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Research article

Classification of riparian woody plant communities along the Thamalakane River in northwestern Botswana

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Abstract: There is still paucity of information on the species composition of woody species along the Thamalakane River, northern Botswana, which may limit efforts aimed at conserving riparian woodland species. The current study was aimed at classifying the vegetation and determining the species composition and diversity of the riparian woodland plant communities along the Thamalakane River. It was hypothesized that there will be no different woodland communities along the Thamalakane River. The 71 sampling plots measured 1000m^2 (20m × 50m). In each plot,the percentage cover for each species was estimated following the Braun-Blanquet scale. Different woodland communities were determined through Hierarchical Cluster Analysis followed by Indicator Species Analysis. Multi-Response Permutation Procedures (MRPPs) were used to determine whether or not there was a significant separation between the groups. The Kruskal-Wallis test was used to statistically compare the diversity between woodland communities. Five major woodland communities were identified along the Thamalakane River, namely *Vachellia tortilis-Gardenia volkensii, Combretum imberbe-Gymnosporia senegalensis, Philenoptera violacea-Garcinia livingstonei, Dichrostachys cinerea-Flueggea virosa* and *Croton megalobotrys-Colophospermum mopane.* There was significant (p <0.05) separation between the plant groups. Species diversity was highest in *Dichrostachys cinerea-Flueggea virosa* community and lowest in *Vachellia tortilis-Gardenia volkensii* community. The distribution of woodland species along Thamalakane river could be influenced by human disturbance, which may override abiotic environmental conditions such as flooding in influencing the composition and distribution of plant species. This calls for proper management initiatives of the riparian vegetation in the study area. Such initiatives may include establishment of exclosures to promote the germination and propagation of the woodland species. Other strategies may include education and raising awareness among local communities to promote their sustainable use of riparian vegetation.

Introduction

The human population in the Okavango Delta relies on riparian woodland vegetation for food and timber (Neelo et al. 2015; Teketay et al. 2016). Recently, it has also been shown that tourists prefer the Okavango Delta for its aesthetic value, which is promoted by the riparian vegetation (Matlhola 2016). The woodland vegetation also indirectly promotes tourism since it serves as source of food for the browsing wild animals, such as elephants, which attract the tourists to the Okavango Delta. In the past, riparian woodland species, such as *Diospyros mespiliformis* Hochst.ex A.DC, *Kigelia africana* (Lam.) Benth, *Philenoptera violacea* (Klotzch) Schrire, *Garcinia livingstonei* T. Anderson, were used for dug-out canoe (*mokoro*) construction, which local communities use for their livelihood activities, such as fishing, hunting and transport of goods (Ecosurv 1988). Despite their importance, riparian woodland species are threatened by over-exploitation, which predispose them to degradation.

Over-exploitation of woodland resources may result from excessive cutting for poles used in construction of fields, homesteads and kraals. Riparian wetland ecosystems offer land suitable for crop production, which results in deforestation due to clearing land for planting and fencing the fields (Reddy and Gale 1994). It is expected that the demand for agricultural and residential land in riparian ecosystems will increase as the human population increases. This will put more pressure on the woodland resources. Currently, there are flood recession fields used for flood recession farming, known locally as *molapo* farming, along the Thamalakane River where woodland species, such as *Senegalia mellifera* (Vahl) Seigler & Ebinger, *Vachellia tortilis* Galasso & Banfi and *V. erioloba* (E. Mey.) P. J. H. Hurter are used for fencing (Neelo et al. 2015). While these fields are generally on the river banks in the seasonal floodplains, they are likely to encroach in the riparian zone in response to increased flooding, which will submerge them. These threats are exacerbated by apparent lack of knowledge on the composition of riparian woodland species along the Thamalakane River.

Riparian woodland species composition has been extensively studied in other ecosystems. These include studies conducted by Medina (1986) in Mexico, Roberts and Ludwig (1991) in Australia, Lyon and Sagers (2002) in Missouri, Fousseni et al. (2011) in Togo, Strohbach (2013) in Namibia, de Oliveira et al. (2014) in the Pantanal, Brazil and Revermann et al (2017) in Angola. However, this is in stark contrast with the Okavango Delta where very few studies (Neelo et al. 2013; Neelo et al. 2015; Teketay et al. 2016; Tsheboeng et al. 2016a) have been carried out on the woodland species composition. Most of the previous studies were conducted on plant community composition and, mainly, focused on the herbaceous seasonal floodplain communities (Ellery et al. 1993; Bonyongo 1999; Bonyongo et al. 2000; Ellery and Tacheba 2003; Murray-Hudson, 2009; Tsheboeng et al. 2014). It is only recently that there were efforts to quantify the species composition of riparian woodland communities. However, such efforts were, mostly, limited to the upper regions of the Delta, excluding the distal areas, such as the Thamalakane River (Tsheboeng et al. 2016a).

The Thamalakane River is used for human settlement, which may result in the destruction of the woodland vegetation, resulting from land clearing for establishment of settlements. This destruction may hamper the ecological functioning of the woodland resources along the Thamalakane River.

Therefore, in order to make informed interventions, there is a need for information to support wise and sustainable woodland resource use. The objective of this study was, therefore, to classify the vegetation, and determine the species composition and diversity of riparian woodland plant communities along the Thamalakane River. We hypothesized that there will be no different woodland communities along the Thamalakane River.

Materials and methods

Description of the study area

The study was conducted along the Thamalakane River in the distal southeast regions of the Okavango Delta (Fig. 1).

The Thamalakane River, which passes through Maun village in Northern Botswana, is flooded from the Okavango Delta. The Delta is flooded from the Angolan highlands with a total inflow, ranging from a minimum of 6.0 to 10^9 m^3 and a maximum of 16.4 × 10^9 m^3 of which only 2% reaches the Thamalakane River (Gumbricht et al. 2004). Floodwater reaches the Thamalakane River around May/June having travelled 4-5 months from the upstream regions of the Delta (Ellery and McCarthy 1998). During low flooding periods, the Thamalakane River becomes dry from January to June (Masamba and Mazvimavi 2008). The local rainfall of ca. 450 mm $year^{-1}$ is asynchronous with flooding and occurs between November and March (Scudder et al. 1993). In terms of temperature, the Thamalakane River is characterized by a minimum monthly mean of 22 °C to 34 °C with average maximum temperature ranging between 30 °C to 32 °C (Scudder et al. 1993).

Livelihood activities along the Thamalakane River include livestock rearing and flood recession farming on the edges of the water as it recedes (Ellery and McCarthy 1998). Other livelihood activities include vegetable gardens, hotels, lodges and residential areas. These activities may negatively impact on the riparian woodland communities along the Thamalakane River.

Sampling procedure

The sampling plots measured $1000m^2$ (20m × 50m). This is the plot size that was used in the earlier study on the quantification of woodland species composition in the upper regions of the Okavango Delta (Tsheboeng et al. 2016a). Riparian woody species were identified in randomly selected plots. The random selection of plots started from Matsaudi to Dikgatlhong junctions, which covered about 50km. A total of 71 plots were selected at 1km

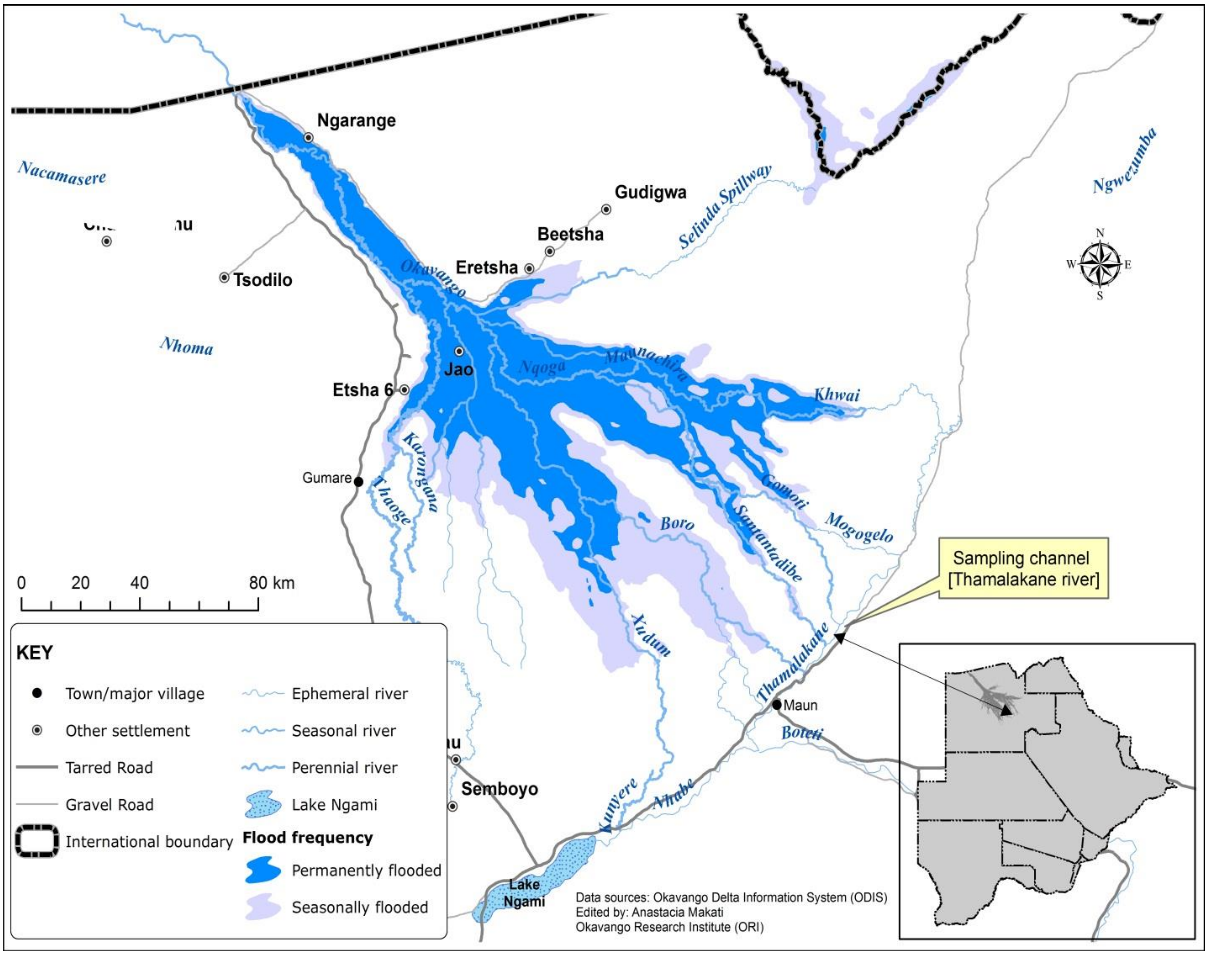

Fig. 1: Map of the Okavango Delta showing the Thamalakane River.

intervals on either side of the river with the distance measured using a GPS. Vegetation sampling was conducted during the growing season of 2015 (January-July) and 2016 (January-July). The sampling plots were placed perpendicular to the riverbank such that their short axes were closer to the water while the long axes ran into the dry reaches of the bank. In each plot percentage cover contributed by each species was estimated following the Braun-Blanquet cover scale (Mueller-Dombois and Ellenberg 1974). Specimens of unknown woody species were collected, pressed, dried and identified in the Peter Smith University of Botswana Herbarium (PSUB) at the Okavango Research Institute. Plant nomenclature of the plant species included in this article follows Setshogo (2005) and Kyalangalilwa et al. (2013) (see also Table 1).

Data analysis

Different woodland communities were classified through Agglomerative Hierarchical Cluster Analysis (flexible β linkage, β = -0.25, Sorensen distance, data relativized by maximum) in PC-ORD version 6. This was followed by Indicator Species Analysis (ISA) (Dufrêne and Legendre 1997), which was used to determine characteristic species for each woodland community defined through cluster analysis.

Indicator species analysis was also used to determine ideal number of clusters from the vegetation data. This is where there was low mean *p* value and high number of statistically significant indicator species (McCune and Grace 2000) given in Fig. 2. Monte Carlo testing was used to determine whether the indicator values for the species were significant. Multi Response Permutation Procedures (McCune and Grace 2000) were also used to determine whether there was a significant separation between the groups. The calculation of the MRPP gives the test statistic *T*, which is calculated as:

$$T = (\delta_{observed} - \delta_{expected}) / SD\ \delta_{expected})$$

where, T = Test statistic, $\delta_{observed}$= Delta observed, $\delta_{expected}$ = Delta expected and SD = Standard deviation.

The *T* statistic determines the level of separation between woodland communities in which more

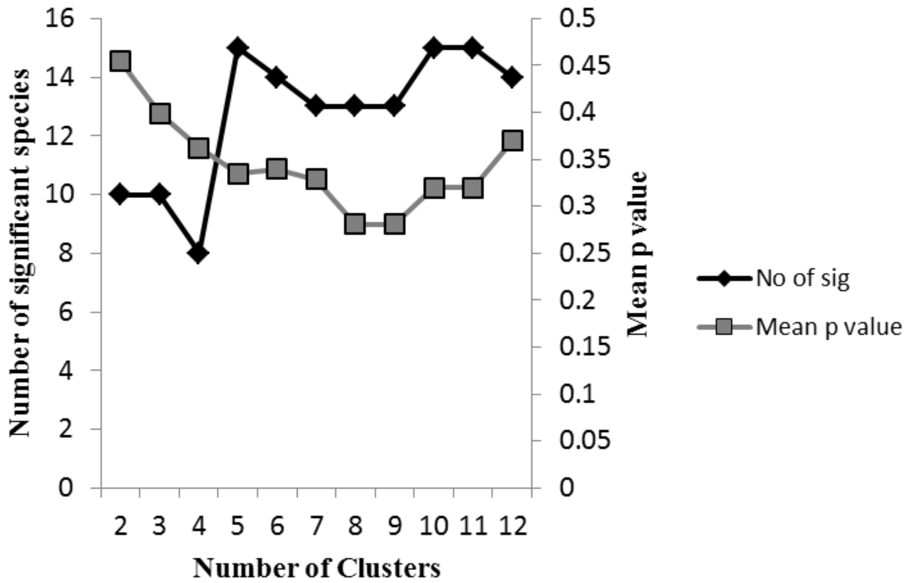

Fig. 2: Number of statistically significant indicator species and mean p value of indicator species in each cluster.

negative values indicate stronger separation while less negative values show weak separation between the groups in terms of species composition.

Another output of MRPPs is the within group homogeneity, which is determined by within group agreement $A = 1\text{-}(\delta_{observed}/\delta_{expected})$.

When all the species are identical within a given group, $A_{\text{maximum}} = 1$, and it is zero when heterogeneity within groups equals expectation by chance. $A < 0$ when there is more heterogeneity within groups than expected by chance. In addition, species diversity, richness, evenness and density were calculated for each woodland community following the methods described by Kent and Coker (1992) and Magurran (2004).

Classification of plant communities

Agglomerative Hierarchical Cluster Analysis followed by Indicator Species Analysis (ISA) (Dufrêne and Legendre 1997), showed that there were five representative woodland communities along the Thamalakane River. The major woodland communities (named after two species with the highest indicator values) identified along the Thamalakane River were: *Vachellia tortilis-Gardenia volkensii, Combretum imberbe-Gymnosporia senegalensis, Philenoptera violacea-Garcinia livingstonei*, *Dichrostachys cinerea-Flueggea virosa* and *Croton megalobotrys-Colophospermum mopane* (Table 1).

Results

Table 1: Woodland plant community composition along the Thamalakane River.

Species	Indicator Value	P value	Growth form	Family
		Philenoptera violacea-Garcinia livingstonei		
Philenoptera violacea (Klotzch) Schrire	69.6	0.0002	Tree	Fabaceae
Garcinia livingstonei T. Anderson	22.9	0.1710	Tree	Guttiferae
Diospyros mespiliformis Hochst. Ex A. DC.	20.8	0.3065	Tree	Ebenaceae
Terminalia prunioides M. A. Lawson	20.4	0.7743	Tree	Combretaceae
Vachellia luederitzii (Engl.) Kyal. & Boatwr.	13.3	0.1724	Tree/Shrub	Fabaceae
Maerua angolensis DC	4.8	0.8508	Tree/Shrub	Capparaceae
		Vachellia tortilis-Gardenia volkensii		
Vachellia tortilis (Forssk) Galasso & Banfi	67.3	0.0002	Tree/Shrub	Fabaceae
Gardenia volkensii K. Schum	24.8	0.1182	Shrub	Rubiaceae
Senegalia erubescens (Welw. ex Oliv.) Kyal. &	9.4	0.6253	Tree/Shrub	Fabaceae

Boatwr.				
Vachellia hebeclada (DC.) Kyal. & Boatwr.	6.3	0.8772	Tree/Shrub	Fabaceae
Markhamia zanzibarica (Bojer ex DC) K. Schum.	6.2	0.7510	Tree	Bignoceae
Sclerocarya birrea (A. Rich.) Hochst.	5.3	1.0	Tree	Anacardiaceae
Dichrostachys cinerea-Flueggea virosa				
Dichrostachys cinerea L) Wight & Arn.	65.7	0.0056	Tree	Fabaceae
Flueggea virosa (Roxb. Ex Willd.) Voigt	55.5	0.0004	Shrub	Euphorbiaceae
Grewia bicolor A.Juss	49.0	0.0016	Shrub	Tiliaceae
Searsia tenuinervis Engl.	44.8	0.0034	Shrub	Anacardiaceae
Combretum mossambicense (Klotzsch) Engl.	43.9	0.0040	Shrub	Combretaceae
Berchemia discolor (Klotzsch) Hemsl.	39.8	0.0280	Tree	Rhamnaceae
Grewia retinervis Burret	35.9	0.0314	Shrub	Tiliaceae
Combretum hereroense Schinz	33.8	0.0224	Tree	Combretaceae
Albizia harveyi E. Fourn.	29.4	0.1172	Tree	Fabaceae
Capparis tomentosa Lam.	24.5	0.1818	Tree	Capparaceae
Diospyros lycioides Desf	22.0	0.3422	Shrub	Ebenaceae
Ximenia americana Welw. ex Oliv.	21.6	0.0970	Shrub	Olacaceae
Phyllanthus reticulatus Poir.	20.9	0.8362	Shrub	Euphorbiaceae
Euclea divinorum Hiern	20.0	0.0300	Shrub	Ebenaceae
Boscia albutrinca (Burch.) Gilg & Gilg-Ben	19.3	0.0486	Tree	Capparaceae
Kigelia africana (Lam.) Benth.	10.0	0.2513	Tree	Bignoceae
Albizia anthelmintica Brongn.	9.9	0.4281	Shrub	Fabaceae
Croton megalobotrys-Colophospermum mopane				
Croton megalobotrys Müll. Arg	61.9	0.0002	Tree	Euphorbiaceae
Colophospermum mopane (J.Kirk ex Benth.) J.Kirk ex J.Léonard	37.1	0.0568	Tree	Fabaceae
Hyphaene petersiana Mart.	31.3	0.0686	Tree	Arecaceae
Senegalia galpinii (Burtt Davy) Seigler & Ebinger	6.6	0.7355	Tree	Fabaceae
Combretum imberbe-Gymnosporia senegalensis				
Combretum imberbe Wawra	78.8	0.0002	Tree	Fabaceae
Gymnosporia senegalensis (Lam.) Loes	38.4	0.0298	Shrub	Celastraceae
Senegalia nigrescens (Oliv.) P.J.H. Hurter.	28.5	0.0836	Tree	Fabaceae
Ziziphus mucronata Willd.	23.3	0.2254	Tree	Rhamnaceae
Senegalia mellifera (Vahl) Seigler & Ebinger	19.8	0.3725	Shrub	Fabaceae
Ficus sycomorus L	18.2	0.3011	Tree	Moraceae
Cordia sinensis Lam	16.2	0.1806	Shrub	Boraginaceae
Commiphora glandulosa Schinz	14.8	0.10008	Tree	Burseraceae
Combretum albopunctatum Suess	12.5	0.5845	Shrub	Combretaceae
Grewia villosa Willd.	8.0	0.8348	Shrub	Tiliaceae
Vachellia sieberiana (DC.) Kyal. & Boatwr.	5.1	0.8670	Tree	Fabaceae
Vachellia nilotica (L.) P.J.H.Hurter & Mabb	4.1	0.9228	Tree	Fabaceae

Description of different woodland communities

i. *Philenoptera violacea-Garcinia livingstonei* community

The main indicator species in this community were *Philenoptera violacea* and *Garcinia livingstonei* (Fig. 3). Other species found in this community were *Diospyros mespiliformis*, *Terminalia prunioides* M. A. Lawson, *Vachellia luederitzii* (Engl.) Kyal & Boatwr and *Maerua angolensis* DC (Table 1). This is a mixture of water loving trees found at the edges of the riverbank and dry land species found at dry

Fig. 3: *Philenoptera violacea-Garcinia livingstonei* community along the Thamalakane River.

Table 2: Species richness, diversity (± SE) and evenness (± SE) in different woodland communities.

Vegetation community	Total number of species	Evenness	H′
PV-GL	6	0.42 ± 0.03	1.45 ± 0.11
VT-GV	6	0.35 ± 0.05	0.88 ± 0.12
DC-FV	17	0.41 ± 0.05	1.78 ± 0.19
CM-CoM	4	0.24 ± 0.01	1.09 ± 0.11
CI-GS	12	0.31 ± 0.03	1.35 ± 0.13

PV-GL (*Philenoptera violacea-Garcinia livingstonei*), VT-GV (*Vachellia tortilis-Gardenia volkensii*), DC-FV (*Dichrostachys cinerea-Flueggea virosa*), CM-CoM (*Croton megalobotrys-Colophospermum mopane*) and CI-GS (*Combretum imberbe-Gymnosporia senegalensis*).

reaches of the riparian woodland patch. Generally, this community was found in sandy soils rich in humus. The total species number in this community was six with mean species diversity and evenness of 1.45 and 0.42, respectively (Table 2).

ii. *Vachellia tortilis-Gardenia volkensii* community

The main indicator species in this community were *V. tortilis* and *Gardenia volkensii* K. Schum (Fig. 4). Other characteristic species of the *V. tortilis-Gardenia volkensii* community were *Senegalia erubescens* (Welw. ex Oliv.) Kyal & Boatwr, *Vachellia hebeclada* (DC.) Kyal & Boatwr, *Markhamia zanzibarica* (Bojer ex DC.) K. Schum and *Sclerocarya birrea* (A. Rich.) Hochst (Table 1). The *Vachellia tortilis-Gardenia volkensii* community is found in dryland reaches of the riparian zone. In most cases this community was found in old fields and previously disturbed sites characterized by thickets of *V. tortilis*. This community had a total of six species. The mean species diversity and evenness were 0.88 and 0.35, respectively (Table 2).

Fig. 4: *Vachellia tortilis-Gardenia volkensii* community along the Thamalakane River.

Fig. 5: *Dichrostachys cinerea-Flueggea virosa* community along the Thamalakane River.

iii. *Dichrostachys cinerea-Flueggea virosa* community

This community was characterized by thickets of *D. cinerea* (L.) Wight & Arn and *Flueggea virosa* (Roxb. ex. Willd.) Voigt (Fig. 5), in old and abandoned fields in the drier reaches of the riparian zone. Species found in this community were mainly shrubs namely: *Grewia bicolor* A. Juss, *Searsia tenuinervis* (Engl.) Moffett, *Combretum mossambicense* (Klotzsch) Engl and a few tree species, including *Albizia harveyi* E. Fourn., *Boscia albitruinca* (Burch.) Gilg & Benedict and *Kigelia africana* (Lam.) Benth (Table 1). This is a species rich community characterized by a total of 17 species. It was also the most diverse with mean species diversity of 1.78. The mean evenness was 0.41 (Table 2).

iv. *Croton megalobotrys-Colophospermum mopane* community

It was characterized by *Croton megalobotrys* Müll. Arg and *Colophospermum mopane* (J.Kirk ex Benth.) J. Kirk ex J. Léonard (Fig. 6). Also, *Hyphaene petersiana* Klotzsch ex Mart and *Senegalia galpinii* (Burtt Davy) Seigler & Ebinger were found in this community (Table 1). The *Croton megalobotrys-Colophospermum mopane* community was found in both sites that were closer to the riverbank and those that were further away. It had a wide range of spatial niche with *C. megalobotrys* found in almost all the plots sampled. This community was species poor with only four species. It was also lowest in evenness and only higher than *Vachellia tortilis-Gardenia volkensii* community in species diversity (Table 2).

v. *Combretum imberbe-Gymnosporia senegalensis* community

The main characteristic species in this community were *Combretum imberbe* Wawra and *Gymnosporia senegalensis* (Lam.) Loes (Fig. 7). Other species in the *Combretum imberbe-Gymnosporia senegalensis* community include *Senegalia nigrescens* (Oliv.) P.J.H. Hurter, *Ziziphus mucronata* Willd, *S. mellifera* and *Ficus sycomorus* L (Table 1). This community was found in the drier margins of the riparian zone characterized by sandy soils. A total of twelve

Fig. 6: *Croton megalobotrys-Colophospermum* community along the Thamalakane River.

Fig. 7: *Combretum imberbe-Gymnosporia senegalensis* community along the Thamalakane River.

species were identified in the *Combretum imberbe-Gymnosporia senegalensis* community with the mean species diversity and evenness of 1.35 and 0.31, respectively (Table 2).

Comparison of communities

Multi-Response Permutation Procedures were used to compare plant communities along the Thamalakane river in terms of their species composition. It was found that the different communities were significantly ($p < 0.05$) different from each other in terms of plant species composition (Table 3).

Table 3: Multi-Response Permutation Procedures pairwise comparisons of woodland communities.

Classes	T	A	*p*
PV-GL[1]vs AT-GV[2]	- 18.00	0.298	< 0.001
PV-GL vs DC-FV[3]	- 8.00	0.0890	< 0.001
PV-GL vs CM-CoM[4]	- 15.00	0.242	< 0.001
PV-GL vs CI-GS[5]	- 10.50	0.260	< 0.001
AT-GV vs CI-GS	- 15.00	0.218	< 0.001
AT-GV vs CM-CoM	- 20.52	0.410	< 0.001
AT-GV vs CI-GS	- 12.64	0.309	< 0.001
DC-FV vs CM-CoM	- 12.57	0.169	< 0.001
DC-FV vs CI-GS	- 8.62	0.173	< 0.001
CM-CoM vs CI-GS	- 12.00	0.351	< 0.001

[1]PV-GL (*Philenoptera violacea-Garcinia livingstonei*), [2]AT-GV (*Vachellia tortilis-Gardenia volkensii*), [3]DC-FV (*Dichrostachys cinerea-Flueggea virosa*), [4]CM-CoM (*Croton megalobotrys-Colophospermum mopane*) and [5]CI-GS (*Combretum imberbe-Gymnosporia senegalensis*).

Discussion

The riparian woodland vegetation along the Thamalakane River was classified into five communities: *Philenoptera violacea-Garcinia livingstonei*, *Vachellia tortilis-Gardenia volkensii*, *Dichrostachys cinerea-Flueggea virosa, Croton megalobotrys-Colophospermum mopane* and *Combretum imberbe-Gymnosporia senegalensis*.

Generally, the constituent species in the woodland communities in our study are similar to those identified by Snowy Mountains Engineering Corporation (1989) (hereafter, SMEC) in their vegetation mapping exercise in the Okavango Delta. In their study, they listed species, such as *S. birrea*, *K. africana*, *G. livingstonei* and *C. imberbe*, which were also identified along the Thamalakane River. The similarities in terms of species composition between these two studies show that the environmental conditions, which these species prefer are present in both upstream and distal regions of the Delta. However, the woodland communities identified in our study are different from *Syzygium cordatum-Phoenix reclinata*, *Garcinia livingstonei-Senegalia nigrescens, Croton megalobotrys-Hyphaene petersiana* and *Vachellia erioloba-Diospyros lycioides* that were identified in the upper regions of the Okavango Delta (Tsheboeng et al. 2016a). This difference could suggest that not all species are favoured by the prevailing environmental conditions in the distal regions of the Delta. The *Syzygium cordatum-Phoenix reclinata* woodland community is associated with frequent flooding conditions, which are absent in the riparian zone of the distal regions of the Okavango Delta (Tsheboeng et al. 2016b), hence, its exclusion along the Thamakalane River, which is a seasonally flooded area. *Croton megalobotrys* was a dominant species along the Thamalakane River and the upstream regions of the Delta. This could be an indication of its wide tolerance of moist conditions in both upstream and distal regions of the Okavango Delta. *Croton megalobotrys* is a pioneer species, which indicates anthropogenic disturbances, such as deforestation/vegetation clearing (Hamandawana, 2012). In Moremi Game Reserve, Hamandawana (2012) found that *C. megalobotrys* increased in abundance in response to woodland degradation by elephants.

Along the Thamalakane River, degradation of riparian vegetation mainly results from clearing land to give space for residential homes, farms and livestock kraals. The communities of *Vachellia tortilis-Gardenia volkensii*, *Dichrostachys cinerea-Flueggea virosa* and *Combretum imberbe-*

Gymnosporia senegalensis characterized by dryland tolerant species are indicative of the low flooding frequency conditions prevalent along the Thamalakane River. These species were *S. erubescens*, *V. hebeclada*, *G. bicolor*, *Ximenia americana* L, *S. mellifera* and *Vachellia nilotica* (L.) P.J.H. Hurter & Mabb. The distribution of the woodland species in the distal regions of the Delta may also be influenced by human disturbance. It has been found that disturbance may override abiotic environmental conditions in influencing the species composition and distribution of plant species (Grime 1977).

The presence of *Vachellia tortilis-Gardenia volkensii* and *Dichrostachys cinerea-Flueggea virosa* communities could also indicate the human disturbance of the distal region of the Delta. The genera *Senegalia* and *Vachellia* as well as species *D. cinerea* are indicators of disturbed sites (Tolsma et al. 1987). This is because the species develop shallow rooting system, which enables them to out-compete the other species for water in the early stages of colonization (Skarpe 1990). As already mentioned previously, along the Thamalakane River, the disturbance mainly results from deforestation for building of houses, agricultural fields, making poles, firewood and road construction. Our observations during data collection showed that genera *Senegalia* and *Vachellia* and species *D. cinerea* were most abundant in abandoned fields, communal grazing areas and kraals. These areas are also characterized by prevalent livestock grazing. Livestock grazing has been identified as one of the threats to biodiversity (Hilton-Taylor 1996). It leads to a reduction in the plant species richness by eliminating the preferred species (Waser and Price 1981). It can also influence species composition through damage to seedlings through trampling and browsing (Fleischner 1994). In addition, livestock grazing/browsing may also influence the woodland species composition through dispersal of seeds (Strang 1974). In the Thamalakane River system, the seeds of species of *Senegalia* and *Vachellia* may be dispersed by livestock from the dry land areas into the moist micro-sites suitable for germination along the riverbank.

If the current land management system along the Thamalakane River continues where residential plots, cattle posts and farms are allocated in the riparian zone, it is likely that the disturbance to the vegetation will also prevail. The prevalence of disturbance along the Thamalakane River will compromise the ecological functioning, ecosystem services and products, which will, eventually, impact negatively on the human communities around the river. This is because the diversity of the functions will be reduced, resulting in low abundance of fruit trees, and species that provide timber and forage for animals. This calls for proper management of the woodland resources along the Thamalakane River such that the functional diversity balance is maintained. Management and conservation of the woodland resources could be achieved through proper and sustainable utilization, education and raising awareness among local communities and creation of conservancies, which will serve as refuge sites for the propagation of the woodland vegetation. The conservancies will protect the woodland plants from prolonged grazing and harvesting (Strang, 1974; San Jose and Farinas 1983; Hatton and Smart 1984; Scholes 1990; Watson and MacDonald, 2014). There should also be consideration of halting allocation of plots along the Thamalakane River while those that are already allocated plots should be encouraged to co-exist with the riparian woodland vegetation.

Conclusion and recommendations

Five plant communities of *Vachellia tortilis-Gardenia volkensii, Combretum imberbe-Gymnosporia senegalensis, Philenoptera violacea-Garcinia livingstonei, Dichrostachys cinerea-Flueggea virosa* and *Croton megalobotrys-Colophospermum mopane* have been identified along the Thamalakane River. These communities may be a product of both abiotic and human influence. The riparian zone along the Thamalakane River is predominantly used for human settlements, which involves cutting down trees to make poles for constructing residential houses, agricultural fields and kraals. The potential response of vegetation to disturbance was shown by the presence of disturbance indicator species, such as *D. cinerea*, *V. tortilis* and *S. mellifera*. The pre-dominance of these species may indicate overgrazing in the area. This calls for proper management initiatives of the riparian vegetation in the study area. Such initiatives may include establishment of exclosures to promote germination and propagation of the woodland species. Other strategies may include education and creating awareness in the communities to promote their sustainable use of the riparian vegetation. Future studies should investigate the environmental factors that influence the composition and distribution of riparian woody plant communities along the Thamalakane River. Such studies should also quantify the extent of use of riparian woodland species by the local communities along the Thamalakane River.

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