 4% of total households in Bwindi. The random sampling was achieved by assigning numbers to all the individual households available per parish in the frontline villages on pieces of papers, placing them in a box, shuffling them and then picking out the households to be included in the study (Bitariho, 2013; Eilu & Bukenya-Ziraba, 2004; Shova & Hubacek, 2011). Any method which achieves a random or near-random selection of households, preferably spread widely over the community, would be acceptable as long as it is clear and unambiguous, and does not give the field worker the opportunity to make personal choices that may introduce bias (Bennett et al., 1991; Clark & Steel, 2007).

Prior to administering the questionnaires, we met the leaders of each sample village to explain to them the purpose and methods of the study. We were therefore granted permission by village leaders to proceed with the interviews in the study villages. We then interviewed households after administering to them the Prior Informed Consent (PIC) forms and then using semi-structured questionnaires with open- ended questions administered the questionnaires to household heads. When the household heads were not available, we interviewed the next willing member of the household (Shova & Hubacek, 2011).

After identifying the household member for interview, we requested information on the households' use of wild climbers and plastic products for food harvesting, processing and storage. Also, together with the respondents, we counted the number of wild climber or plastic products owned by each household for purposes of harvesting, processing and storing food crops. This information allowed us to assess the local people use of forest wild climbers and plastics for food harvesting, processing, and storage purposes (Muhwezi et al., 2009; Ndangalasi et al., 2007). We asked the respondents to estimate the durability and storage capacity of the products, and limitations for the use of the products (e.g., cost of product, entry into the park restrictions or scarcity of products). The materials used for making the products was also collected during the interviews. We further used the questionnaires to get information on the status of households in terms of access to the forest for the wild climbers that is, authorized or non-authorized users. We also asked households to report on the specific wild climbers harvested to make food harvesting, processing and storage products, from which the top three most reported species were identified as the commonly harvested wild climbers.

2.2.2 | Sampling strategy for forest surveys

As noted above, we purposively selected two parishes along which are gazetted two wild climbers harvest zones (Rutugunda and Southern ward) in Bwindi for the forest surveys (Figure 1). In each of the two designated zones, we established a total of 60 forest sample plots along five 1 km line transects (10 in total) running from the forest edge into the forest interior. The first transect was randomly selected and placed at the boundary of each zone using a numbered grid system map of Bwindi, from which subsequent transects were systematically placed at intervals of 100 m. We permanently marked the transects using concrete blocks. On each transect, we established 30–10 × 10 m forest sample plots at intervals of 15 m. We used the 10 × 10 m forest sample plots to assess the diameter size class distribution of wild climbers of the liana life form harvested for food harvesting, processing and storage products following the methods of Muhwezi et al. (2009). Inside the 10 × 10 m plots, we established 5 m × 5 m forest sample plots to assess the diameter size class distribution of wild climbers of the vine life form harvested for food harvesting, processing and storage products following the methods of Hall and Bawa (1993) and Ndangalasi et al. (2007). We recorded the location of the plots using a hand held Global Positioning System (GPS) unit (Garmin GPSMap 60csx, Garmin Ltd, KS). Inside the sample plots and using the list of the wild climbers generated from the household surveys above, we counted and measured the size (basal diameter) of all the commonly harvested wild climbers (of lianas and vines life forms) that measured 1.3 m long and above using a Vernier caliper. An experienced botanist identified the wild climbers in the plots to species level, marked and tagged them at the base.

2.3 | Data analysis

All data from household questionnaire interviews and forest sample plots were collated in excel spreadsheets, and then analyzed using appropriate statistical techniques as described below in subsections of household surveys data and forest surveys data. We conducted the analysis in R statistical computer programme (R Core Team, 2018). We assumed statistical significance for all the data analysis at 95% confidence interval.

2.3.1 | Household surveys data

For objectives 1 and 3 of the study, we measured use of the products as the number of products owned by households for purposes of food harvesting, processing, and storage. The "number of products owned" was count data that was not normally distributed. We confirmed non-normality of the data using the Shapiro–Wilk test of normality. For this reason, we used Generalized Linear Models (GLM) which are fit for non-normality, in this case the Poisson distribution which is typically used for count data. However, we detected over-dispersion in the models and therefore we re-fitted the

GLMs with a Quasi-Poisson distribution which accounts for overdispersion.

We used the aforementioned GLMs to compare the use of wild climber vs. plastic products by households for purposes of food harvesting, processing and storage (objective 1), and to analyze the factors associated with the use of the respective products (objective 2). For the GLM comparing the use of wild climber vs. plastic products in households, the number of food harvesting, processing and storage products in the household was the response variable and product type (wild climber vs. plastic) was the explanatory variable.

For the GLM identifying the factors associated with the use of respective product, the number of products in the household was the response variable and the explanatory variables were Resource User status of the household (whether the household is a registered resource user or not); acquisition of product (whether the food harvesting, processing and storage products are bought or self-made), limitations to accessing the products (e.g., cost of product, entry into the park restrictions or scarcity of products), estimated product storage capacity and product durability. For this analysis, our aim was to know which explanatory variables are most important for the use of the respective product by finding the optimal model. We used a backwards step-wise selection with *drop1* function in R which drops the most non-significant term in the model, and then refitting the model with the remaining terms to check if there are still any non-significant terms. The process is repeated until only significant terms remain in the model and hence the optimal model.

To assess the contribution of wild climber vs. plastic products to food harvesting, processing and storage, we compared the estimated storage capacity and durability between the product types using GLMs with a Gaussian error distribution. In this analysis, estimated storage capacity and durability of product were the response variables and product type (wild climber vs. plastic) was the explanatory variables. GLMs with a Gaussian error distribution were appropriate for this analysis because both product storage capacity and durability were continuous variables.

After successful implementation of the models, we conducted model validation by plotting response residuals, Pearson residuals, scaled Pearson residuals (obtained by dividing the Pearson residuals by the square root of the overdispersion parameter), and the deviance residuals against the fitted values and all explanatory variables. The purpose was to check for model fit and identifying patterns in the deviance or Pearson residuals. The analysis of deviance table for the optimal model assessing the association between the number of products owned per household and the most important factors was generated using the *ANOVA* function of the "*car*" R package (Fox & Weisberg, 2011).

2.3.2 | Forest surveys data

Forest sample plots' data of the wild climbers was grouped into size classes of 5 cm diameter class interval to depict population structures of the wild climbers. We then plotted the grouped size classes in histograms to show the number of individuals in particular size classes. The size class distribution histograms show the population status of the harvested wild climbers based on four classifications of diameter class distributions; inverted "J" type, bell shaped, "L" shaped, and "J" shaped. The classifications for these diameter class distribution depict impacts of harvesting on plant resources (Hall & Bawa, 1993; Mwavu & Witkowski, 2009).

3 | RESULTS

Of the interviewed 119 respondents, 58.8% were males while 41.1% were females. The respondents' age ranged between 21 and 118 years with an average age of 52 years. Registered resource users were 47% of the respondents and 53% were non-registered resource users.

3.1 | Number and type of food security products used by households

The food harvesting, processing and storage products were those items used by households to enhance food availability. A total of 1,458 products were recorded in all the study households. Of these, 65.02% were those made from wild climbers while 34.97% were those made from plastics. The data for the response variable (number of products owned) was not normally distributed ($W = 0.96214$, $p = .001$). Using a GLM appropriate for this kind of data distribution, we found that the number of products per households significantly differed between those of wild climbers and those of plastics (GLM, $\chi^2 = 65.4$, DF = 1, $p < .001$, Figure 2a).

Key products made from the wild climbers were; baskets, granaries, mats, tea-baskets, serving trays and winnowing trays. Baskets were the most commonly used products followed by mats and winnowing trays. Baskets are used for food crops harvesting and food crops transporting, mats are used for drying cereals and grains, winnowing trays for drying and winnowing/sorting grains and cereals and granaries for storing the food crops. At least each household owned an average of 3.6

baskets, 2 mats and 1.5 winnowing trays. Small granaries were the least used product made from wild climbers (Figure 2b). Key plastic products used by households were; plastic sacks, plastic baskets, plastic basins, plastic buckets, plastic drums (containers) and plastic granaries (Figure 2c). The plastic sacks (locally known as *obudeeyi*) were the most commonly used plastic products in all the households. Each household owned an average of 3.7 plastic sacks.

3.2 | Factors associated with use of food security product types by households

There were two types of food harvesting, processing and storage products as previously mentioned; those made from wild climbers and those already made from plastics. The number of wild climber products owned by households was significantly associated with limitations to accessing the wild climbers (GLM, $\chi^2 = 10.04$, DF = 3, $p = .018$) and the products' estimated storage capacity (GLM, $\chi^2 = 8.71$, DF = 1, $p = .003$). On the other hand, the other important factor associated with the use of plastics for food security was the wild climber access status by households (houses with resource users) (GLM, $\chi^2 = 5.14$, DF = 1, $p = .023$), with households with registered resource users owning less plastic products than those with non- registered resource users. For those households with more plastic products (with non-registered resource users), 75% of them reported to own plastics because they were readily available than the wild climber products; 14.3% of them used plastics because wild climbers were restricted for harvesting; 8.9% of them used plastics because plastics were cheaper; 1.8% them used plastics because of larger storage capacity.

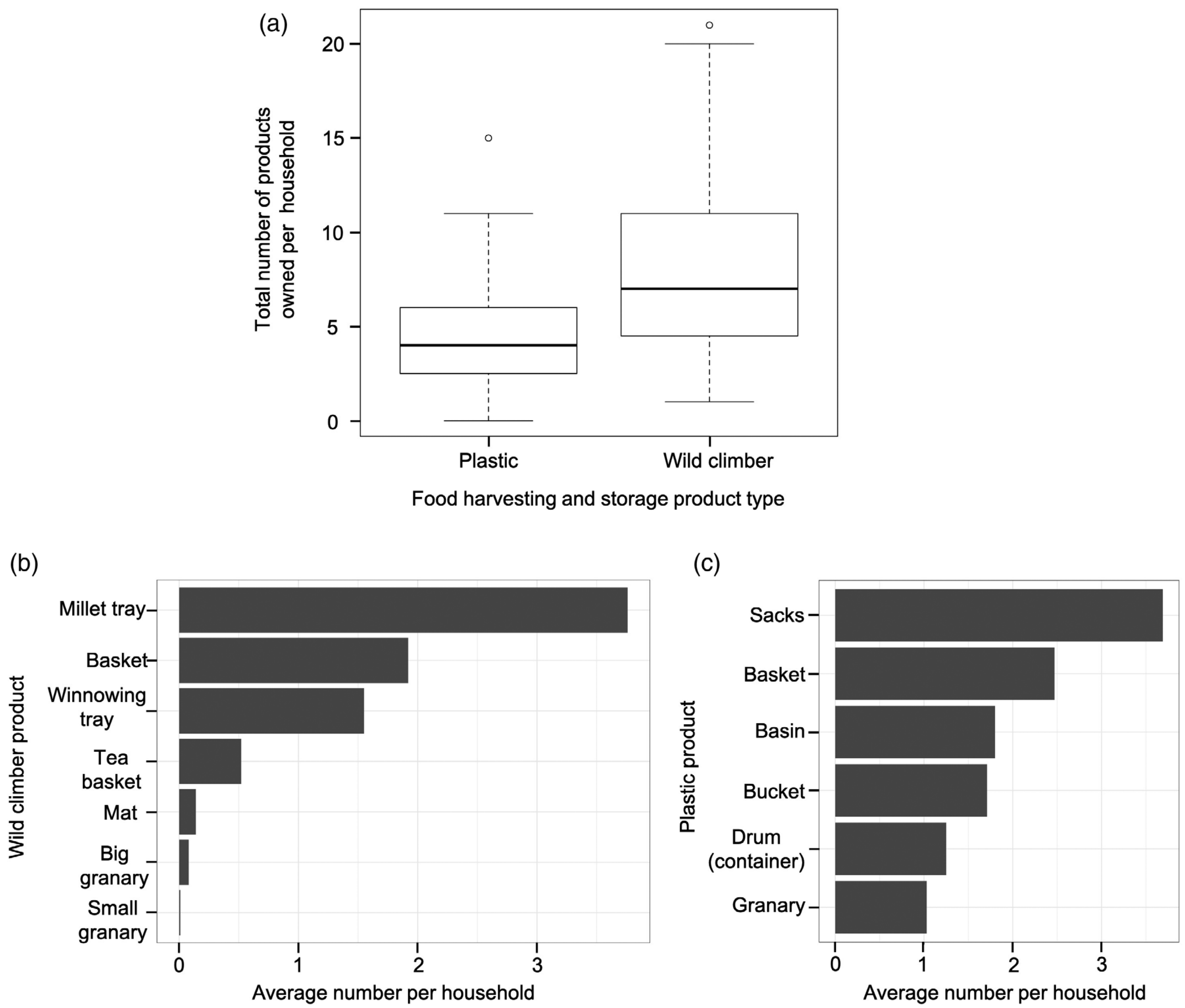

FIGURE 2 (a) Use of plastic and wild climber products for food harvesting, processing and storage purposes by households around Bwindi. Products used for food harvesting, processing and storage which are of wild climber products (b) and plastic products

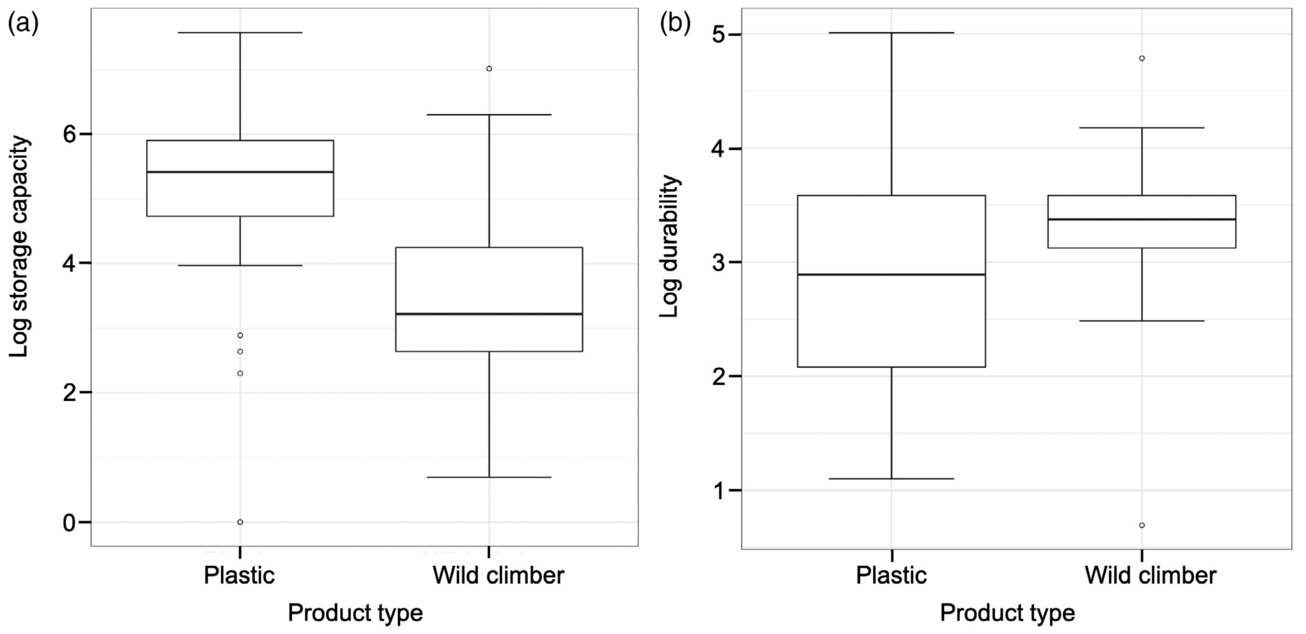

FIGURE 3 Storage capacity (a) and durability (b) compared between plastic and wild climber products for harvesting, processing and storing food

TABLE 1 Wild climber species harvested for food security products from Bwindi

Wild climber					
Family	**Genera**	**Species**	**IUCN red listed**	**Respondents (%)**	**Product**
Smilacaceae	*Smilax*	*anceps*	No	23.6	Basket, winnowing tray, millet basket, tea-basket, millet tray
Annonaceae	*Monanthotaxis*	*littoralis*	No	20	Small granary, basket, winnowing tray, tea basket, millet tray, big granary
Asparagaceae	*Dracaena*	*laxissima*	No	10.9	Basket, winnowing tray, tea-basket, millet tray
Rubiaceae	*Rytigynia*	*ruwenzoriensis*	No	5.5	Small granary, winnowing tray, big granary
Passifloraceae	*Efulensia*	*montana*	No	5.5	Small granary, basket. Winnowing tray, tea-basket, big granary
Malvaceae	*Triumfetta*	*sp.*	No	5.5	Mat, basket, winnowing tray
Celastraceae	*Loeseneriella*	*apocynoides*	No	5.5	Basket, winnowing tray, tea-basket
Plantaginaceae	*Plantago*	*palmata*	No	5.5	Millet basket
Sapindaceae	*Dodonaea*	*viscosa*	No	3.6	Small granary, winnowing tray, big granary
Rutaceae	*Toddalia*	*asiatica*	No	3.6	Winnowing tray
Cyperaceae	*Cyperus*	*papyrus*	Least concern	3.6	Mat
Euphorbiaceae	*Alchornea*	*hirtella*	No	1.8	Millet basket, millet tray
Icacinaceae	*Iodes*	*usambarensis*	No	1.8	Tea-basket
Cyperaceae	*Cyperus*	*latifolius*	No	1.8	Mat
Malvaceae	*Hibiscus*	*fuscus*	No	1.8	Mat, winnowing tray

Note: Percent respondents refers to the percent of registered resource users ($N = 56$) who reported a given wild climber species as raw material for a given food security product.

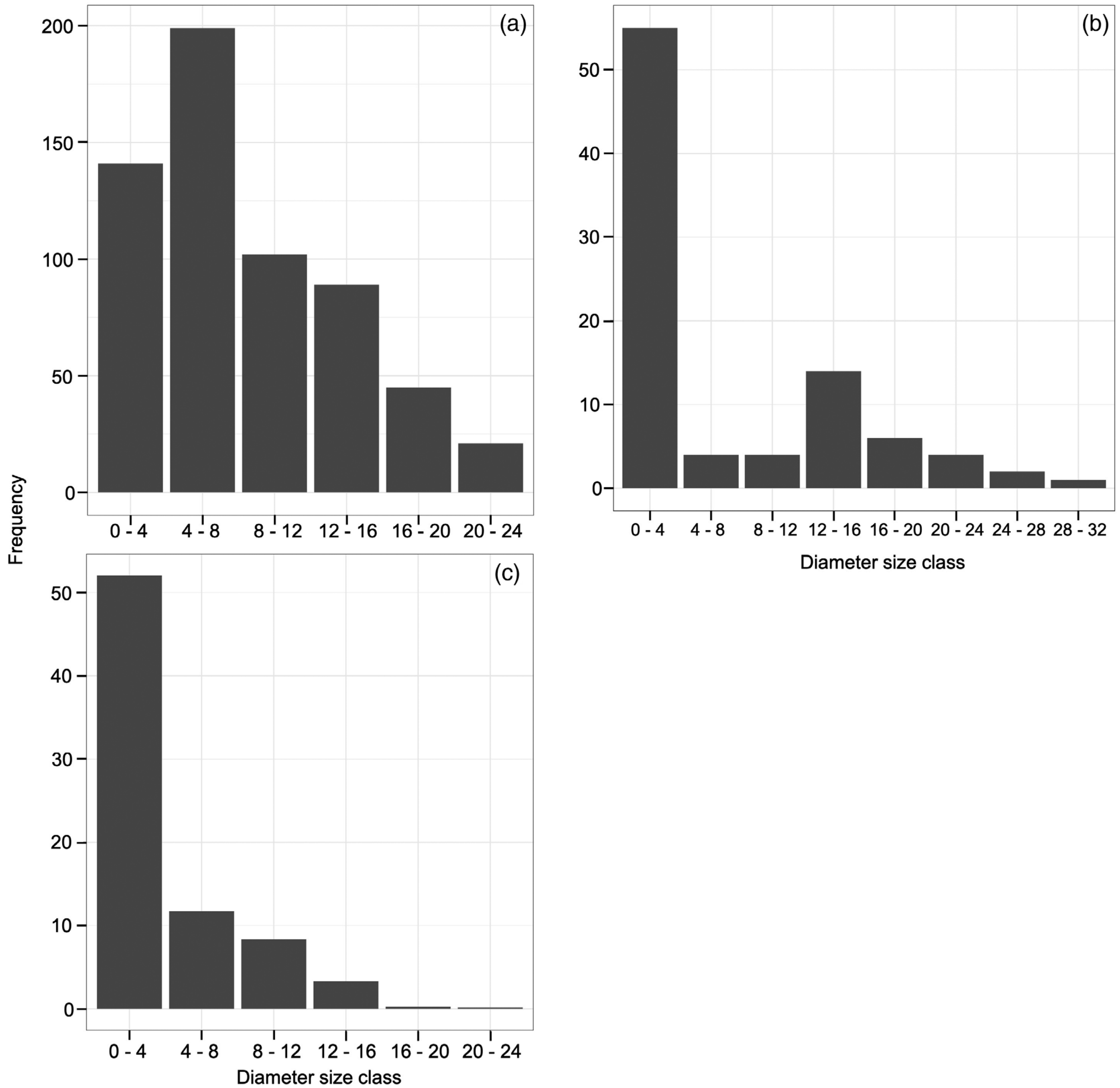

FIGURE 4 Diameter size class distribution for the three most common wild climber species harvested for food harvesting, processing and storage products around Bwindi: (a) *Smilax anceps*, (b) *Monanthotaxis littoralis*, and (c) *Dracaena laxissima*

Comparing the perceived contribution of products to food harvesting, processing and storage, the reported food storage capacity differed significantly between wild climbers and plastic products (GLM, $\chi^2 = 22.4$, DF = 1, $p < .001$), with storage capacity reported to be higher for plastic products than for wild climber products (Figure 3a). On the other hand, products' durability was reported to be significantly higher for wild climber products than for plastic products (GLM, $\chi^2 = 8.32$, DF = 1, $p = .004$, Figure 3b).

3.3 | Population structure of the commonly utilized wild climbers in Bwindi

Registered authorized resource users reported to harvest 15 species of wild climbers belonging to 13 families and 15 genera as raw materials for food harvesting, processing and storage products (Table 1). None of these wild climbers are listed on the IUCN's Red List of threatened species. For a fact none of the wild climbers has been assessed with exception of one (*Cyperus papyrus*) which is listed as of "Least Concern". Of the 15 wild climbers, the topmost three species utilized were *Smilax anceps*, *Monanthotaxis littoralis* and *Dracaena laxissima*. These were used for making food security products by the households. The least used wild climber species were *Hibiscus fuscus*, *Cyperus latifolius*, and *Iodes usambarensis* (Table 1). The population structure of the three commonly utilized wild climbers are shown in Figure 4. Two of these climbers (*S. anceps* and *D. laxissima*) exhibited an inverted "J" type of distribution while one (*M. littoralis*) exhibited an "L" shaped diameter size distribution.

4 | DISCUSSION

4.1 | Number and type of food security products used by households

The most important food crops grown by the local people around Bwindi are beans, peas, maize, wheat, sorghum, millet and potatoes, with tea being the single most important cash crop (Bitariho & Akampurira, 2019). Some of the food harvesting, processing and storage products perform more roles than others and were therefore commonly observed among the households (Bitariho & Akampurira, 2019). The type of food harvested, processed and stored dictates the type of product used for those particular purposes. For example, the wild climber baskets and plastic bags are used for harvesting and storing food and cash crops mentioned above (Bitariho & Akampurira, 2019). The winnowing trays are used for processing, sorting, drying and winnowing cereals and grains, while the tea-baskets are used for picking, transporting and storing tea (Bitariho & Akampurira, 2019; Muhwezi et al., 2009).

As the results have shown, the wild climber products were more commonly observed in the study area than the plastics for harvesting, processing and storing food crops. It therefore goes without saying that the contribution of the wild climbers to food security for the households around Bwindi cannot be overempathized (Bitariho & Akampurira, 2019; Muhwezi et al., 2009). The use of baskets for harvesting, drying, winnowing, grinding, and storing food crops by African subsistence farmers has also been reported elsewhere in southern African countries (Cunningham & Terry, 2006). Since agricultural production is a seasonal activity, while the demands for food commodities are evenly spread throughout the year, food storage is an important aspect of food security in general (Nukenine, 2010). Therefore, authorized access to the wild climbers by the frontline villages around Bwindi may have indirectly enhanced food security while at the same time minimized use of plastics.

4.2 | Factors associated with the use of food security product types by households

Despite the wild climbers importance to food security, the use of wild climber products around Bwindi is limited by access restrictions set by the Bwindi park management. Even within the MUP parishes, wild climbers' access is restricted to only authorized registered resource users. It is worth noting that majority of the people around Bwindi are poor and heavily dependant on forest resources for their livelihoods (Bitariho et al., 2016; Plumptre et al., 2004). The low income makes it even more difficult for households to purchase the wild climber products that are crucial to their livelihoods. Some of the households therefore resort to using alternatives such as plastics as a coping mechanisms since plastics are readily available and cheap to them.

The alternative use of plastics may have detrimental impacts on biodiversity in Bwindi (Windsor et al., 2019). Plastic accumulation in terrestrial ecosystems and eventual ingestion by wildlife has been reported to have negative effects on wildlife from blockages in the digestive tracts to reduced growth and mortality (Derraik, 2002). Indeed, at Bwindi, there is evidence of very poor disposal of plastics that get littered everywhere. As a matter of fact, plastic wastes have been observed in carnivore scats (probably of the serval cat [*Leptailurus serval*] or African golden cat) in Bwindi (Badru Mugerwa, personal communication). The release of chemicals after degradation of plastics has been reported to be toxic to wildlife since it alters and disrupts invertebrate and vertebrate hormonal systems. It is therefore important to minimize use of plastics by frontline households around protected areas such as Bwindi in order to mitigate the plastics impacts on the biodiversity therein.

The use of plastic products might however be challenging to mitigate since as the results show, plastic products have a significantly higher food storage capacity than wild climber products. Nevertheless, the higher durability of the wild climber products may be a lucrative option to the households because, durability not only allows multiple re-use of the products, but also saves households from recurrent spending of money as is the case with the less durable plastic products (Cooper et al., 2018).

4.3 | The most commonly harvested wild climbers in Bwindi

The three commonly used wild climbers are not listed on the IUCN red list of threatened species; a safeguard to the wild climbers conservation status. However, the first signal that a plant population is being subjected to an overly intensive level of harvest is usually manifested by its population structure (Hall & Bawa, 1993). The inverted "J" type of size class distributions exhibited by the two wild climbers (*S. anceps* and *D. laxissima*) shows that the species have more seedlings than adults representing a self-replacing population that is usually found in healthy plant populations (Hall & Bawa, 1993; Mwavu & Witkowski, 2009). The fact that these species showed this type of distribution may be an indication of the sustainable plant harvests as noted by Hall & Bawa, 1993; Struhsaker, 1998; Pfab & Scholes, 2004. On the other hand, for *M. littoralis*, its population distribution suggests a heavily harvested wild climber population (Hall & Bawa, 1993; Mwavu & Witkowski, 2009). Indeed, this climber has been heavily harvested in Bwindi for making tea-baskets and granaries (Bitariho, 2013; Muhwezi et al., 2009; Ndangalasi et al., 2007). Bwindi park management should restrict its use to forestall its overexploitation from the forest until recovery (Bitariho, 2013; Bitariho et al., 2006).

5 | CONCLUSION

Overall, we are cognizant of the fact that this study might not in totality show a complete picture of all the local people's use of wild climbers and plastics by all the parishes around Bwindi, however, what is undisputable is the fact that the study has shown trends of use of the wild climbers and plastics by the frontline villages/households adjacent Bwindi. In fact, the wild climbers are important in enhancing food security among the frontline households around Bwindi and probably elsewhere. The limitations to wild climbers access by the local people have led to use of other available alternatives such as the ubiquitous plastics that are detrimental to not only the environment but also pose a myriad of threats to the biodiversity in the PAs. Except for one species, that is, *M. littoralis*, this study has not detected any potential negative harvest impacts of the commonly harvested wild climbers in Bwindi. We therefore recommend that for those studied and known wild climbers, the Bwindi park managers should consider increasing more access by the local communities to those wild climbers that particularly depict healthy populations. This would benefit household food security while at the same time minimize the use of plastics by the frontline households.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest in this study.

AUTHOR CONTRIBUTIONS

Robert Bitariho: Conceived and designed the study, planned and compiled the data collection tool for the manuscript, contributed to the text, data analysis and the logical discussions and conclusions of the manuscript. Emmanuel Akampurira: contributed to the study design, data collection tool, participated in the data collection for the manuscript, contributed to the text, data analysis and the logical discussions of the manuscript. Badru Mugerwa: Contributed to the data analysis, manuscript aligning, text and logical discussions and conclusions of the manuscript.

DATA AVAILABILITY STATEMENT

The data that support findings of this study are available and can be accessed from the corresponding author after reasonable requests are made.

ETHICS STATEMENT

Ethical clearance and research approval were granted by the Uganda government. The Institute of Tropical Forest Conservation (authors' affiliate institution) has a longstanding Memorandum of Understanding (MoU) with the Uganda Wildlife Authority (UWA) to undertake research in Bwindi Impenetrable National Park and other national parks in southwest Uganda on behalf of UWA. Prior to the household interviews, the authors sought PIC from the local communities in the study area.

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