Impact of Wine Tapping on the Population Structure and Regeneration of *Hyphaene petersiana* Klotzsch ex Mart. in Northern Botswana

Thamani M. Babitseng and Demel Teketay

Research

Abstract

Palms are tapped around the world as sources of sugars for fermentation. A comparison of tapped and untapped populations of *Hyphaene petersiana* Klotsch ex Mart. palm trees was conducted in northern Botswana. The objectives of the study were to: determine the densities, dominances, population structures and regeneration of natural palm stands. Social objectives of the study included assessment of preferred tree sizes for wine tapping, investigation of methods, frequency and processes involved in the wine tapping, and marketing of the tapped palm wine. The results revealed a significant difference in the mean total density of the species at the two study sites (Shorobe with 2,275 individuals/ha and Tubu with 1,402 individuals/ha). Total seed densities at Tubu (6,822/ha) and Shorobe (62/ha) were dramatically different. Mean total dominance (basal area) was significantly higher at Tubu than Shorobe where wine tapping is common. The species exhibited a pattern indicative of hampered population structures/regeneration at both sites. In Shorobe, the hampered regeneration can be attributed mainly to wine tapping associated with cutting down the trees. Palm wine tappers used destructive methods such as burning, felling, pruning and trimming the stem. The results revealed that the methods of wine tapping employed negatively impacted the population structure.

Introduction

Regeneration is a central component of tropical forest ecosystem dynamics and restoration of degraded forest lands. Sustainable forest utilization is only possible if adequate information on the regeneration dynamics and factors influencing important tree species are available (Tesfaye *et al*. 2010). Tropical forests regenerate from one or more pathways: seed rain (recently dispersed seeds), the soil seed bank (dormant seeds in the soil), the seedling bank (established, suppressed seedlings in the understory), and coppice (root/shoot sprouts of damaged individuals) (Garwood 1989, Grime 1979, Teketay 1997a, Teketay & Granström 1995, Tesfaye *et al*. 2002, 2010, Whitmore 1996).

Studies on tree species population structure and density can help to understand the status of regeneration and, thereof, forest woodland management history and ecology (Alvarez-Buylla *et al*. 1996, Harper 1977, Hubbel & Foster 1986, Lykke 1993, Saxena *et al*. 1984, Tesfaye *et al*. 2010). Plant population structure shows whether or not the population has a stable distribution that allows continuous regeneration to take place (Enright & Watson 1991, Rao *et al*. 1990, Tesfaye *et al*. 2010). If regeneration was taking place continuously, then, the distribution of species cohorts would show a reverse J shape curve, which is an indicator of healthy or good regeneration (Harper 1977, Silvertown 1988, Teketay 1997b). Such population structures are common in natural forests where external disturbances are limited (Teketay 1997b, Tesfaye *et al*. 2002,

Correspondence

Thamani M. Babitseng, P.O. Box 71, Gumare, BOTSWANA. babitseng@yahoo.co.uk
Demel Teketay, University of Botswana, Okavango Research Institute, Private Bag 285, Maun, BOTSWANA. dteketay@yahoo.com

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2010). Thus, regeneration studies have significant implications on the management, conservation and restoration of degraded natural forests and woodlands (Tesfaye *et al*. 2010).

Forests throughout the world provide both timber and non-timber forest products (NTFPs). NTFPs comprise all goods derived from forests of both plant and animal origin other than timber. NTFPs contribute to household income and subsistence and are of cultural importance in many rural societies. *Hyphaene petersiana* Klotzsch ex Mart. is a multipurpose palm known for its socio-economic contribution to the livelihood of the rural communities (Mollet *et al*. 2000). People derive a wide range of benefits, such as construction materials, mat making, handicrafts, palm wine as well as edible palm heart and fruits (Konstant *et al*. 1995, Sullivan *et al*. 1995, Sambou *et al*. 2002).

Economic hardships experienced in many rural communities (e.g., frequent occurrences of severe droughts associated with climate change, land scarcity for arable agriculture (Byg & Balslev 2006, Coomes 2004), increasing rural population densities (Sullivan *et al*. 1995) and lack of alternative income generating activities) have led to heavy reliance on, and over exploitation of NTFPs (Agbo *et al*. 2011, Byg & Balslev 2006, Konstant *et al*. 1995). In the northern part of Botswana, *H. petersiana* is exploited mainly for basket weaving (Cunningham & Milton 1987) and production of palm wine (pers. obs.).

Palm wine tapping is a very common practice in most continents, and Africa has been rated second while Asia and Latin America were ranked first and third respectively, in terms of sap tapping (Johnson 1992). In areas with significant palm population stands, palm wine is one of the principal commodities in the livelihood of the rural communities. It is used in social occasions (Herlehy 1984, Mollet *et al*. 2000), rituals (Herlehy 1984) and as a source of income (Cunningham 1990a, Sambou *et al*. 2002).

The effects of harvesting of NTFPs can be assessed by comparing the survival, growth and reproduction rates of individuals subjected to different harvesting intensities. Since changes in these rates can affect the population structure, comparison of structures among populations subjected to different harvesting intensities can potentially reveal the impact of harvesting over time (Sampaio *et al*. 2008).

Sullivan *et al*. (1995) reported the occurrence of high numbers of juvenile un-stemmed and very low numbers of stemmed individuals of *H. petersiana* in the replacement height classes, indicating that growth of immature suckers and seedlings into mature, sexually reproductive palms was not occurring in Namibia. This pattern was more pronounced in a heavily utilized area. The palm population structure in the areas studied in north-central Namibia, thus, appeared to be changing from stands of tall, fruit-bearing stemmed palms of various heights to short palm scrub consisting of clumped juvenile plants. Such a transformation may have significant negative implications for the future viability of the palm population. A similar change in population structure has been observed in heavily utilized *H. petersiana* populations in northwestern Botswana. For example, it has been attributed to the felling of palms for their fruits, browsing by livestock and the over-utilization of unopened leaves for basketry (Cunningham 1988, Cunningham & Milton 1987).

Tapping palm sap remains a great challenge for the existence of certain palm species, because some tapping methods are considered lethal for the survival of the tapped trees (Davis & Johnson 1987, Mollet *et al*. 2000, Sambou *et al*. 2002). Tappers use destructive harvesting techniques such as piercing palm stems (Govender *et al*. 2005), excision of the apical bud (Sullivan *et al*. 1995), cutting a hole into the tree trunk and repeatedly removing a small part of the apical meristem (Sambou *et al*. 2002), felling the whole stem and continuously reactivating palm sap flow by trimming the palm heart, until some of the apical meristem is completely removed (Cunningham 1990a, Sola *et al*. 2006), repeated horizontal incision into the apical meristem and tapping from immature inflorescence (Johnson 1992). Sambou *et al*. (2002) reported average mortality of as high as 56 individuals of the palm species studied per year and tapper.

Several studies were conducted on harvesting leaves of *H. petersiana* for basketry in Botswana (Cunningham & Milton 1987, Konstant *et al*. 1995, Sullivan *et al*. 1995). Nevertheless, no study was conducted in Botswana on the impacts of palm wine harvesting on regeneration and population structures of the species. The literature revealed contradictory findings regarding the survival and sustainability of palm species in relation to various harvesting techniques used for palm wine extraction. Burning and felling of stem that are associated with palm wine harvesting were perceived as very destructive and deadly for the survival of the plant (Sambou *et al*. 2002). However, Sola *et al*. (2006) revealed that wine tapping does not necessarily kill the plant, and the survival of the plant depends solely on the extent of removal of the apical meristem, and the skills and experience of the palm wine tapper (Chowdhury *et al*. 2008, Cunningham 1990b).

Therefore, the purpose of this study was to find out the impact of palm wine tapping on the regeneration and population structure of *H. petersiana* by taking into account the tapping methods used, targeted plant sizes, frequency of tapping, and people involved in wine tapping activities. This was done in Shorobe (northern Botswana) where the palm wine tapping activities are carried out. Comparison was made with regeneration and population structures of the same species at Tubu Village (northern Botswana) where wine tapping is not practiced.

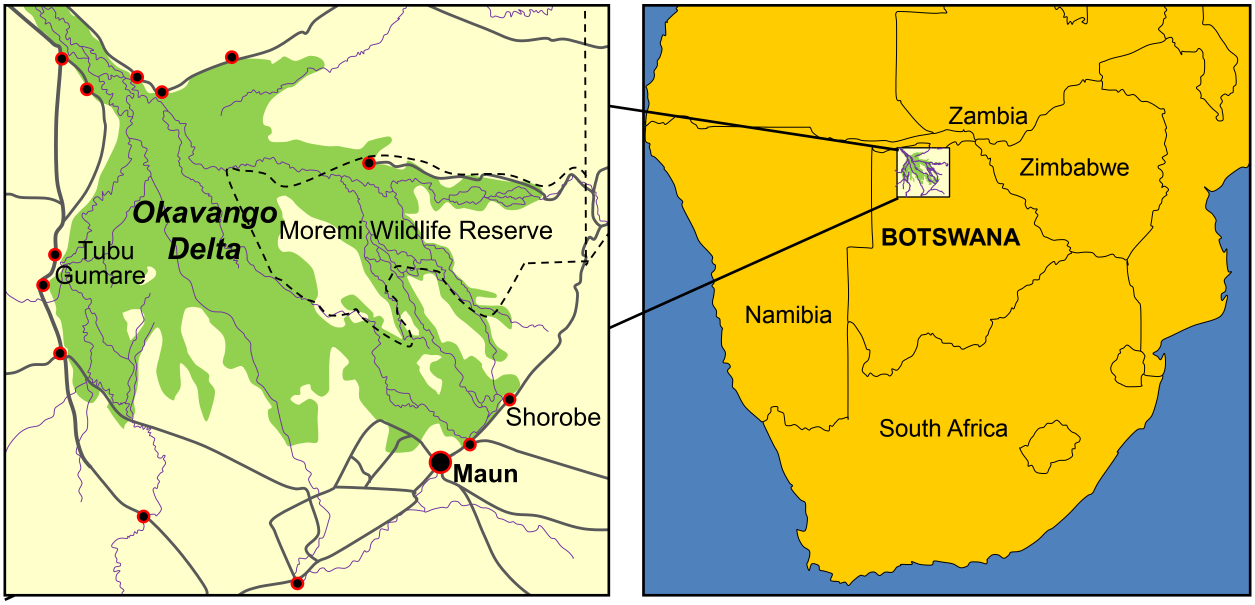

Figure 1. Shorobe and Tubu villages of the Okavango Delta, northern Botswana.

The following questions were addressed through the study: (i) What are the densities, dominances and status of *H. petersiana* regeneration? (ii) How does wine tapping affect the *H. petersiana* population structure? (iii) Who is involved in the production and marketing of palm wine? (iv) Which tree sizes are targeted for tapping palm wine? (v) How, and in what frequency, is palm wine tapped, processed and marketed? (vi) When is the tapping carried out?

The study was designed to test the following hypotheses: (i) wine tapping is carried out through cutting of matured trees, leading to decline in the densities of seeds and individuals as well as *H. petersiana* tree dominance; (ii) wine tapping negatively affects the population structure and regeneration of *H. petersiana*.

The specific objectives of the study were to: (i) determine the densities and dominances of the species at both sites; (ii) assess the population structures and regeneration of the species at both sites; (iii) assess the preferred sizes (diameter and cutting heights) of trees for wine tapping at Shorobe Village; (iv) investigate the method and frequency of wine tapping from the trees at Shorobe Village; (v) determine the amount of production, means of transportation, methods of processing and storage, and marketing of tapped palm wine at Shorobe; and (vi) forward recommendations for the responsible management, sustainable utilization and conservation of the study species.

Study areas

The study areas comprised two distinct localities, namely Shorobe and Tubu Villages, located in northern Botswana (Figure 1).

Shorobe is located on the fringe of the Okavango Delta, about 900 km NNW from Gaborone, the capital City of Botswana. This is the area where *H. petersiana* is harvested or exploited for palm wine extraction. Tubu is located on the flood plains of the Okavango Delta, 250 km west of Maun and about 1,200 km NNW from Gaborone. Palm wine extraction is not carried in Tubu, hence, it was chosen as a control. Basically, the people of Shorobe and Tubu are predominantly from the Bayei tribe, and Baherero, Hambukushu and Basarwa tribes are numerically low.

Average annual rainfall in Tubu (410 mm) and Shorobe (430 mm) usually occurs between the months of November and February (NDSS 2003). Tubu normally experiences flooding from Thaoge channel between March and July while Shorobe experiences floods as a result of back flows from the Thamalakane River, between May and August.

Study species

Hyphaene petersiana (Arecaceae) has several names in Setswana (i.e., **mokola**, **mokolane**, and **mokolwane**) and English (i.e., northern ilala palm, and real fan palm) (Setshogo & Venter 2003). The palms are evergreen medium sized trees up to 18-20 m high (Cunningham & Milton 1985, Setshogo & Venter 2003, Sola 2004) with single, bare, straight stems and rounded crowns. The leaves are fan shaped, 1.5-2 m long with black petiole thorns (Figure 2B). The fruit are more or less globose, 40-60 mm in diameter, ripening from green through orange to glossy dark brown (Figure 2A,B) (Ellery & Ellery 1997, Setshogo & Venter 2003, van Wyk & van Wyk 2009).

Figure 2. *Hyphaene petersiana* Klotzsch ex Mart. (**A**) trees, (**B**) leaves and fruit,and (**C**) coppicing juvenile in the Okavango Delta, northern Botswana. All photos used in this article were taken by Thamani M.Babitseng.

Hyphaene petersiana is reported to occur naturally in Botswana (Setshogo & Venter 2003), Namibia, and Zimbabwe (van Wyk & van Wyk 2009). *Hyphaene petersiana* is found in open woodland, flood plains, banks of rivers and the fringes of pans. It thrives in a wide range of edaphic and climatic conditions, e.g., semi-arid conditions with sufficient underground water supply, swampy, lagoons (Cunningham & Milton 1987, Fujioka 2005), high atmospheric temperature, sand blown soil in Namibia, sodic, saline, lovisols, alluvial and clay reach soils (Blach-Overgaard *et al*. 2009, Sola 2004). *Hyphaene petersiana* is thought to be an indicator of saline soils (Setshogo & Venter 2003).

This species is a keystone species important in life cycles of certain insects and food source of food and habitat for a wide range of organisms such as elephants, baboons, rodents, bats, primates (Fujioka 2005). Over-utilization is not only a great threat to the palm, but also a detriment to survival of other species depending on it, resulting in a loss of species diversity (Kinnaird 1992).

Uses

In Botswana, *H. petersiana* stem kernel/pith, young leaves and seeds are eaten. The plant is defoliated to expose the stem and the sap is collected from the stem, then fermented into alcoholic wine, known as **muchama**. The leaves are used to make baskets (being one of the major species supporting the basket industry in the Okavango Delta). Ivory-colored endosperm seeds are eaten raw and carved into buttons and ornaments. The palms are also browsed (Ellery & Ellery 1997, Setshogo & Venter 2003, Roodt 1993, van Wyk & van Wyk 2009).

Methods

Data Collection in the Field

The areas at both sites where the species occurred were systematically stratified by stand density gradients (i.e., high, medium and low. Five 20 × 20 m quadrats were laid out in each of the three density stands (15 total) in both sites with a minimum distance of 50 m between each other. The objective of this stratification was to capture distribution variation. Pegs and nylon strings were used to mark the four corners and sides of the quadrats. This systematic sampling method was chosen (rather than transects) since a preliminary survey of both sites revealed sparsely distributed, and at times, scattered clumps of palm coppices as well as areas without any individuals.

In each quadrat, the numbers of: all live and dead (stumps) individuals, seedlings (juveniles originating from seeds), coppices per live stump (juveniles originating vegetatively) and seeds were counted and recorded. Diameter at breast height (1.3 m) (dbh) of live individuals, basal diameter as well as heights of both live and dead stumps were measured with a caliper and measuring tape, and recorded.

To collect data on trees tapped for wine, five tapping areas, having minimum distances of 500 m between them, were identified at Shorobe with the help of key informants (experienced palm wine tappers). The five areas have been exploited by different groups of households. In these areas: (i) all tapped live and dead stumps were counted; (ii) basal diameters and heights of all stumps of tapped trees were measured; and (iii) the number of coppices produced by each of the tapped live stumps were recorded.

Socio-economic survey

A survey of wine tappers was conducted at Shorobe since it is where production activities are common. Variables learned were: preferred sizes (diameters) and cutting heights of trees for wine tapping, sap tapping methods, amount of production, transportation, processing, storage, and marketing.

Prior to the commencement of the survey, permission was obtained from the village chief (**kgosi**) and his advisors. Village elders, as well as the interviewees, were briefed on the purpose and aims of the study to address uncertainty or suspicion regarding the information to be collected, and to gain respondent confidence. The village chief and members of the village development committee served as key informants.

The socio-economic survey was carried out using household interviews (HHI) and a focus group discussion (FGD). For the HHI, a questionnaire was prepared and pre-tested with five wine tappers in Matsaudi settlement (10 km from Shorobe). The pre-testing was done to ascertain the flow, understandability and the time required to complete a questionnaire. The questionnaire was revised based on the finding of the pre-test results.

The questionnaire was designed to obtain the socio-economic and demographic characteristics on the tappers. These included gender, age, marital status, literacy levels, frequency of palm wine tapping, quantities of palm wine obtained per day and tree, number of trees tapped per day, preferred size (diameters) and heights of trees for tapping wine, how, where and the length of period the wine is kept before consumption or sale, the materials and methods of harvesting or cutting trees for wine tapping, harvesting and collecting the palm wine, and sustainability of the methods used for tapping and harvesting the palm wine.

In the reconnaissance survey, it was found that the number of households involved in wine tapping was 16. Hence, it was decided to interview most, instead of a sample of wine tappers. Hence, the questionnaire was administered to 14 individuals identified by village key informants as being regular wine tappers. The interviews were conducted in the Setswana language since all of the tappers preferred to be interviewed in their own language. The tappers were interviewed one at a time, and each interview took, on average, 20 minutes per person. The whole exercise of interviewing took two days.

Questions were prepared in advance for the FGD meeting (Appendix 1). Seven knowledgeable members of the local community (a mix of old and young, male and female) were selected with the help of the key informants. The FGD was conducted to verify information obtained with the questionnaire and field surveys in order to bridge information gaps.

Data analyses

Densities and dominance

Student's t-test, at the confidence level of $P < 0.05$ (Zar 1999), was used to assess if differences existed between the mean values at Shorobe and Tubu for tree densities and dominances of individuals with dbh > 2 cm and for seed densities.

Tapped stems

Individual palm stems were counted and categorized as live or dead (stumps), and their respective proportions determined at the five areas in Shorobe. Live stumps were grouped into seven diameter (cm) classes (i.e., 1 = < 2; 2 = 2-10; 3 = 10-20; 4 = 20-30; 5 = 30-40; 6 = 40-50; and 7 = > 50), and three height (cm) classes (i.e., 1 = 1-19; 2 = 20-39 ; and 3 = > 40). These data were used to develop histograms.

Correlation tests, at the confidence level of $P < 0.05$ (Zar 1999), were used to determine if there were any relationships between cutting diameter and height of tapped stumps, and the number of coppices produced per stump.

Population structure and regeneration status

The statuses of population structure and regeneration of the species were assessed using the same diameter classes as above and histograms. Based on the pattern of distribution of individuals in the different diameter classes in the histograms, the populations of the species were determined to exhibit either stable/healthy, or hampered structures/regeneration. Significant differences (at the confidence level of $P < 0.05$) between mean densities of palm individuals in the different diameter classes at Tubu and Shorobe were tested by using Student's t-test (Zar 1999).

Socio-economic survey

Descriptive statistics (primarily percentages) were employed for analyzing data collected through closed ended questions. Results of open ended questions were summarized and presented.

Results

Population densities

Total *H. petersiana* densities were 2,275 individuals/ha in Shorobe and 1,403 individuals/ha in Tubu (Figure 3). Mean total density at Shorobe was significantly ($P = 0.001$) higher than that at Tubu. Mean densities of seedlings at both sites did not exhibit significant ($P = 0.8$) differences, while Shorobe had significantly ($P = 0.00002$) higher density of juveniles/coppices than Tubu. Conversely, Tubu exhibited significantly higher mean densities of trees ($P = 0.000004$) and seeds ($P = 0.03$) than Shorobe (Figure 3). The total densities of seeds were 6,822 seeds/ha at Tubu and 63 seeds/ha at Shorobe.

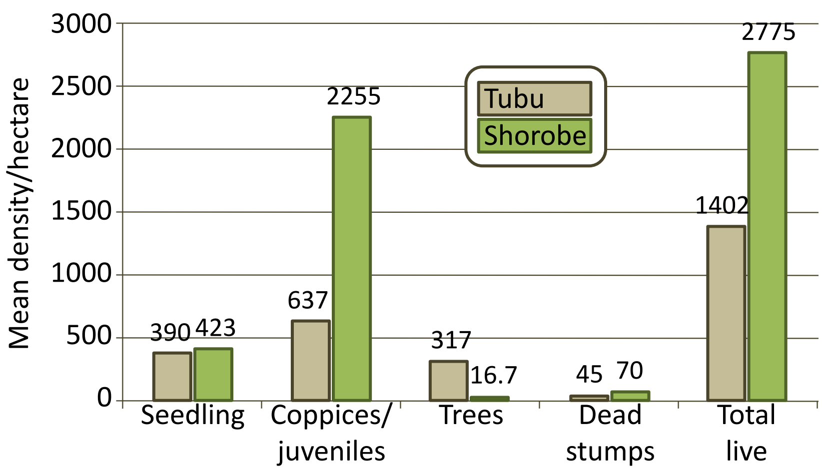

Figure 3. Population densites of *Hyphaene petersiana* Klotzsch ex Mart. in Tubu and Shorobe, the Okavango Delta, northern Botswana. **Seedling** included individuals that originated from seeds and showing no stump above ground; **Coppices/juveniles** included all individuals that did not fall under seedling category and did not have dbh (1.3 m); **Trees** included all individuals with DBH (1.3 m); **Dead stumps** included all visible stumps killed by natural causes or anthropogenic activities; and **Total** densities of live individuals.

Dominance

Mean total dominance (basal area) of *H. petersiana* was significantly (P = 0.00000001) higher at Tubu than at Shorobe (Figure 4). There were also significantly higher differences in mean dominances of *H. petersiana* at Tubu than Shorobe when the high (P = 0.00003), medium (P = 0.000006) and low (P = 0.003) stand densities were considered. As expected, the mean dominance of *H. petersiana* was higher at the high density stand followed by the medium and low density stands at Tube. But, at Shorobe, the mean dominance of *H. petersiana* was relatively higher at the medium density stand followed by the low and high density stands although the differences were not pronounced (Figure 4).

Population structure and regeneration

The population structures at both sites exhibited a pattern indicative of hampered structures/regeneration (Figure 5). At both sites, the lowest diameter classes had high densities suggesting good recruitment. In Tubu, the densities of the next two diameter classes (2nd and 3rd) were very low followed by increasing densities at the 4th and 5th and declining densities at the 6th and 7th diameter classes (Figure 5A). In Shorobe, the pattern of distribution was broken with no individuals at the 2nd as well as the 6th and 7th diameter classes, and very low densities of individuals in diameter classes 3-5 (Figure 5B).

The density of individuals of *H. petersiana* in diameter class 1 at Shorobe was significantly (P = 0.0001) higher than at Tubu. Similarly, densities of individuals at diameter classes 4 (P = 0.01), 5 (P = 0.0000004) and 6 (P = 0.00005) were significantly higher at Tubu than those at Shorobe. However, the densities of individuals in diameter classes 2 (P = 0.33), 3 (P = 0.07) and 7 (P = 0.16) did not show any significant differences between the two sites.

It is interesting to note that compared with the situation at Shorobe, the densities recorded for diameter classes 4-6 in Tubu were relatively high indicating that the population of *H. petersiana* contained bigger trees with dbh of 20-50 cm (Figure 5).

Tapped stems, coppices and shoots

The total number of stumps encountered from tapped stems of *H. petersiana* in the five sites at Shorobe was 646 with a diameter range of 12-49 cm. Of these, 67% were alive. The mean of stump diameters from all sites was 26±6.7 cm. The stumps produced coppice shoots from the top and sides or both. Of the live stumps, 58, 25

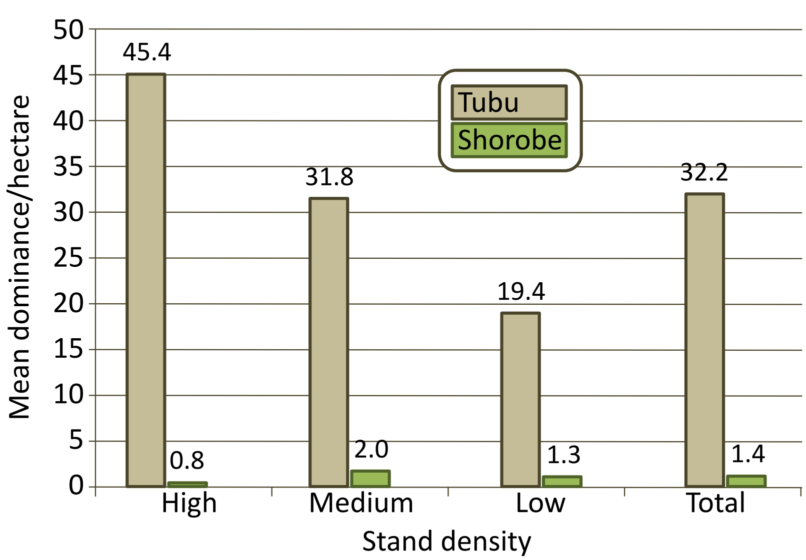

Figure 4. Dominance of *Hyphaene petersiana* Klotzsch ex Mart. in Tubu and Shorobe, the Okavango Delta, northern Botswana.

and 17% produced coppices (Figure 6), and coppice shoots (Figure 7) and both coppices and shoots, respectively.

In all the sites, no individuals were recorded in the diameter classes 1, 2 and 7 (Figure 8). In site 4, no individuals were recorded in diameter class 6 (Figure 8: Site 4). Proportions of individuals increased sharply from diameter class 3 to 4 and, then, declined sharply in the diameter classes 5 and 6 in all the five sites (Figure 8). The three dominant diameter classes that the tappers preferred most were 4, 5 and 3, which represented basal diameters of 10-40 cm. Although the proportions of individuals were relatively low, diameter class 6 was also targeted for wine tapping in all the sites except site 4 (Figure 8), increasing the range of exploitable diameter sizes of trees to 50 cm.

The height of tapped stem stumps ranged between 1 and 109 cm above ground. Tapping was carried out, and the stumps were abandoned at different heights. The dominant stump height ranged between 1-20 cm (Figure 9).

No correlations (P > 0.05) were found between the stump basal diameter and the number of coppices/shoots as well as stump height and number of coppices/shoots.

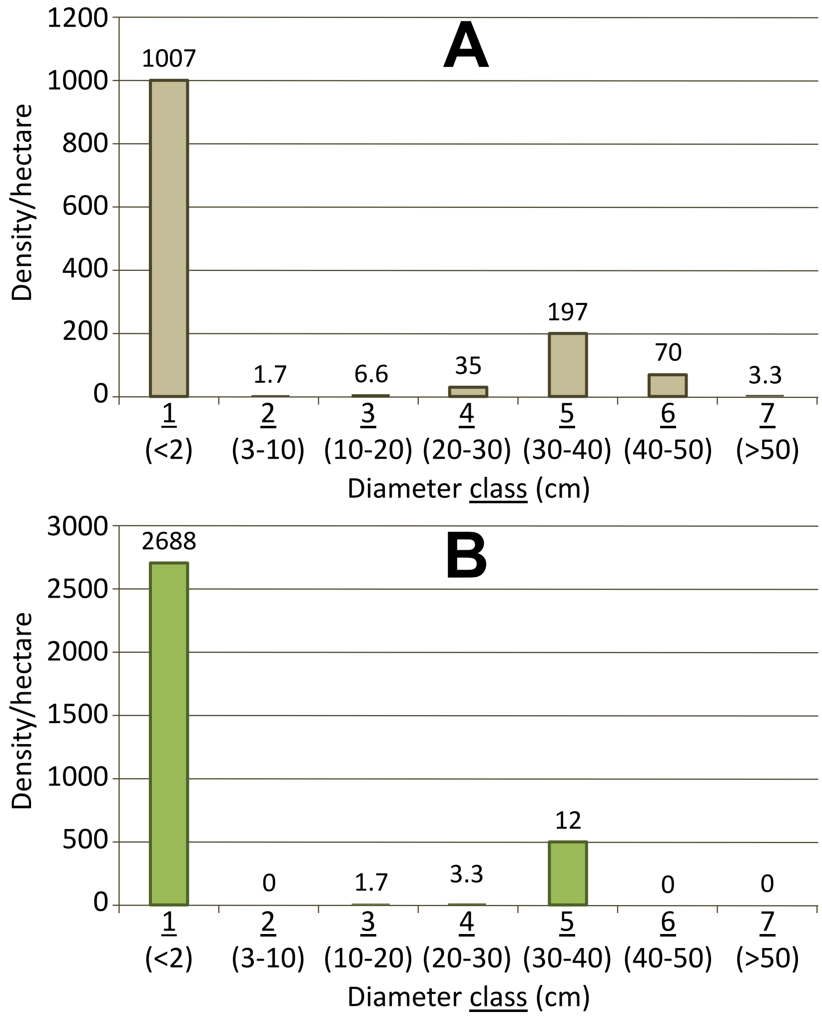

Figure 5. Population structure of *Hyphaene petersiana* Klotzsch ex Mart. in (**A**) Tubu and (**B**) Shorobe, the Okavango Delta, northern Botswana. Individuals grouped by classes based on diameter at breast height in cm.

Socio- economic results

Demographic characteristics of tappers

Surprisingly, 13 out of 14 palm wine tappers (93%) were males. Among them, nine (64%) never received any education (formal or non-formal), three (21%) went up to four years of primary education, and two (14%) had seven years of primary education. In terms of age, 58% were between 50-60 years old, 21% (60-70), 14% (70-80), and 7% of tappers were 20-30 years old. There were no tappers interviewed within the age range of 40-50 and <20 years. Wine tapping experience varied with 72% having 21 years, 7% having 14 years, and 21% with only 5 years of experience.

Figure 6. Coppice shoots developing from the side of *Hyphaene petersiana* Klotzsch ex Mart. stem at Shorobe, the Okavango Delta, northern Botswana.

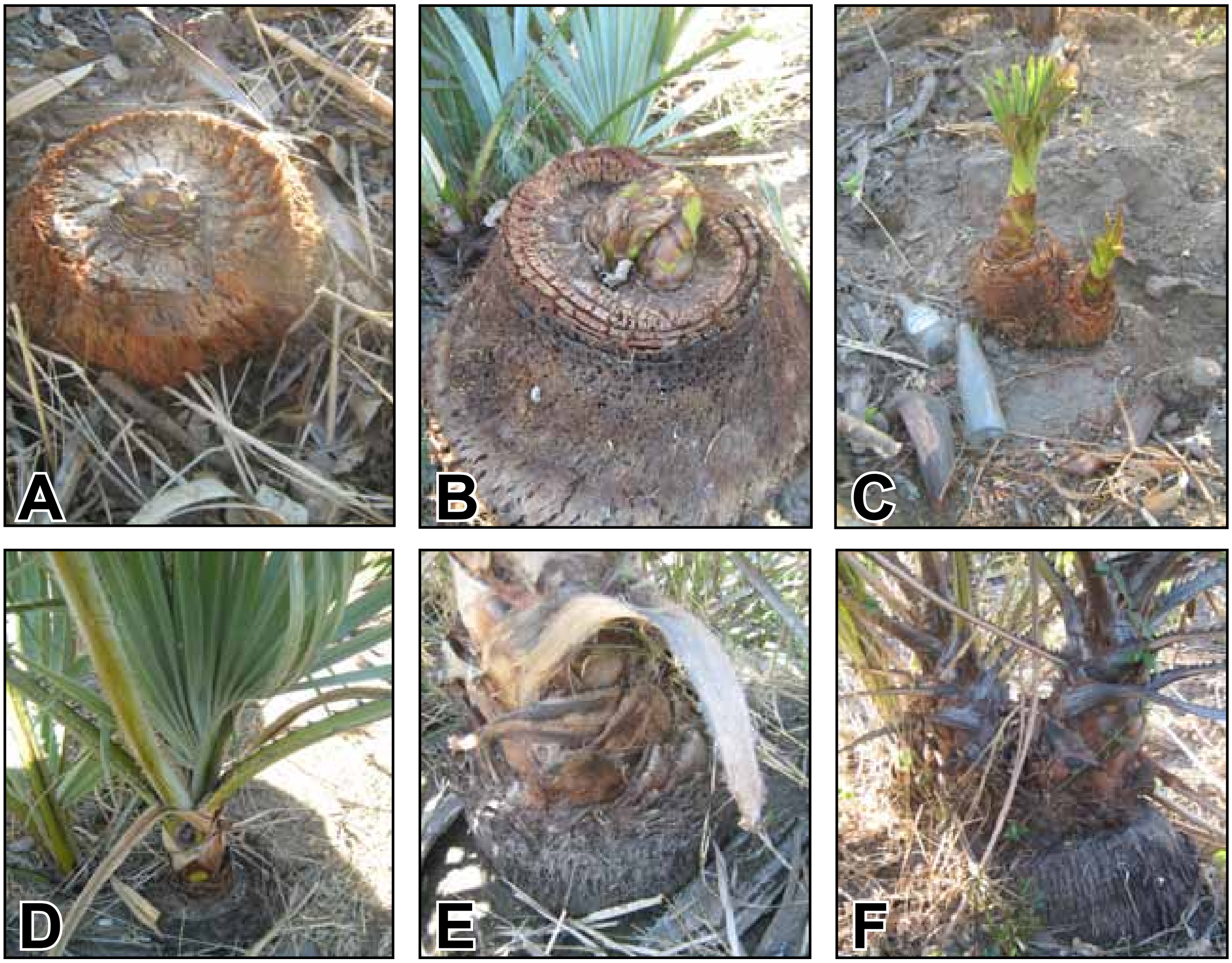

Figure 7. Examples of shoots developing from *Hyphaene petersiana* Klotzsch ex Mart. stumps tapped for wine production at Shorobe, the Okavango Delta, northern Botswana. (**A**) A single bud from a stump; (**B**) Two buds from a stump; (**C**) Very young stem shoots; (**D**) Young shoot and coppice; (**E**) Older shoot; and (**F**) Old stump shoots.

Process of tapping

All tapping activities were carried out during spring, summer and autumn, and all the interviewees revealed that they freely tapped *H. petersiana* growing in the wild on communal land, except for one palm tapper who was tapping on his own land. They used equipment such as axes, sickles, knives, hand hoes, and spades for tapping.

The palm tappers assess the palm clumps and after identification of appropriate trees (0.5–1.5 m stem height), they begin the process. First, a buffer or a fire break (Figure 10) is cleared if the area is covered by grass. The clumps are then burned and cleared of all the dead leaves, coppices and other juveniles. The desired stem is then cut at the tip and left for three days to rejuvenate. Burning plays a crucial role in scaring away snakes, wasps, etc. that might pose a danger to the lives of the tappers. Fire helps to remove dead petioles and thorns, and, most importantly, it is believed to increase outflow of sap from the tapped stems. How this is achieved requires further investigations. Finally, underground stems are dug out and exposed. These are trimmed and the stem is cut at the desired height (Figure 11). When tapping is done during the rainy period, the sap would be diluted and insects (Figure 12) may contaminate it. A single *H. petersiana* tree is tapped for a period of about 35-60 days before it is abandoned.

Number of trees tapped and amount of palm wine produced

On average, an individual palm wine producer tapped 16-20 palm trees. Eighty six and 14% of the respondents tapped 16 or more and less than 10 palm trees, respectively. Collection is done twice a day, in the morning and evening. The tappers used 340 and 750 ml bottles for collection but indicated that cattle horns and calabashes were used in the old days. Sap flow was activated or renewed twice a day, in the morning and evening, by cutting a small piece of the apical meristem with a knife.

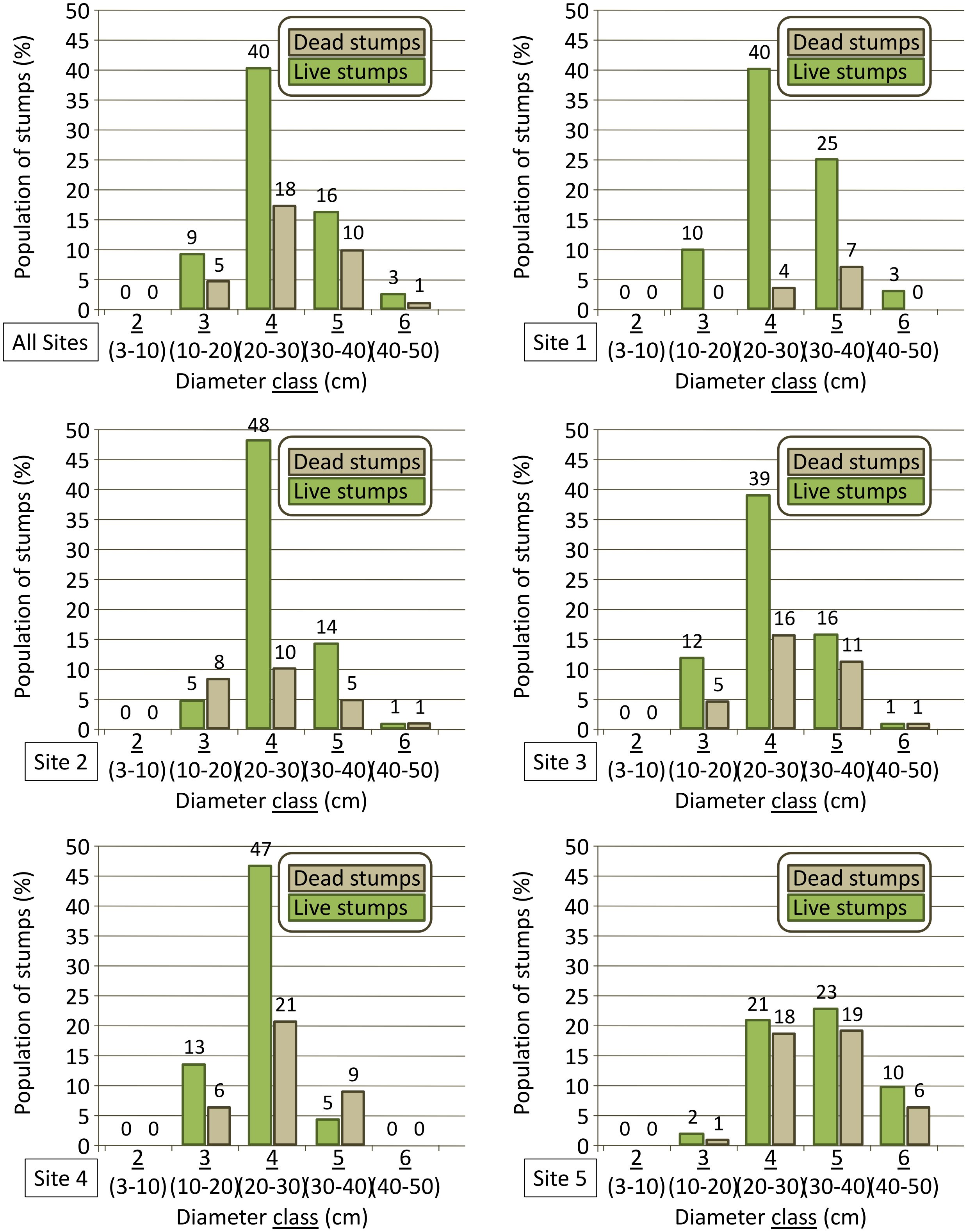

Figure 8. Proportion of live and dead stumps of *Hyphaene petersiana* Klotzsch ex Mart. stems for wine production at Shorobe, the Okavango Delta, northern Botswana. Individuals grouped by classes based on diameter at breast height in cm. None were recorded in size classes 1 (< 2 cm) or 7 (> 50 cm).

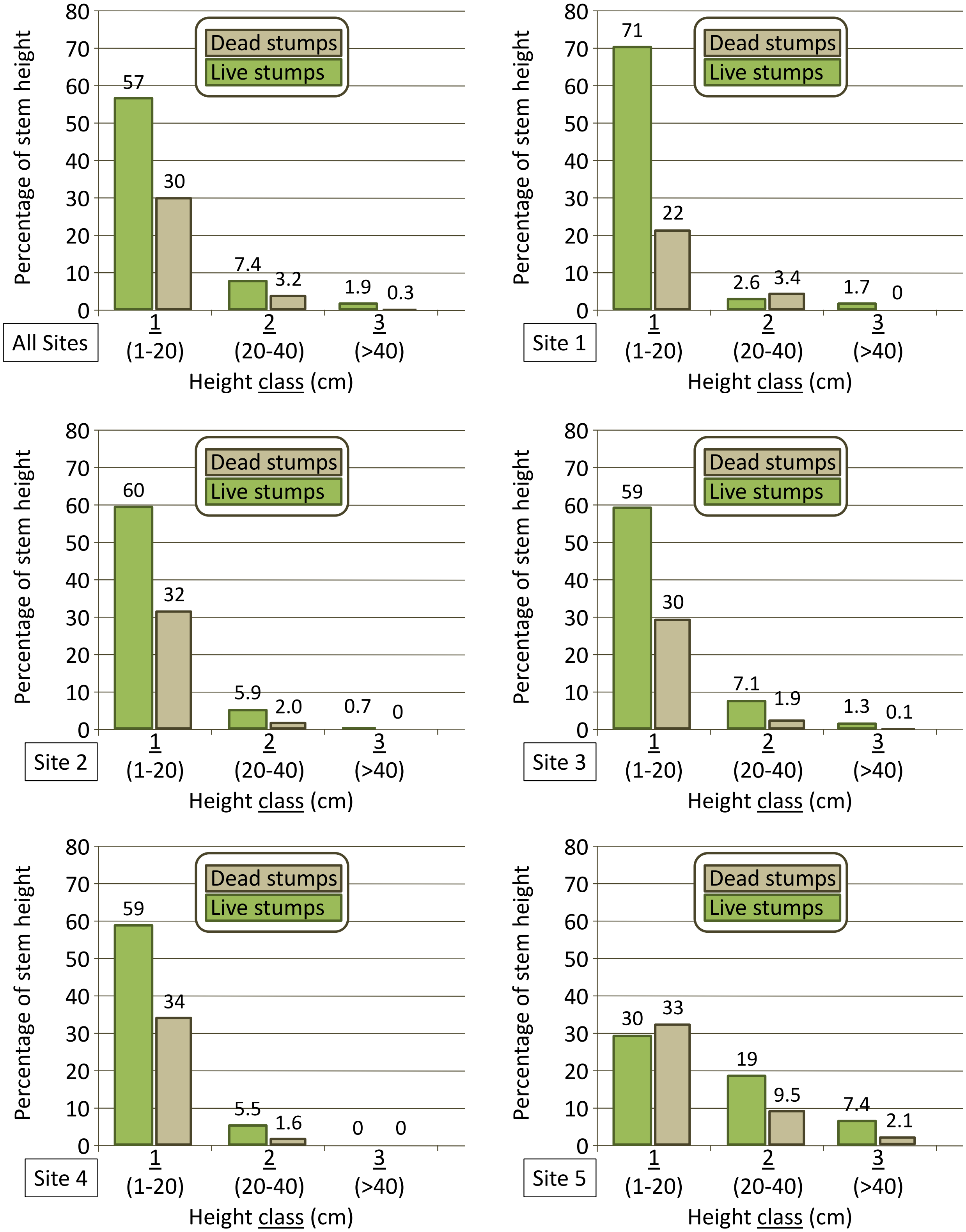

Figure 9. Percentage of *Hyphaene petersiana* Klotzsch ex Mart. stem height tapped for wine production at Shorobe, the Okavango Delta, northern Botswana. Individuals grouped by height classes in cm.

Figure 10. Preparation for wine tapping process from *Hyphaene petersiana* Klotzsch ex Mart. at Shorobe, the Okavango Delta, northern Botswana. (**A**) Burning; and (**B**) Clearing.

Transportation, storage, fermentation, use and sell of palm wine

The sap is stored in five and 20 liter containers and transported to the village using donkey carts, or carried on head since the tapping area is about a kilometer away from the village. The palm sap is stored within its containers overed with cloth for hygienic purposes at room temperature in the house. However, it was indicated that during the winter, the containers will be wrapped with blankets to maintain favorable temperatures for fermentation. The respondents revealed that the fermentation processes (natural fermentation with no additives) could take about 3 days for initial fermentation, and later on, about 1.5 days (using the same containers) before the wine was ready for consumption. Using the same containers has been claimed to accelerate the fermentation process since they already contain micro-organisms responsible for the fermentation process.

Palm sap is tapped for personal refreshment, entertainment, and/or business purposes. It is sold to local people and some is transported and sold in Maun, a nearby town. In 2010, palm wine is sold at BWP 6.00 (USD 0.81) per liter. Each palm tree yielded one liter of palm sap/day translating to 16-20 liters collected by a wine tapper per day. Hence, a wine tapper may obtain BWP 96.00–120.00 per day. Palm wine takes precedence over other local brewed alcoholic beverages because it sells faster. It was indicated that money obtained from sales was used for payments of school fees, buying food, and other family expenses. The sap is very sweet before fermentation, and this makes it conducive for use in preparing porridge, which can be consumed without relish or adding sugar.

Sustainability of the tapping exercise

All palm tappers indicated their opinions that the methods used (i.e., burning/felling stems) are sustainable because the plants are not killed. They acknowledged that, at times, the tapped stem dies not only as a result of the tapping methods used but also due to destructive animals (e.g., elephants). They also indicated that they do not remove the whole apical meristem as it is very important for rejuvenation. Furthermore, they always cover the tapped stump with *Acacia* species (Figure 13) branches to protect it from damage by goats, sheep, donkeys and other livestock. They also attributed the death of tapped stumps to inexperienced tappers since they do not take the appropriate care during and after the tapping exercise.

Wine tapping and other products: conflicting interests

It was revealed during the FGD that there was a conflict between use of trees for producing palm wine and other products [e.g., food (fruit, palm heart and leaf meristems), baskets, mats, hats] and other environmental services. Users of the species for other products than wine indicated that wine tappers indiscriminately burn and clear all clumps, unlike, for example, the weavers who only targeted unopened leaves. They pointed out that the destructive methods used by palm tappers are responsible for the shrinking resource used for their weaving purposes. They revealed that regeneration of the burned clumps takes more time to produce desirable leaf sizes for weaving.

Figure 11. *Hyphaene petersiana* Klotzsch ex Mart. stems cut at the desired height for sap collection with bottles at Shorobe, the Okavango Delta, northern Botswana.

Figure 12. Examples of insects that may contaminate palm wine from *Hyphaene petersiana* Klotzsch ex Mart. at Shorobe, the Okavango Delta, northern Botswana.

Discussion

The higher densities of individuals in Shorobe than in Tubu may be attributed to palm tapping methods (burning and felling). The field survey revealed that some tapped stems produced two shoots while others produced multiple coppices. This finding concurs with that reported by Sola *et al*. (2006). Cunningham & Milton (1987) also found out that heavy utilization through repeated cutting of apical buds using hand hoes and axes increased palm density per unity area. High numbers of coppices were recorded in three areas under intensive utilization compared to coppices recorded under low utilization. Leaf harvesting for basketry activities at Shorobe might also have contributed to the higher coppice production and low number of mature individuals, which is in line with the results reported by McKean (2003). The studies by McKean (2003) and Sampio *et al*. (2008) revealed that excessive removal of leaves affects the reproduction and growth or prevents individuals in early stages from growing and changing or proceeding to other growing stages, i.e., adult stage, ultimately impacting on the palm population structure (Kinnaird 1992).

There was no significant difference in seedling densities at the two sites despite the fact that seed densities at Tubu was significantly higher than at Shorobe. High numbers of seeds in Tubu were ascribed to higher population densities and dominance of reproductive trees (mature individuals) since destructive palm sap harvesting is not practiced. *Hyphaene petersiana* was the only visible species fruiting, and the dominant tree at Tubu leading to the observed high number of seeds compared with those at Shorobe. However, the densities of seedlings were not commensurate with the number of mature individuals producing large amount of seeds. This might be related to the fact that the seeds are consumed by humans and other animals (e.g., baboons and elephants) before germination and seedling emergence (Davis & Johnson 1987).

Low numbers of seedlings and high numbers of coppice juveniles at Shorobe indicated that the majority of the cop-

Figure 13. *Hyphaene petersiana* Klotzsch ex Mart. stumps protected from animals with *Acacia* sp. branches at Shorobe, the Okavango Delta, northern Botswana.

pice juveniles resulted from vegetative recruitment and the majority, if not all, remain stunted and never reach reproductive maturity. Sola *et al*. (2006) reported that the scenario may be lethal, or pose a serious threat to the survival of plants during diseases, pest outbreaks, and climatic change because of loss of genetic diversity, which is enhanced through sexual propagation or recruitment of new individuals.

The population structure of *H. petersiana* at both study areas did not show the "reverse J" distribution pattern indicative of stable populations with healthy regeneration (Harper 1977, Silvertown 1988, Teketay 1997b, Wehncke *et al*. 2010). At both sites, there were high numbers of individuals at the lowest diameter classes suggesting good recruitment either from seeds or coppices or both. At Tubu, the distribution pattern was affected by having very few individuals in the next two higher diameter classes but considerable densities were recorded in the subsequent diameter classes with mature trees that are serving as seed sources. With appropriate management of the stands, the gap created in the second and third classes could be bridged to promote a stable population structure and healthy regeneration. The reasons for the low densities at the second and third diameter classes require further investigation.

In Shorobe, the broken distribution pattern at the second as well as sixth and seventh diameter classes can be attributed to, mainly, wine tapping practices associated with cutting down trees. Medium- (dbh = 12 cm) and bigger-sized trees (dbh = 49 cm) are preferred for producing palm wine. It is interesting to note that the diameter classes that are targeted for wine tapping are missing in the population structure of *H. petersiana*. This, in turn, has resulted in the promotion of coppice/shoot production as evidenced from the large density of individuals in the lowest diameter class. Similar studies (Mollet *et al*. 2000) showed that high palm tapping negatively impacted on population structure, because of the depletion of adults, gaps or absence of recruitment of subsequent age classes within tapped populations in Assouakro, Côte D'Ivoire. While the high density of individuals in the lowest classes has a potential to promote perpetuation, there is an urgent need for developing a strategy to promote growth of the individuals to reproductive/maturity stages (Sampio *et al*. 2008), that will, in turn, bring about diversity within the population through sexual reproduction.

The fact that 67% of the stumps of tapped stems were able to regenerate through coppices, shoots and/or both provided empirical evidence against those who are claiming that wine tapping totally kills the trees. This finding concurs with that reported by Cunningham (1990a) and Sola *et al*. (2006). Also, the respondents were of the opinion that the death of 33% of the stumps was caused by both wild and domestic animals as well as the poor care taken by inexperienced wine tappers.

Shortage of seeds at Shorobe may also impact negatively on the recruitment of individuals and spreading or colonizing of new habitats by *H. petersiana* through long distance dispersal mediated by floods (seeds floating) (Montufar *et al*. 2011), baboons, elephants and human beings (Fujoika 2005). Being a keystone species, the decline in the population of *H. petersiana* may affect a number of organisms, which depend on it for their survival.

The community at Shorobe seemed not to have been worried about the lack of reproductive maturity on the outskirts of the village, because they felt that already there was plenty of *H. petersiana* growing within the village and their individual households that will compensate for wild production. They also denied that shortage of reproductive maturity was due to repeated tapping. Rather, this was blamed on elephants and 20 years of prolonged drought in the area. Drought has resulted in drying up of large water bodies and changes in underground hydrology, which led to dying of large populations of *H. petersiana* (supported by findings of Blach-Overgaard *et al*. 2009). The population of *H. petersiana* has also been reported to have been attacked by termites during the drought periods.

The FGD revealed that there are conflicting interests when it comes to the multipurpose uses of *H. petersiana*. For instance, wine tapping leads to felling of trees thereby denying other uses that could have been obtained (e.g., leaves for weaving, fruit, stem hearts and tender meristems for food, and wood for various purposes). In addition, the importance of trees for environmental/ecosystem services (e.g., carbon sequestration, food/feed, habitat and breeding ground for different organisms, control of soil erosion, and regulation of watershed) is compromised. However, participatory plans can be put in place to address these conflicting interests. For example, before felling the trees, the leaves can be harvested for weaving purposes.

Conclusions and recommendations

The results revealed that *H. petersiana* has relatively high total densities both at Shorobe and Tubu. However, the high densities at both sites are attributed to the high number of juveniles (seedlings and coppices), especially at Shorobe. Individuals in higher diameter classes at Shorobe were either lacking or had very low densities suggesting negative impacts from the wine tapping. Similarly, individuals with diameter ranges of 2-20 cm were very few in Tubu while those with diameter ranges of 20-50 exhibited considerable densities with a good potential to contribute to the future regeneration of the species.

The dominance of *H. petersiana* was much higher in Tubu than Shorobe, which is also associated with the relatively high densities of individuals of trees with larger dbh in Tubu. At both sites, the population structures of *H. petersiana* exhibited missing or few individuals in some of the diameter classes, especially in Shorobe, suggesting impacts from either anthropogenic (e.g., tapping), animal (e.g., elephants), or other disturbances. These disturbances need to be investigated in the future.

Palm wine tappers at Shorobe used destructive methods such as burning, felling, pruning and trimming stems. A high proportion of tapped stems survived/regenerated, because tapping was carried out by experienced middle to old aged men. They applied their indigenous conservation techniques, such as leaving some apical meristem after tapping, which promoted rejuvenation, protection of tapped stems from being further destroyed by cattle, goats, and donkeys. In the absence or poor enforcement of relevant policies and legislation on the sustainable use of species such as *H. petersiana*, indigenous conservation knowledge and tappers' wisdom played a fundamental role on the perpetuation of *H. petersiana*. However, there is still a problem associated with getting some trees to grow to maturity/reproductive stages.

Palm sap harvesting is no longer as popular as in the old days. Probably, nowadays people have a wide range of alternatives with regard to food acquisition as revealed during the FGD. The tappers were neither employed nor absorbed in government programs such as poverty eradication or food baskets (handouts). They reported that they are very poor and have large families to take care of, hence, had no alternative but to continue with the tedious and laborious palm tapping exercise to insure basic food availability for their households.

Based on the results from the study, the following recommendations are suggested:

- The gap identified in this study (unstable population structure and hampered regeneration of the species through seeds), especially in Shorobe Village, should be addressed by the appropriate authorities, including the local communities themselves. This requires additional research as well as the development of strategies that could include a program to aid in restoration of the population of *H. petersiana* through direct seeding or enrichment plantation.

- Palm wine tappers should be encouraged to form associations or cooperatives that will coordinate their activities for better benefits or returns from their engagement as well as monitoring the various activities associated with the traditional wine tapping practices. This will ensure that the tappers adhere to the set rules and regulations of the associations or cooperatives and government.

- Efforts should be made to explore alternative, more efficient methods of wine production without necessarily felling the trees. This would also prevent the conflicts discussed above in the use of this multipurpose species.

- Awareness creation campaigns should be undertaken among the wine tappers and other members of the community to promote responsible management, sustainable utilization, and conservation of the species.

- Further research on the nutritional or beverage content of the palm wine, fruit, and palm hearts should be conducted with attempts to add local value contributing more to community livelihoods.

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Appendix 1. Focus-group discussion questions used to ask about socio-economics of palm wine production with *Hyphaene petersiana Klotsch ex* Mart. at Shorobe, the Okavango Delta, northern Botswana.

1. List uses/values of **mokola** in your community.
2. How is **mokola** harvested for wine tapping?
3. Which tree sizes are mostly targeted and why?
4. How long has wine tapping been carried out by some members of the community?
5. Who is involved in wine tapping and Why?
6. When and where is wine tapping carried out?
7. Do you think that the number of people involved in wine tapping is increasing or decreases? Explain why?
8. Do you think that the harvesting is sustainable? Please explain your answer.
9. What are the effects of palm wine in the community?
10. Are there any control mechanisms with regards to wine tapping?
11. Have you tasted palm wine? Do you like it?
12. How do you compare the test of palm wine with other local drinks and commercial wines?
13. How long do you think palm trees have been in existence within the village?