Impact of Women's Harvest Practices on *Pandanus guillaumetii* in Madagascar's Lowland Rainforests[1]

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Impact of Women's Harvest Practices on *Pandanus guillaumetii* in Madagascar's Lowland Rainforests. *Pandanus guillaumetii* B.C. Stone is endemic to the east coast rainforests of Madagascar. The plant is an important non-timber forest product (NTFP) for the local population living near these forests, and its leaves are collected by women to be woven into mats. These mats have economic value and are also used for daily activities. At present, little is known about how local harvesting practices impact this plant species. In this study, we describe women's local harvest practices and quantify their impact on the *P. guillaumetii* population. We carried out plant inventories as well as interviews and participatory observations with local people harvesting *P. guillaumetii* in two villages with different population densities in the Manompana region. Inventories were conducted at varying distances from the villages in order to better understand the influence of human pressure on the plant population. The results suggest that local communities apply practices that tend to minimize the harvest impact on the plant. Harvesting seems to have no effect on the actual density of *P. guillaumetii*. However, the availability of plants with leaves of sufficient quality for mat production is influenced by human pressure. Considering the decreasing number of plants suitable for handicraft, we assume that their availability in the long term may not fulfill the needs of the local people.

Impact de la récolte de *P. guillaumetii* par les femmes dans les forêts pluviales de basse altitude de Madagascar. *Pandanus guillaumetii* B.C. Stone, une espèce endémique de Madagascar, se trouve dans les forêts ombrophiles du versant oriental de l'île. Les femmes des communautés vivant à proximité de ces forêts en utilisent les feuilles pour confectionner des nattes. Il s'agit de produits forestiers non ligneux en usage dans la vie quotidienne et qui ont une valeur économique. Les prélèvements de feuilles contribuent-ils à la raréfaction de l'espèce? A ce jour, peu de recherches ont été réalisées à ce sujet. Dans notre étude, nous décrivons les modes de prélèvement des feuilles de *P. guillaumetii* et cherchons à quantifier l'impact des prélèvements sur les populations de l'espèce. Nous avons réalisé des inventaires en forêt et effectué des interviews et des observations participatives avec les habitants de deux villages de la région de Manompana. Afin de saisir les effets de la pression humaine, nous avons effectué des inventaires à différentes distances des villages. Il ressort des résultats que les pratiques de prélèvement des feuilles par la population locale tendent à minimiser l'impact de la récolte. Les prélèvements ne paraissent pas avoir d'effet sur la densité de la population de l'espèce. Néanmoins, les plantes fournissant des feuilles convenant à la confection de nattes sont moins abondantes à proximité des villages. Considérant la diminution du nombre d'individus se prêtant à un usage artisanal, nous estimons qu'à long terme, les besoins de la population ne pourront plus être satisfaits.

Key Words: *Pandanus*; harvest impact; leaf harvest; non-timber forest product; Madagascar; harvest practices.

Introduction

For centuries, the harvest of non-timber forest products (NTFPs) has supported the needs of

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millions of people worldwide (Lawes 2004). Rural people living in remote areas in particular often rely on the harvest of NTFPs for their subsistence (Perez 2006). Although it is often assumed that the harvest of NTFPs has less negative environmental impact than other land uses, harvest may affect biological processes at many levels: ecosystem, population, and individual (Cunningham et al. 2001; Peters 1994). Several studies have focused on the ecological consequences resulting from the harvest of NTFPs (Cunningham et al. 2001), and it is generally agreed that such consequences are species-specific, depending on the population dynamics and structure, natural distribution, and growth rate (Ticktin 2004). However, the impact depends not only on the species being harvested but also on local harvesting techniques and practices (Anderson and Rowney 1999; Runk et al. 2004).

The importance of these factors is reflected in the ongoing debate over whether local people manage NTFPs sustainably or not (Joyal 1996; Ndanyalasi et al. 2007). This discussion implies that management strategies influence the future availability of NTFPs. Despite the recognized importance of local harvest practices, few studies have considered their influence on NTFP availability (Ticktin 2004). Nevertheless, in a few cases, harvest intensity and impact on NTFPs has been reported to decline with increasing distance from the local village (Karanth et al. 2006; Shaanker et al. 2004a). Thus, both the local harvest practices and the human population density can have an effect on NTFPs. Management that can mitigate the long-term negative effects of harvest is especially important in regions where the pressure on natural resources is already high (Ticktin 2004).

In Madagascar, where forests are disappearing at an alarming rate (MEFT et al. 2009), pressure on natural resources is severe (Dufils 2003). Due to a high deforestation rate in the lowland rainforests on the east coast (Green and Sussman 1990; Harper et al. 2007), many species are suffering from habitat loss. Pandanaceae species growing in this region are particularly affected (Good et al. 2006); 91% of Pandanaceae species are threatened with extinction (Callmander et al. 2007), especially those inhabiting the forests of the east coast. Several plant species belonging to the Pandanaceae family are important to local people, who use their leaves for handicraft production (Callmander and Laivao 2003; Kremen et al. 1998; Urech et al. 2011).

To better understand the impacts of local harvesting practices on *Pandanus* species, we launched a combined analysis of the local *Pandanus guillaumetii* B.C. Stone population and the local harvesting practices. The aims were (i) to document the uses and harvest practices of *P. guillaumetii* by women, the main users of the plant, (ii) to assess its current population density and population characteristics, and (iii) to evaluate the possible influence of harvest practices and intensities on this species. In particular, we investigated how *P. guillaumetii* is influenced by the proximity to villages, the human population density, and local harvest practices.

Method

Study Site

Two villages located at the border of remaining forests were selected (Fig. 1): Bevalaina (S 16° 38'24.936", E 49°43'43.608") and Ambofampana (S 16°37'32.916", E 49°36'1.5114"). The forest at both locations is classified as an "evergreen humid forest of low altitude" (Humbert and Cours Darne 1965). The mean annual precipitation in the region is 3,600 mm and the average annual temperature is 24°C (Koechlin et al. 1997).

Most of the population at our study sites belongs to the Betsimisaraka ethnic group, who traditionally practice small-scale slash-and-burn agriculture, one of the principal reasons for forest clearance (Casse et al. 2004; Messerli 2000; Pfund 2000). In order to better understand the influence of local people on *P. guillaumetii*, we selected two villages with different anthropogenic pressures and forest resource availabilities, as reflected by the percentage of forested area and by the density of human population (Table 1). Ambofampana is situated close to a large forest in a landscape with a very low human population density. In contrast, Bevalaina has a large human population density and, due to a high deforestation rate, few remaining forest fragments.

Species Selection and Description

From the most important Pandanaceae species used by local inhabitants, we selected the species that has the highest commercial potential, a large number of users and a high preference rate. *Pandanus guillaumetii* was the species that best fit

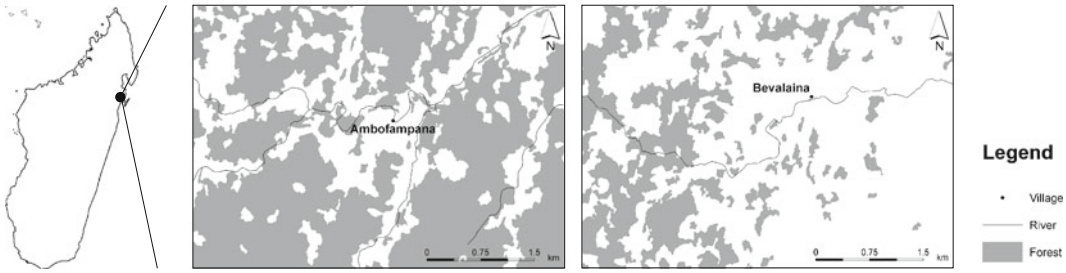

Fig. 1. The study site locations, Bevalaina and Ambofampana, Madagascar.

these criteria. Its common name is *Tsiriky* and it has been recently put in synonymy with *P. ferox* Huynh and *P. pichi-sermollii* B.C. Stone (Laivao et al. 2006). The species is endemic to humid forests of low and middle altitudes (<700 m) between the Masoala Peninsula and Nosy Varika (Laivao et al. 2006). If the criteria of the IUCN Red List were applied, *P. guillaumetii* would be considered as vulnerable (Laivao et al. 2006). This long-lived, dioecious plant can reach 6–9 m in height, with stem diameters of 10–15 cm. Prior to reaching the adult habit, *P. guillaumetii* follows a succession of life-history stages, each with unique morphological characteristics (Guillaumet 1973). The morphological differences of plant parts are important for our study because the species is used primarily for its leaves, which reach their maximum length as juveniles and then decrease with increasing plant age (Rickard and Cox 1984). We recognize four life stages for *P. guillaumetii*: seedlings, juveniles (bearing the longest leaves, suitable for mat weaving), young adults, and branching adults (the only life-history stage that produces flowers and fruits).

Harvest Practices

In the first study, we conducted household surveys of 57 randomly selected households (25 in Ambofampana and 32 in Bevalaina) to collect data about income and use of several NTFPs. To complete information about use, criteria for plant and leaf selection, and harvest practices of *P. guillaumetii,* we continued with semistructured interviews with 12 randomly selected women (6 from Bevalaina and 6 from Ambofampana). Additionally, we accompanied and assisted women throughout the harvest and weaving process three times per village. Male roles with regards to species harvest were also considered. Men usually have better knowledge concerning remote forests and species identification (Cunningham et al. 2001; Styger et al. 1999).

Harvest Impact

In order to identify the impact of harvest practices on *P. guillaumetii* populations, we assessed plant density, life-history stage, harvest signs, and leaf length by conducting plant inventories. Harvest signs have been quantified according to frequency and number of leaves harvested per plant and according to damage to the central leaves (apex leaves). Harvested plants were identified by the cutting signs, which remain visible many years after the harvest. We also noted the position of each inventory plot

Table 1. Characteristics of the two research villages (modified from Urech et al. 2011).

Characteristics	Ambofampana	Bevalaina
Altitude (m.a.s.l.)	375	20
Forested area (% of village territory)	86	43
Number of households (N)	27	110
Population density (households/km^2 forest)	1	20
Main ethnic group (% of people)	Betsimisaraka (~95%)	Betsimisaraka (~85%)
P. guillaumetii as source of income (% of households)	65	8
Average income from *P. guillaumetii* per selling household and year (MGA)	11,875[a]	13,330[a]

[a] MGA 1,000 = USD 0.49.

according to the vertical slope section (hill bottom, hill top, slope) and the exposition (N/E/S/W). Based on similar studies (Hall and Bawa 1993), we sampled 18 plots per village that were distributed over 5 transects in each village at altitudes between 376–420 m.a.s.l. in Ambofampana and 40–320 m.a.s.l. in Bevalaina. Following an inventory design from a similar study (Karanth et al. 2006), the transects radiated outward from the village in different directions, with attention to the forest coverage. Transects were initially thought to go through undisturbed areas. Previous research has suggested that women walk for a maximum 98 minutes to collect leaves (Kremen et al. 1998). Based on this information, we conducted inventories within a 150-minute walk from the village. Each 10 by 50 meter (0.05 ha) plot was located along a transect at least 20 minutes walking time from the next plot. If after 20 minutes no *P. guillaumetii* was found, the plot was marked as empty and we moved on until we reached a plot with at least one plant. We used walking-time measurements instead of spatial measurements because the heterogeneous topography and vegetation density can negatively influence the accessibility of some sites, causing an underestimation of the effective distance to the village.

Statistical Analysis

We assessed the density of juveniles and branching adults per study plot (stem/hectare) and tested the influence of distance from village (in minutes), relief, and aspect on the density of the local *P. guillaumetti* population. Assessing branching adults provides information about the impact of harvest practices on the long-time regeneration.

The harvest intensity was assessed using four indicators of human pressure on *P. guillaumetii*: harvest frequency (number of harvests per plant), the presence/absence of plants with suitable length of leaves for handicrafts, number of harvested leaves per plant, and the presence/absence of damaged apex leaves. For each village, we analyzed the influence of distance from the village on these four indicators.

For all analyses, Generalised Linear Models (GLM) were applied and significance was tested using the Likelihood-Ratio Test (LRT). Confidence intervals of 95% (CI 95%) were included for the interpretation of results.

Results

Harvest Practices

Harvest practices by women are concentrated at the juvenile life-history stage. The leaves of the juvenile plants are collected, prepared, and woven into mats (see Fig. 2), which are then used to dry rice and cloves or sold. Women explained that the weaving technique is well anchored in Betsimisaraka culture and is passed from mother to daughter at an early age (11–12 years old). Women are responsible for the trade of mats. Only a few women walk far distances (up to 8 hours) to sell their handicrafts in the nearest markets (MGA [Malasgasy Ariary] 1,000–2,000/mat). Others sell the mats to families of the same village (MGA 600–1,200/mat), but most women sell them to traders coming directly into the village (MGA 800–1,500/mat). Their visits coin-

Fig. 2. Production of handicrafts made from *P. guillaumetii* leaves: a man helping his wife (left) and a woman weaving a mat (right).

cide with the start of the main rice and clove harvest seasons (October–November, March–April), when mats are required. Due to the durability of *P. guillaumetti* handicrafts (one year on average) and population growth, the leaves are in high demand.

During our observations, women usually went into known forests, alone or in groups of 2–5 women, walking for up to 150 minutes from the villages. It seemed that the search radius was not limited by time, but rather by village territories. Although according to custom, all people have access to NTFPs in all forests, women prefer to stay in forests within the village territory. They clearly favored locations where *P. guillaumetii* is easily accessible, abundant, and relatively young with numerous long leaves (minimum 1.5 meters). Some women meticulously chose the best 2–3 leaves per plant; others chose a plant and cut 3–9 leaves at a time. In both cases, however, they were especially careful not to damage the 2–3 apex leaves, the central leaf shoots. In fact, there is a well-recognized understanding that the apex leaves of all *Pandanus* spp. should not be cut. Otherwise, raindrops are able to reach the plant heart (apical meristematic tissue), causing its decay. Interestingly, all dead juveniles we found had damaged apex leaves. After collection, leaves were arranged in bundles of approximately 30 leaves for transport. Due to physical constraints, women can carry a maximum of about 15 bundles (i.e., 90–180 leaves, 15 kg).

We found three important differences related to the use and harvest practice of *P. guillaumetii* between the two villages. First, in Ambofampana, all mats are produced using only *P. guillaumetii*. No domestication is practiced and people have not replaced *P. guillaumetii* with an alternative wild species. *Lepironia mucronata* Pers., a typical Cyperaceae growing in marsh land, can also be used to produce mats, but is rarely found in Ambofampana proximities. Additionally, a traditional taboo prevents the use of handicrafts made from this species in rice fields. In contrast, most inhabitants of Bevalaina have already replaced *P. guillaumetii* with *L. mucronata*. Mats made from this alternative plant are more durable, but require a more laborious preparation and have less drying capacity. As a result of the scarcity of suitable *P. guillaumetii* leaves in village proximities, the taboo was removed in 2001 by the *Mpisikidy*. The *Mpisikidy* is one of the village elders with the ability to contact ancestors and spirits and to interpret their messages (Danielli 1949). He explained that it was possible to rescind the taboo because villagers had expressed the need for an alternative source of leaves for mat production. This change of taboo due to resource scarcity was also observed in other villages near the study area.

The second significant difference in harvest practices between the study villages relates to the involvement of men in leaf collection. All interviewed women from Ambofampana indicated that they do not need men to help them harvest *P. guillaumetii* leaves. In contrast, women from Bevalaina often ask a husband to guide them if they want to travel to more remote forests. Men are also useful for carrying the heavy leaf loads over the long distances back to the village. Women from Bevalaina indicated that in the past, the forests were closer and that they could more easily harvest the plants alone. However, due to continuous forest clearing, the women have had to change their harvest practices to adapt to the increasing remoteness of harvestable plants.

A third key difference between the study villages is that women from Ambofampana practice communal planning in regard to their harvest practices. They decide as a community which locations are most suitable for harvesting at the moment and avoid returning to locations that have been harvested within the past two years. Women from Bevalaina do not engage in this practice of communication.

Harvest Impact

We calculated an average density of 977.22 ± 803.99 juveniles per hectare in the study area (Ambofampana: ± SE: 1,240.00 ± 751.78; Bevalaina: ± SE: 704.44 ± 783.46). In Ambofampana, we did not find an influence due to distance from the village on plant density (LRT = 0.47; df = 1; $P = 0.494$), nor an influence due to geographical relief (LRT = 0.01; df = 2; $P = 0.993$). However, we did find that plant density is influenced by the exposition (LRT = 9.00; df = 2; $P = 0.013$). The highest density was observed at the east exposition (2,470.00 ± 890.96 juveniles/ha), followed by south (985.71 ± 205.82 juveniles/ha) and north (957.78 ± 830.51 juveniles/ha). In Bevalaina, plant density was not influenced by distance from the village (LRT = 0.60; df = 1; $P = 0.440$), relief (LRT = 4.70; df = 2; $P = 0.097$), or exposition (LRT = 4.40; df = 2; $P = 0.110$).

With regard to the availability of branching adults in the study area, we estimated an average density of 38.89±7.56 branching adults per hectare (Ambofampana: ± SE: 60.00±10.73; Bevalaina: ± SE: 17.78±8.23). We did not find a significant influence on plant density due to distance (LRT = 0.13; df = 1; P=0.722), relief (LRT = 1.00; df = 2; P=0.530), or exposition (LRT = 5.00; df = 2; P=0.067) in Ambofampana. Plant density was similarly unaffected by distance (LRT = 2.56; df = 1; P=0.110), relief (LRT = 1.03; df = 2; P=0.598), or exposition (LRT = 4.98; df = 2; P=0.083) in Bevalaina.

Of the juveniles observed in Bevalaina, 31.9% showed evidence of harvest (N=1,116), whereas only 13.5% of juveniles in Ambofampana (N=686) had harvest signs. Surprisingly, we continued to find harvested plants up to our maximum distance (150 minutes walking) from the villages. In Ambofampana, plants showed signs of a maximum of two previous harvests. In Bevalaina, plants were harvested up to three times. The harvest frequency decreased with increasing distance in Bevalaina (LRT = 32.87; df = 1; P< 0.001; Fig. 3 left) and in Ambofampana (LRT = 52.69; df = 1; P<0.001; Fig. 3 right).

For the occurrence of juveniles with a leaf length minimum of 1.5 m, a positive correlation between plants with suitable leaves and increasing distance was found for Bevalaina (N=632; LRT = 11.96; df = 1; P<0.001; Fig. 4 left) but not for Ambofampana (N=954; LRT = 3.30; df = 1; P= 0.069; Fig. 4 right).

On average, women collected 6.36±0.19 and 7.65±0.22 leaves per harvested plant in Bevalaina (N=402) and Ambofampana (N=492), respectively. The number of leaves used was positively correlated with distance for Bevalaina (LRT = 50.86; df = 1; P<0.001; Fig. 5 left) but not for Ambofampana (LRT = 0.07; df = 1; P=0.785; Fig. 5 right).

The preservation of apex leaves is known to be fundamental to the survival of the plant. However, the practice of preserving apex leaves was not respected equally in the two villages; in Bevalaina, 2.6% of the recorded plants (N= 1116) were found to have damaged apex leaves, whereas only 0.6% were damaged in Ambofampana (N=686). The occurrence of plants with damaged apex leaves decreases with increasing distance in Bevalaina (LRT = 10.55; df = 1; P= 0.001; Fig. 6 left) but not in Ambofampana (LRT = 2.90; df = 1; P=0.089; Fig. 6 right).

Discussion

Harvest Practices

P. guillaumetii is an important species for the local population and is used by almost all households for personal consumption or income generation. As a result of the plant's importance and local knowledge, harvest practices that are well anchored in the local culture have evolved, as has been observed in other studies (Gadgil et al. 1993). The practice of preserving the apex leaves, for example, is still present in both villages and has even been observed in other regions of eastern Madagascar (Jones et al. 2008). However, probably as a result of increasing resource scarcity, specific harvest rules have been adapted in one of

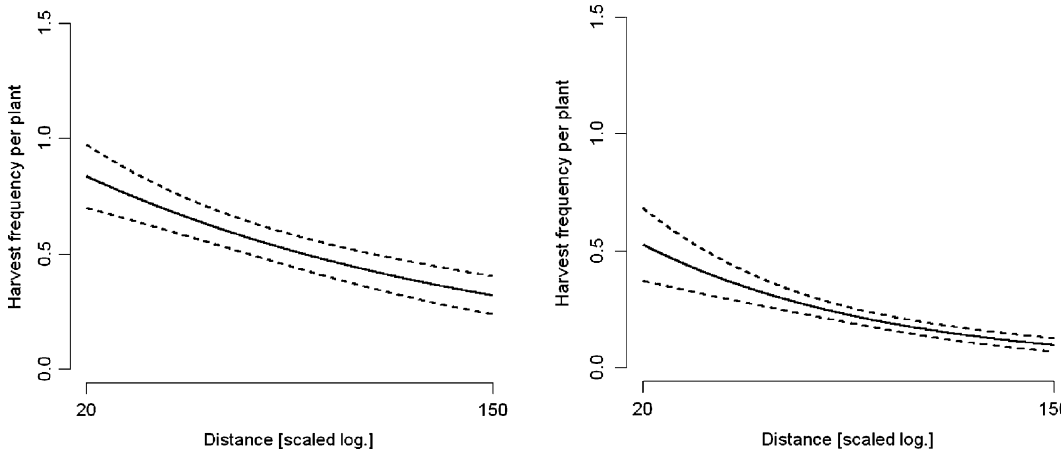

Fig. 3. Harvest frequency of *P. guillaumetii* in relation to distance in (left) Bevalaina (N=686) and (right) Ambofampana (N=1,116) (— logistic regression- - -CI 95%).

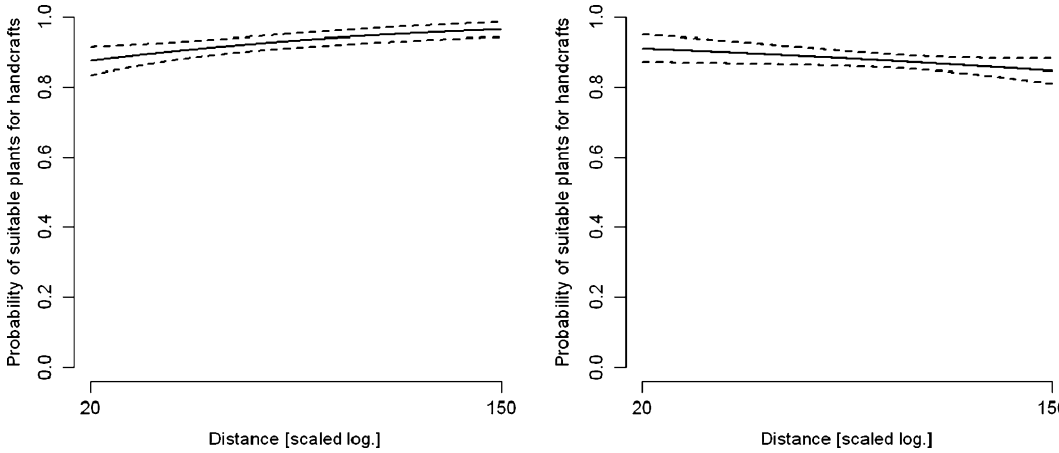

Fig. 4. Probability of suitable plants for mats production (lengths of leaves≥1.5 m) in relation to distance in (left) Bevalaina (N=632) and (right) Ambofampana (N=954) (— logistic regression- - -CI 95%).

our villages. This suggests that even long-standing traditions can be adapted to modern circumstances and are not unchangeable.

Harvest Impacts

Our inventories show that juvenile *P. guillaumetii* are still well represented in the forest at our study sites. In neither village do we observe a significant change in the population density with regard to distance, although the human pressure on the plant in Bevalaina is particularly high. We can therefore assume that a high demand on the plant's leaves does not critically affect the plant's survival.

We find a significant coherence between the density of juveniles and the exposition in Ambofampana. However, due to our small sample size (36 plots), this is a relationship that should be further explored before assumptions are made.

It has been reported that the removal of plant tissues such as leaves can cause the reallocation of stored reserves. Nutrients allocated for growth are instead used for repairing wounds, which may eventually prevent the plants from reaching successive life-history stages, particularly if the wounding occurs in the juvenile stage (Arnold and Pérez 2001; Hall and Bawa 1993; Joyal 1996). To determine the survival rate of *P. guillaumetii* after harvesting, we analyzed the availability of branching adult plants in a reproductive stage. Our results showed that in both villages the availability of branching adults is not

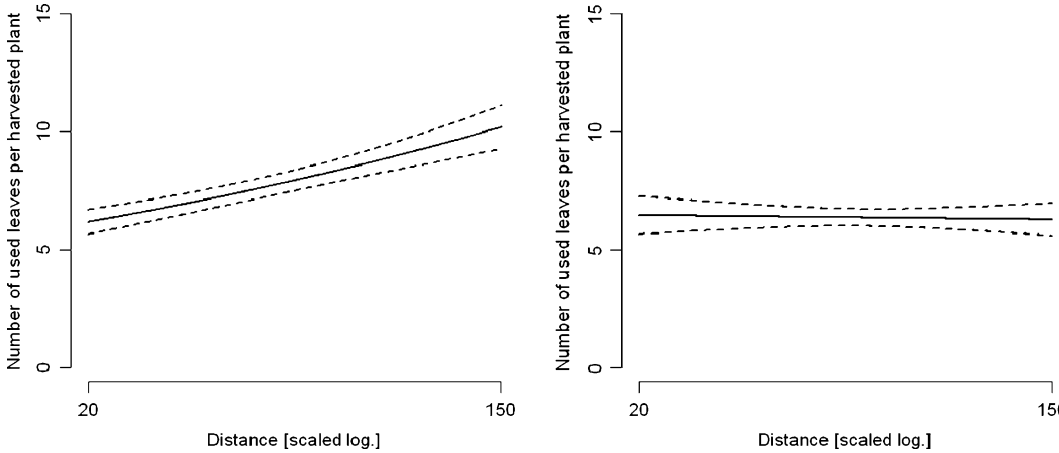

Fig. 5. Number of leaves used per harvested plant in relation to distance in (left) Bevalaina (N=402) and (right) Ambofampana (N=492) (— logistic regression- - -CI 95%).

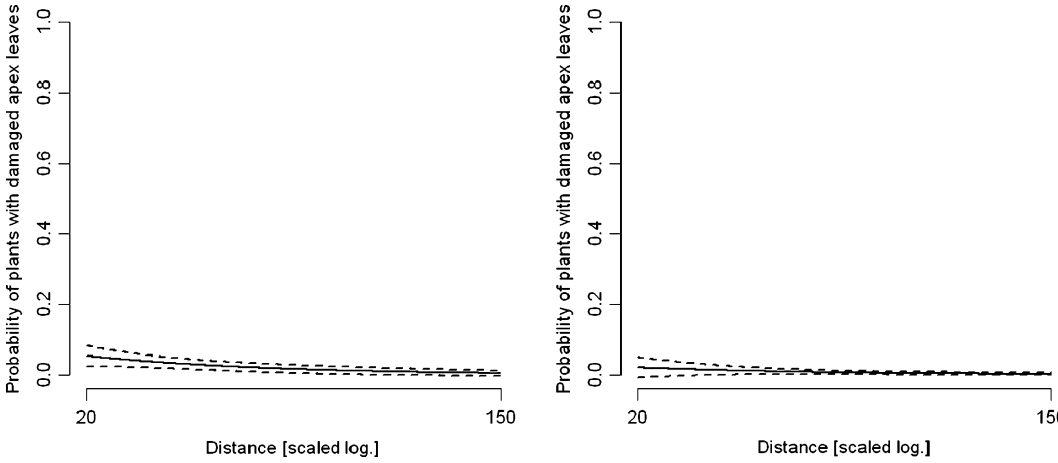

Fig. 6. Probability of plants with damaged apex leaves in relation to distance in (left) Bevalaina (N=686) and (right) Ambofampana (N=1,116) (— logistic regression- - -CI 95%).

dependent on distance to village. We therefore assume that the harvest of juveniles does not have a significant negative impact on the plant's regeneration.

In exploring the influence of human pressure on the plant, we find coherence between harvest frequency and distance from the village for both Bevalaina and Ambofampana, as has been observed in other studies (Sampaio et al. 2008; Shaanker et al. 2004a). The farther a plant is from the village, the less frequently it is harvested. This is not surprising, as many women do not have the time to walk very far to collect leaves and prefer to stay in the village proximity. It is interesting, however, that harvest signs were observed even at 150 minute walking distances. This suggests that women have a large search radius that is not necessarily limited by walking time, as is assumed in other studies (Kremen et al. 1998). We found that it is more important for women not to infringe on territories visited by women from other villages.

Harvest frequency, however, differs significantly between the two villages examined in this study. Almost three times as many plants are harvested in Bevalaina as compared to Ambofampana. The human pressure on plants around Bevalaina is much higher and can also be observed in the number of plants with long leaves. The farther one is from Bevalaina, the more plants with suitable leaves (≥1.5 meters) one can find. While all women prefer long leaves, not all women are willing or have the time to walk long distances to find them. In contrast, there is no correlation between distance to village and plants with suitable leaves in Ambofampana. A large number of plants with long leaves can be found within the village proximity. This is explained by the practice of only harvesting a location every two years. This practice distributes the harvest pressure over a wider area and at greater distances from the village, but can only be realized by good communication between women. This coordination does not seem to apply in Bevalaina, which has about 110 households in comparison to the 27 households in Ambofampana. Thus, it may be that communication breaks down with increasing population, which in return affects the availability of plants with long leaves. Further investigation over a long time period should shed more light on how communication changes with population growth.

In response to the decreasing availability of plants with long leaves near the village, women in Bevalaina adapted local practices to coordinate harvest timing. Normally, women search in groups to avoid getting lost in the forest, although their ability to carry large loads over long distances is limited. In Bevalaina, women have adapted to collecting long leaves at further distances by bringing men with them to bear the heavy loads back to the village. Due to the time and energy required for these trips, women collect as many leaves as possible. This explains the increasing number of leaves women collect per plant the further they are from the village. This correlation does not exist in Ambofampana,

where plants with long leaves exist at any distance.

The impact of human pressure on the plant population can also be observed with regard to the local practice of not damaging the apex leaves. This is one of the most important practices and is widely known among the women. This practice helps to ensure the plant's regeneration, even if several leaves are cut at a time. In Ambofampana, there is no correlation between distance to the village and damaged apex leaves. The number of damaged apex leaves is very low, even near the village. In Bevalaina, however, the number of damaged apex leaves increases with increasing proximity to the village. We can therefore assume that human pressure and the distance to the village have an influence on plant survival. An explanation for the damaged apex leaves in Bevalaina is that an alternative plant, *L. mucronata,* exists at this location. *P. guillaumetii* may therefore be viewed as more expendable at Bevalaina and less care is taken to protect the apex leaves. In fact, it is well known that local botanical knowledge depends strongly on the extent of dependence on forest products (Shaanker et al. 2004b). Villagers from Bevalaina have been able to use *L. mucronata* since 2001 and may therefore be losing their harvest knowledge about *P. guillaumetii* since they no longer depend on it.

Conclusion

Women have developed harvest practices that tend to mitigate the harvest impact on plants. As a result, in both villages the density of juvenile and branching adult plants did not vary significantly with regard to distance to village. The high human population density in Bevalaina, combined with the decline of suitable habitat for *P. guillaumetii,* does, however, lead to a decreasing availability of juvenile plants with leaves suitable for mat production, as plants may not regenerate fast enough to meet the demand. On the one hand, this situation forces women to change their practices and to travel further from their villages, or to find alternative leaf sources. On the other hand, household welfare will be affected if women do not find suitable leaves to produce their handicrafts. Income generated by these NTFPs plays an important role in the local livelihood and cannot be easily replaced by alternative plants. Harvest practices are not static; as demonstrated in Bevalaina, harvest practices can be adapted to increasing demand and decreasing availability. This does not, however, imply a sustainable management of NTFPs, though this is possible. The knowledge and practices of local women have great potential for influencing natural resource management in ways that can both enhance local livelihood and ensure that resources like *P. guillaumetii* are protected.

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Literature Cited

Anderson, M. K. and D. L. Rowney. 1999. The edible plant *Dichelostemma capitatum*: Its vegetative reproduction response to different indigenous harvesting regimes in California. Restoration Ecology 7:231–240.

Arnold, J. E. M. and M. R. Pérez. 2001. Can non-timber forest products match tropical forest conservation and development objectives? Ecological Economics 39:437–447.

Callmander, M. W. and M. O. Laivao. 2003. Biogeography and systematics of the Malagasy *Pandanus* (Pandanaceae). In: The natural history of Madagascar, eds. S. M. Goodman and D. J. Benstead, 460–467. Chicago: University of Chicago Press.

———, G. E. Schatz, P. P. Lowry, M. O. Laivao, J. Raharimampionona, S. Andriambololonera, T. Raminosoa, and T. K. Consiglio. 2007. Identification of priority areas for plant conservation in Madagascar using Red List criteria: Rare and threatened Pandanaceae indicate sites in need of protection. Oryx 41:168–176.

Casse, T., A. Milhoj, S. Ranaivoson, and J. R. Randriamanarivo. 2004. Causes of defores-

tation in southwestern Madagascar: What do we know? Forest Policy and Economics 6:33–48

Cunningham, A. B. 2001. Applied Ethnobotany: People, wild plant use and conservation. London: Earthscan.

Danielli, M. 1949. The "Mpanandro" (Maker of Days) of Imerina, Madagascar. Folklore 60:375–387.

Dufils, J.-M. 2003. Remaining forest cover. In: The natural history of Madagascar, eds. S. M. Goodmann and J. P. Benstead, 88–96. Chicago: The University of Chicago Press.

Gadgil, M., F. Berkes, and C. Folke. 1993. Indigenous knowledge for biodiversity conservation. Ambio 22:151–156.

Good, T. C., M. L. Zjhra, and C. Kremen. 2006. Addressing data deficiency in classifying extinction risk: A case study of a radiation of Bignoniaceae from Madagascar. Conservation Biology 20:1099–1110.

Green, G. M. and R. W. Sussman. 1990. Deforestation history of the eastern rain forests of Madagascar from satellite images. Science 248:212–215.

Guillaumet, J.-L. 1973. Formes et développement des *Padanus* malgaches. Bulletin du Museum national d'histoire naturelle 28:495–517.

Hall, P. and K. Bawa. 1993. Methods to assess the impact of extraction of non-timber tropical forest products on plant populations. Economic Botany 47:234–247.

Harper, G. J., M. K. Steininger, C. J. Tucker, D. Juhn, and F. Hawkins. 2007. Fifty years of deforestation and forest fragmentation in Madagascar. Environmental Conservation 34:325–333.

Humbert, H. and G. Cours Darne. 1965. Notice de la carte Madagascar. Pondichéry: Institut français de Pondichéry.

Jones, J. P. G., M. M. Andriamarovololona, and N. Hockley. 2008. The importance of taboos and social norms to conservation in Madagascar. Conservation Biology 22:976–986.

Joyal, E. 1996. The palm has its time: An ethnoecology of Sabal uresana in Sonora, Mexico. Economic Botany 50:446–462.

Karanth, K. K., L. M. Curran, and J. D. Reuning-Scherer. 2006. Village size and forest disturbance in Bhadra Wildlife Sanctuary, western Ghats, India. Biological Conservation 128:147–157.

Koechlin, J., J. L. Guillaumet, and P. Morat. 1997. Flore et végétation de Madagascar. Vaduz: Cramer.

Kremen, C., I. Raymond, and K. Lance. 1998. An interdisciplinary tool for monitoring conservation impacts in Madagascar. Conservation Biology 12:549–563.

Laivao, M. O., M. W. Callmander, and S. Buerki. 2006. Sur les *Pandanus* (Pandanaceae) à stigmates saillants de la côte est de Madagascar. Paris: Editions Scientifiques du Muséum.

Lawes, M. J. 2004. Indigenous forests and woodlands in South Africa: Policy, people and practice. Pietermaritzburg: University of Kwazulu-Natal Press.

MEFT, USAID, and CI. 2009. Evolution de la couverture de forêts naturelles à Madagascar, 1990–2000–2005. Ministère de l'Environnement, des Forêts et du Tourisme.

Messerli, P. 2000. Use of sensitivity analysis to evaluate key factors for improving slash-and-burn cultivation systems on the eastern escarpment of Madagascar. Mountain Research and Development 20:32–41.

Ndanyalasi, H. J., R. Bitariho, and D. B. K. Dovie. 2007. Harvesting of non-timber forest products and implications for conservation in two montane forests of East Africa. Biological Conservation 134:242–250.

Perez, M. R. 2006. Poverty alleviation and forest conservation: The role of non-timber forest products. In: Non-timber forest products between poverty alleviation and market forces, eds. J.-L. Pfund and P. Robinson, 53. Berne: Intercooperation.

Peters, C. M. 1994. Sustainable harvest of non-timber plant resources in tropical moist forest: An ecological primer. Washington, D.C.: Biodiversity Support Program.

Pfund, J.-L. 2000. Culture sur brûlis et gestion des ressources naturelles: Evolution et perspectives de trois terroirs ruraux du versant Est de Madagascar. Zurich, Switzerland: EPFZ.

Rickard, P. and P. Cox. 1984. Custom umbrellas (Poro) from *Pandanus* in Solomon Islands. Economic Botany 38:314–321.

Runk, J., P. Mepaquito, and F. Pena. 2004. Artisanal non-timber forest products in Darien Province, Panama: The importance of context. Conservation and Society 2:217–234.

Sampaio, M., I. Schmidt, and I. Figueiredo. 2008. Harvesting effects and population

ecology of the buriti palm (*Mauritia flexuosa* L. f., Arecaceae) in the Jalapão region, Central Brazil. Economic Botany 62:171–181.

Shaanker, R., K. Ganeshaiah, M. Rao, and N. Aravind. 2004a. Ecological consequences of forest use: From genes to ecosystem—A case study in the Biligiri Rangaswamy Temple Wildlife Sanctuary, South India. Conservation and Society 2:347–363.

———, ———, S. Krishnan, R. Ramya, C. Meera, N. A. Aravind, A. Kumar, D. Rao, G. Vanaraj, J. Ramachandra, R. Gauthier, J. Ghazoul, N. Poole, and B. V. C. Reddy. 2004b. Livelihood gains and ecological costs of non-timber forest product dependence: Assessing the roles of dependence, ecological knowledge and market structure in three contrasting human and ecological settings in south India. Environmental Conservation 31:242–253.

Styger, E., J. Rakotoarimanana, R. Rabevohitra, and E. Fernandes. 1999. Indigenous fruit trees of Madagascar: Potential components of agroforestry systems to improve human nutrition and restore biological diversity. Agroforestry Systems 46:289–310.

Ticktin, T. 2004. The ecological implications of harvesting non-timber forest products. Journal of Applied Ecology 41:11–21.

Urech, Z. L., M. Rabenilalanana , J.-P. Sorg, and H.-R. Felber. 2011. Traditional use of forest fragments in Manompana, Madagascar. In: Collaborative governance in tropical landscapes, eds. C. J. P. Colfer and J.-L. Pfund, 133–156. London: Earthscan.