The long-term effects of burning and utilisation on *Phragmites australis* reeds in the Muzi Swamp of the Tembe Elephant Park, South Africa

J.A. Tarr[1], M.W. van Rooyen[2] and J. du P. Bothma[1]

[1] Centre for Wildlife Management, University of Pretoria, Pretoria, South Africa, 0002

[2] Department of Botany, University of Pretoria, Pretoria, South Africa, 0002

Key-words: burning, Maputaland, Muzi, *Phragmites australis*, utilisation.

Running title: Burning and utilisation on *Phragmites* reeds

Revised article accepted as short communication: *African Journal of Ecology* In Press.

Abstract

The long-term effect of burning and utilisation of the common reed *Phragmites australis* was investigated in the Muzi Swamp, Tembe Elephant Park over a 2-year period from 2000 to 2002. The effects of four different treatments on the density and size structure of the reed beds were compared. The aim of the study was to determine what consequences utilisation and/or burning have on the reeds within the Muzi Swamp. Continual harvesting combined with burning markedly reduces reed production in terms of reed density. Uncontrolled utilisation results in the overall decrease of reed quality in terms of reed height and diameter. The implications of the results are integral to the further management of the reed beds in terms of providing good quality reeds for neighbouring communities, and to secure the ecological integrity of the ecosystem for conservation.

[1] Correspondence to: J. A. Tarr, Centre for Wildlife Management, University of Pretoria, Pretoria, South Africa, 0002.
E-mail: jason.tarr@tuks.co.za
Tel: +27 (0) 12 420-2338
Fax: +27 (0) 12 420-6096

Introduction

Phragmites australis (Cav.) Trin. ex Steudel is a common species in both temperate and sub-tropical regions. It tends to dominate the landscape by forming monospecific stands (Granéli, 1989; Den Hartog, Květ, & Sukkop, 1989; Van der Werff, 1991). It occurs in the Muzi Swamp in the form of extensive reed beds interspersed with higher-lying islands and hygrophilous grasses (Matthews *et al*., 2001). The reason for the dominance of *Phragmites australis* in the Muzi Swamp is its competitive advantage over other terrestrial plants that co-occur in the flooded conditions in the swamp. *Phragmites australis'* emergent shoots are not known to succumb to competition from species such as Bulrush *Typha capensis* and Sedge *Cyperus sphaerospermus* (Haslam, 1969b; Matthews *et al*., 2001). The major natural cause for the loss of the reed beds is the terrestrialisation of waterlogged areas (Granéli, 1989). The high production potential of the aerial parts of the reeds and the length of time that it takes for these annual parts, more especially the culms, to decompose, contributes substantially to the rate of terrestrialisation and subsequent loss of their competitive advantage. The dead but not yet decomposed moribund material accumulates which in turn collects silt. This results in drier conditions where other terrestrial plants are able to colonise and survive (Granéli, 1989; Chambers, Meyerson & Saltonstall, 1999). Other natural causes of reduced reed quality include stochastic events such as burning and frost (Van der Toorn & Mook, 1982). However, little is known about the reed beds and the way they maintain their dominance of the habitat that they create over time.

The utilisation of *Phragmites australis* in the Muzi Swamp has resulted in the need for careful study and monitoring of the reed beds in recent times. The commercialisation of the harvesting of reeds by neighbouring local community members has increased the demand for reeds in the area. Reed utilisation by members of the Sibonisweni Reed Cutters Association has reached a peak as far as maintaining the inherent quality of the reeds in the Muzi Swamp is concerned. There is some evidence that reed quality is declining in the utilisable areas in the southern Muzi Swamp because of overutilisation (Tarr, Van Rooyen & Bothma, 2004). In the case of the Tembe Elephant Park, local communities have harvested reeds in the Muzi Swamp for use in hut building, craftwork and thatching material for many generations (Cunningham, 1985; Begg, 1988; Browning, 2000; Tosh, 2000). Reeds have also been used in other parts of the world for paper pulp, heating, forage and litter material (Allirand & Gosse, 1995). In the past the harvesting of reeds was done purely for subsistence use but currently a flourishing market has emerged from the sale of reeds. Increasing demand for reeds and a mounting utilisation pressure on the harvesting area has already influenced the quality of the reeds negatively in the harvesting areas within the Muzi Swamp (Tarr *et al*., 2004).

The severity of the influence of harvesting on the quality of the reeds within the Muzi Swamp partly depends on the time at which reeds are harvested. Although the Tembe Elephant Park's management staff encourages harvesting in the winter in the Muzi Swamp, harvesting still occurs in the summer. Quotas are reduced in the summer compared with the winter. Evidence suggests that like most other pastures, harvesting during the growing season has a detrimental effect on the next replacement crop. Harvesting during the reed emergence period in early spring (August to early September) has little effect on the reed quality and produces a replacement crop similar to an unharvested population. However, harvesting in the summer (late September to April) reduces growth for up to half the growing season. This effectively depresses the production potential of *Phragmites australis*. Continual harvesting of reeds in the early summer or the latter half of the growing season will result in a persistent reed population but it will also greatly reduce the condition and quality of the reeds produced (Haslam, 1969b).

Especially in Africa, fires are a determining factor in the dynamics of terrestrial ecosystems (Van Wilgen & Scholes, 1997). Fire as a management tool has been used successfully in many areas in South Africa. The use of fire to remove moribund and unacceptable plant material, stimulate rotational grazing, prevent bush encroachment, and to reduce the numbers of parasites such as ticks are all examples of this type of management (Trollope, 1990; Van Rooyen, 2002). The practice of burning by local farmers and individuals involved in palm wine tapping (traditional alcoholic drink made from the sap of the lala palm *Hyphaene coriacea*), has had an unknown effect on the ecology of the area. These practices have been recorded since the 1500's when the Portuguese sailed past Maputaland and named it *Terra dos Fumos*, from the endless grass fires lit by the local tribes people (Bruton, Smith & Taylor, 1980). Fires started outside Tembe Elephant Park frequently enter the reserve and occasionally even penetrate the waterlogged areas of the reed beds. Although

Phagmites australis beds are known to burn every two to five years according to Van Wilgen and Scholes (1997), the effect of the sporadic fire events in the Muzi Swamp is yet to be determined. The impact of fire and harvesting on the density, basal diameter and reed length of individual reeds in the Muzi Swamp was first investigated in 2000 (Tosh, 2000).

The former expansive reed beds outside Tembe Elephant Park have all but vanished because of its uncontrolled harvesting. Controlled harvesting within the Tembe Elephant Park has ensured that the resource base remains intact. The objective of the study was to determine what the effects of burning and utilisation have on the reed quality within the reedbeds. The study was deemed necessary to determine what type of management systems need to be implemented to maintain reed quality in the unharvested areas and improve reed quality in the harvested areas within the Muzi Swamp. It is important that the work undertaken in this study be applicable and pliable to both the Tembe Elephant Park's management staff as well as the Sibonisweni community members that utilise the resource. It was hoped that a detailed study of the Muzi Swamp would result in a greater understanding of the workings of the reed as a resource and thereby promote conflict resolution for the parties involved.

Study area

The study area is situated in the eastern portion of Tembe Elephant Park in KwaZulu-Natal, Maputaland, South Africa (Fig. 1). It forms a polygon between the following WGS 84 coördinates: 26º 53' 08'' S and 32º 34' 58'' E; 26º 53' 04'' S and 32º 34' 59'' E; 27º 01' 25'' S and 32º 29' 54'' E; and 27º 01' 24'' S and 32º 29' 44'' E. The Muzi Swamp extends northwards from south of the KwaMsomi Gate to the Muzi Gate in the north, where it continues into Mozambique and becomes the *Rio Futi*.

The portion of the Muzi Swamp that lies within Tembe Elephant Park is approximately 560 ha in size. It lies on Holocene peat deposits that are controlled by the topography of the underlying Pleistocene KwaBonambi coastal dunes (Grundling, 1996). The Muzi Swamp is an elongated interdune valley that is orientated parallel to the present coastline because of the dune topography. This interdune peatland and isolated wetland are fed by groundwater from perched aquifers within the sand dunes (Grundling, 1999).

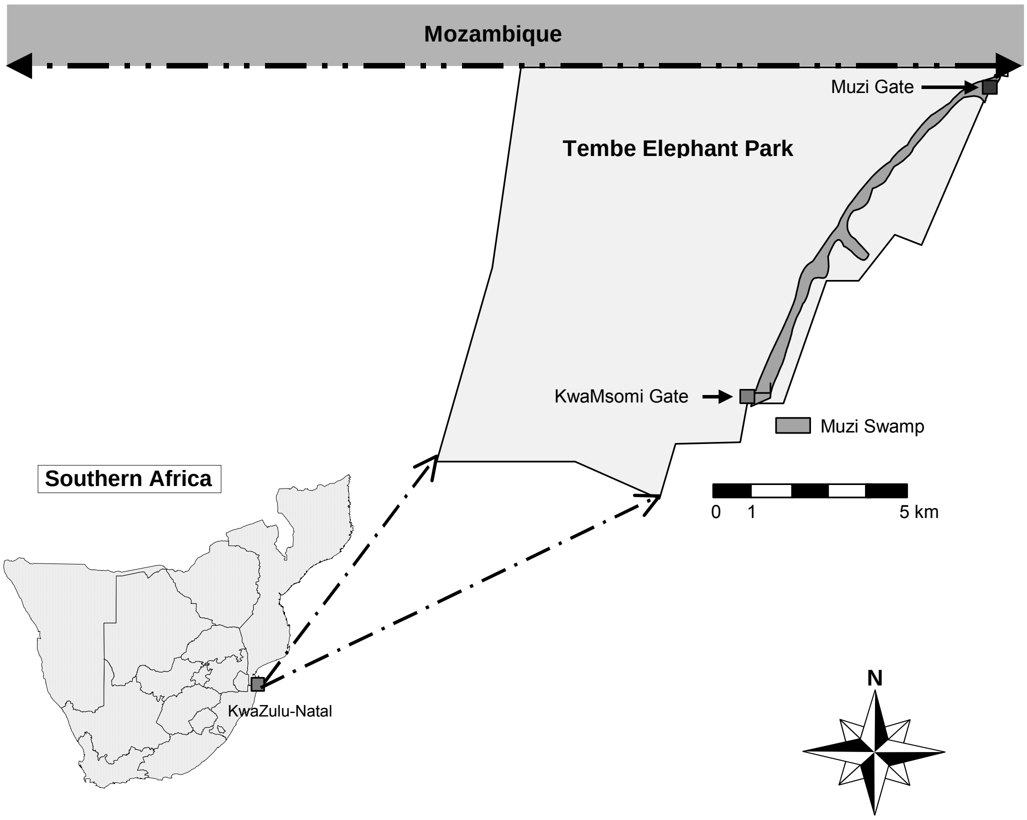


Fig. 1 The location of the Muzi Swamp in Tembe Elephant Park, South Africa.

The mean annual rainfall is 721.5 mm. Most of the rainfall occurs in the summer, but it is not limited to the summer and some precipitation occurs throughout the year. The minimum recorded annual rainfall is 245.0 mm, while the maximum is 2 105.0 mm. The ambient temperature in Tembe Elephant Park ranges from a minimum of 4.0ºC to a maximum of 45ºC. The climatological data for the study area appear in Figure 2. The proximity of Tembe Elephant Park to the coast and its low-lying topography results in a high relative humidity of the air (KwaZulu-Natal Nature Conservation Service, unpublished data).

Materials and methods

This study was part of an MSc (Wildlife Management) by the senior author. Harvesting plots that had been sampled in 2000 were revisited in 2002. These included areas that had undergone four different treatments before the initial harvesting trial in 2000. These treatments were: (i) utilised and burnt, (ii) utilised and unburnt, (iii) unutilised and burnt, and (iv) unutilised and unburnt. Six 1 m^2 quadrates (sample plots) were destructively harvested at each of the harvesting plots. Burnt and unburnt sites within a specific utilisation zone were close to each other to minimise possible effects of other environmental factors. All the reeds within a 1 m^2 square frame were harvested at water level, or at ground level in the absence of water.

The stem diameter (mm) and reed height (m) were measured for each reed. The basal stem diameter was measured by using callipers. The reed height was measured by using a tape measure from the stem base to the tip of the outstretched apical-leaf blade. Total reed height was obtained by correcting for water depth. This was consistent with the methods of Tosh (2000). The number of reeds harvested per sample plot was counted to determine the reed density per m^2.

Results were analysed using a multifactor analysis of variance (ANOVA) with the General Linear Model of the Statistical Analysis Systems (1994) computer package at $\alpha = 0.05$. Fischer's protected least significant difference (LSD) test was used to determine significant differences between means.

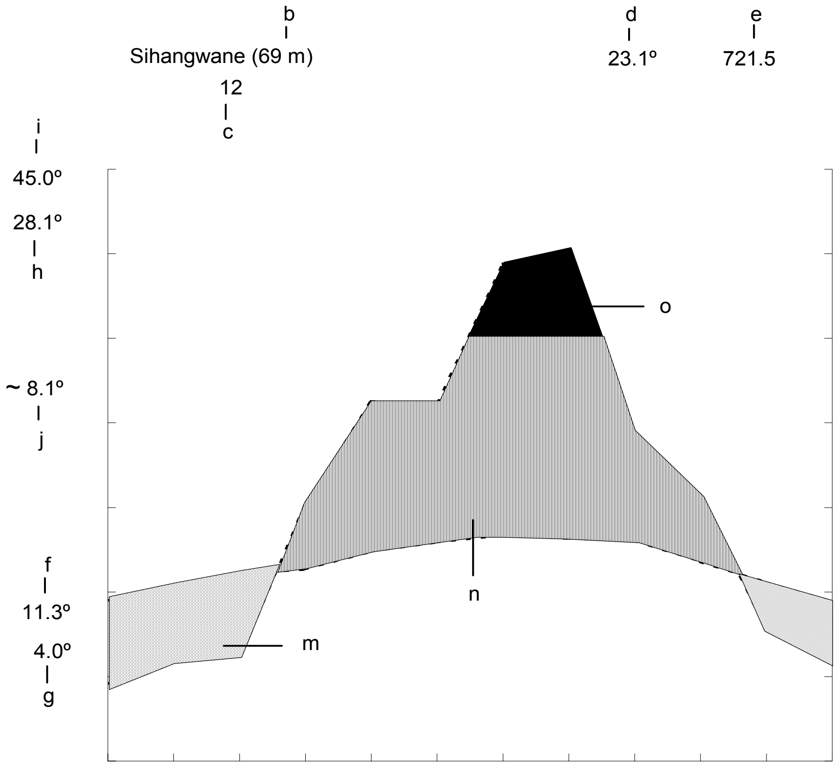


Fig. 2 Climatogram of Sihangwane Weather Station, Tembe Elephant Park, following Walter (Cox and Moore, 1994). b = height above sea-level in m; c = duration of observations in years; d = mean annual temperature in ºC; e = mean annual precipitation in mm; f = mean daily minimum of the coldest month; g = lowest temperature recorded; h = mean daily maximum of the warmest month; i = highest temperature recorded; j = mean daily temperature variation; m = relative period of drought; n = relative humid season; o = mean monthly rainfall > 100 mm.

Results and discussion

The results of the statistical analysis are summarised in Table 1 and show the following:

Reed height

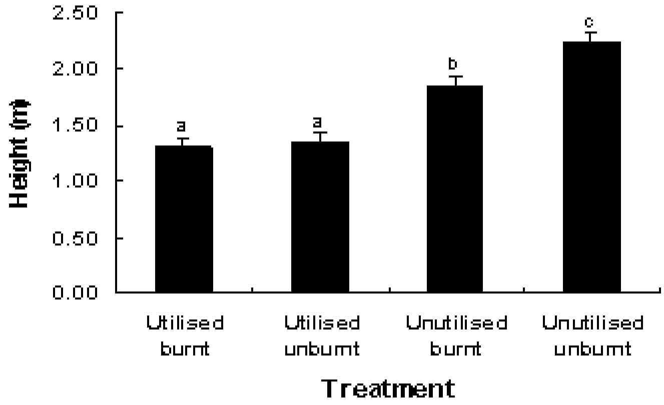
The mean reed height of areas within the Muzi Swamp that had undergone various treatments differed significantly between the utilised and the unutilised reed beds (Fig. 3A). Utilised reed beds had shorter reeds than the mean height for unutilised ones. In the unutilised areas the unburnt reeds were also significantly (P = 0.0015) taller than the burnt reeds. Constant utilisation of the reedbeds has therefore lead to a significant reduction in reed height in the utilised reedbeds. The potential reed height cannot be reached if the environment is permanently unfavourable (Haslam, 1969a) or in this case constantly utilised.

There is also a significant difference between the mean reed height over the entire sample area between 2000 and 2002 (Fig. 3B). The mean reed height in 2000 was significantly lower than that in the same areas in 2002. The unusually high rainfall that was experienced in 1999/2000 might explain this phenomenon. The summer season prior to the 2000 harvest was an exceptionally wet season with 1 541.3 mm of rain falling from August 1999 to June 2000. Extraordinarily high water levels in the Muzi Swamp, due to flooding in southern Mozambique and northern KwaZulu-Natal at this time, could also have resulted in a lower than expected biomass and subsequent replacement crop because of damage to reeds during that growing season. It is known that elevated water levels for extended periods can prevent shoot emergence in *Phragmites australis* (Armstrong *et al*., 1999).

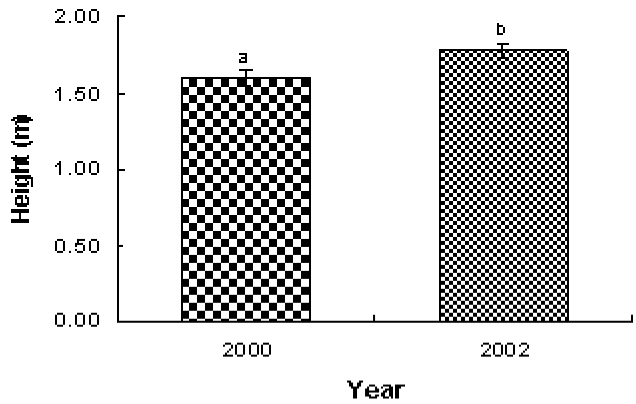
The combined effect of year and treatment also supported a significant difference between the reed height in the utilised and unutilised areas with the unutilised reeds being taller than the utilised ones (Fig. 3C). Within the utilised zone, year of examination and burning did not significantly affect reed height. However, in the unutilised zone the unburnt reeds were significantly taller than all the other treatments in 2002. The unutilised unburnt areas in 2002 had apparently recovered from the damage sustained in the flooding in 1999/2000, and were producing taller reeds than at the previous burnt site.

Table 1: *Analysis of variance results for a comparison of Phragmites australis reed height, diameter and density by comparing utilised burnt, utilised unburnt, unutilised burnt and unutilised unburnt treatments from 2000 to 2002 in the Muzi Swamp, Tembe Elephant Park.*

	Height (r^2 = 0.70)				Diameter (r^2 = 0.74)				Density (r^2 = 0.40)			
Source of variation	df	Sum of squares	F	Pr>F	df	Sum of squares	F	Pr>F	df	Sum of squares	F	Pr>F
Time	1	0.45	5.16	0.0276	1	23.23	33.01	< 0.0001	1	4210.01	5.10	0.033
Treatment	3	8.24	31.26	< 0.0001	3	42.26	20.02	< 0.0001	3	21509.35	8.69	< 0.0001
Time X Treatment	3	1.66	6.29	0.0011	3	35.19	16.67	< 0.0001	3	4969.07	2.01	0.126
Total	7	10.35	-	-	7	100.68	-	-	7	30688.43	-	-



(B)



(C)

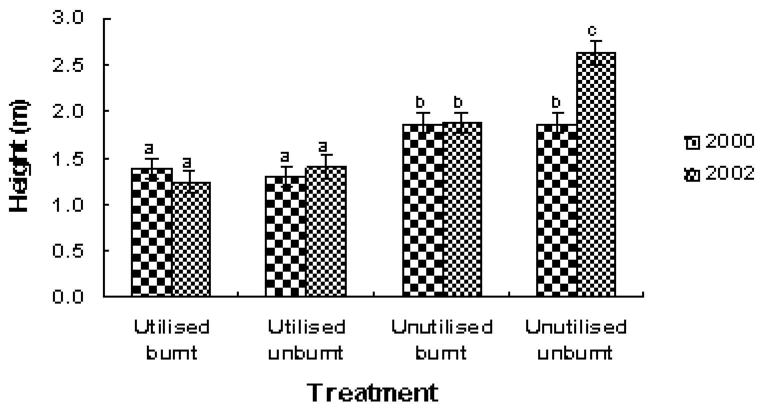


Fig. 3 Mean reed height under different utilisation and burning regimes in two years in the Muzi Swamp, Tembe Elephant Park. (A) Marginal means for different treatment as main effect. (B) Marginal means for year as main effect. (C) Cell means for all combinations of treatment and year. Bars with the same superscripts do not differ significantly by Fisher's least significance test at $\alpha = 0.05$.

Reed diameter

There was a significant difference in mean reed diameter between the utilised and unutilised reedbeds within the study area when the effects of time were removed from the data (Table 1) (Fig. 4A). This implies that if the effects of time are removed, then the unutilised reedbeds will produce thicker reeds. The mean diameter of the unutilised burnt reedbeds was also significantly smaller than that of the unutilised unburnt ones.

If the effects of the various treatments were removed from the data (Fig. 4B) then the mean diameter of the reeds collected in 2002 was significantly larger than in 2000. This reduction could be ascribed to the damage from the flooding in 2000. Reedbeds that experience a stochastic event such as a flood or fire later in the growing season do not recover fully during that season. Nutrient return to the rhizomes is reduced after such an event because of a lack of aerial parts that are required in the photosynthetic process. This inhibition of nutrient return will also cause a lack of nutrient reserves in the rhizomes, which in turn will cause a limited production of thick reeds during the next growing season (Haslam, 1969b; Thompson & Shay, 1985; Granéli, 1989). Reed buds require a substantial amount of nutrients from the rhizomes until they reach a critical height. Thereafter photosynthesis allows the reed to meet its own energy requirements (Allirand & Gosse, 1995).

There were no clear trends in terms of the variations in reed diameter when the combined effects of time and treatment are examined (Fig. 4C). There is, however, a significant difference between the unutilised unburnt reedbeds of 2002 and all of the other reedbeds.

Reed density

Both main effects, namely year and treatment, significantly affected reed density (Table 1). When the effects of time were removed from the data the two types of burnt reedbeds had similar reed densities, as did the two unburnt ones (Fig. 5A). The differences in reed density between the burnt and unburnt reedbeds were not significant. However, there was a significant reduction in reed density between the utilised burnt reedbeds and the utilised unburnt one. This emphasises the damage that an untimely burn, followed by continual harvesting can inflict on a reedbed.

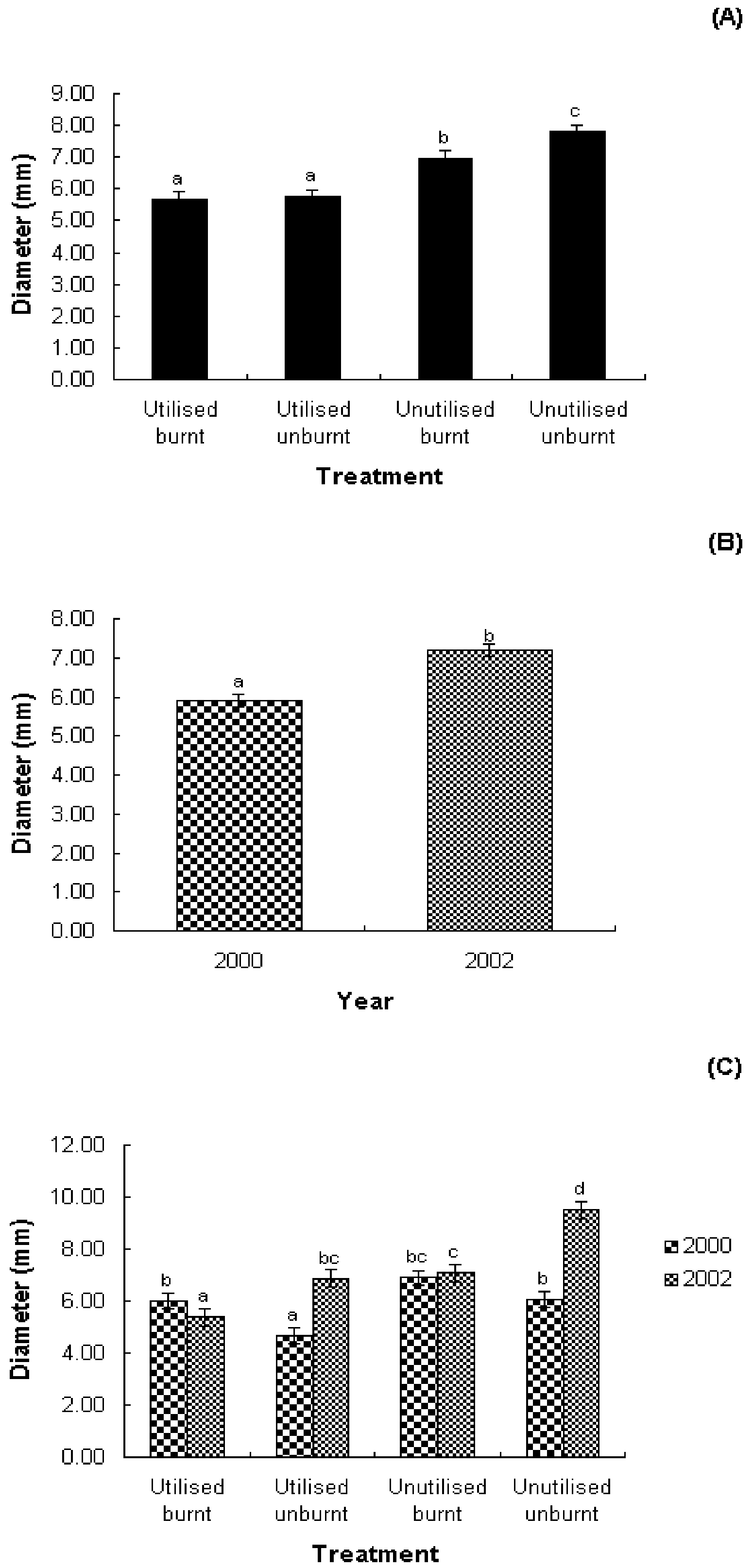


Fig. 4 Mean reed diameter under different utilisation and burning regimes in two years in the Muzi Swamp, Tembe Elephant Park. A. Marginal means for different treatment as main effect. B. Marginal means for year as main effect. C. Cell means for all combinations of treatment and year. Bars with the same superscripts do not differ significantly by Fisher's least significance test at $\alpha = 0.05$.

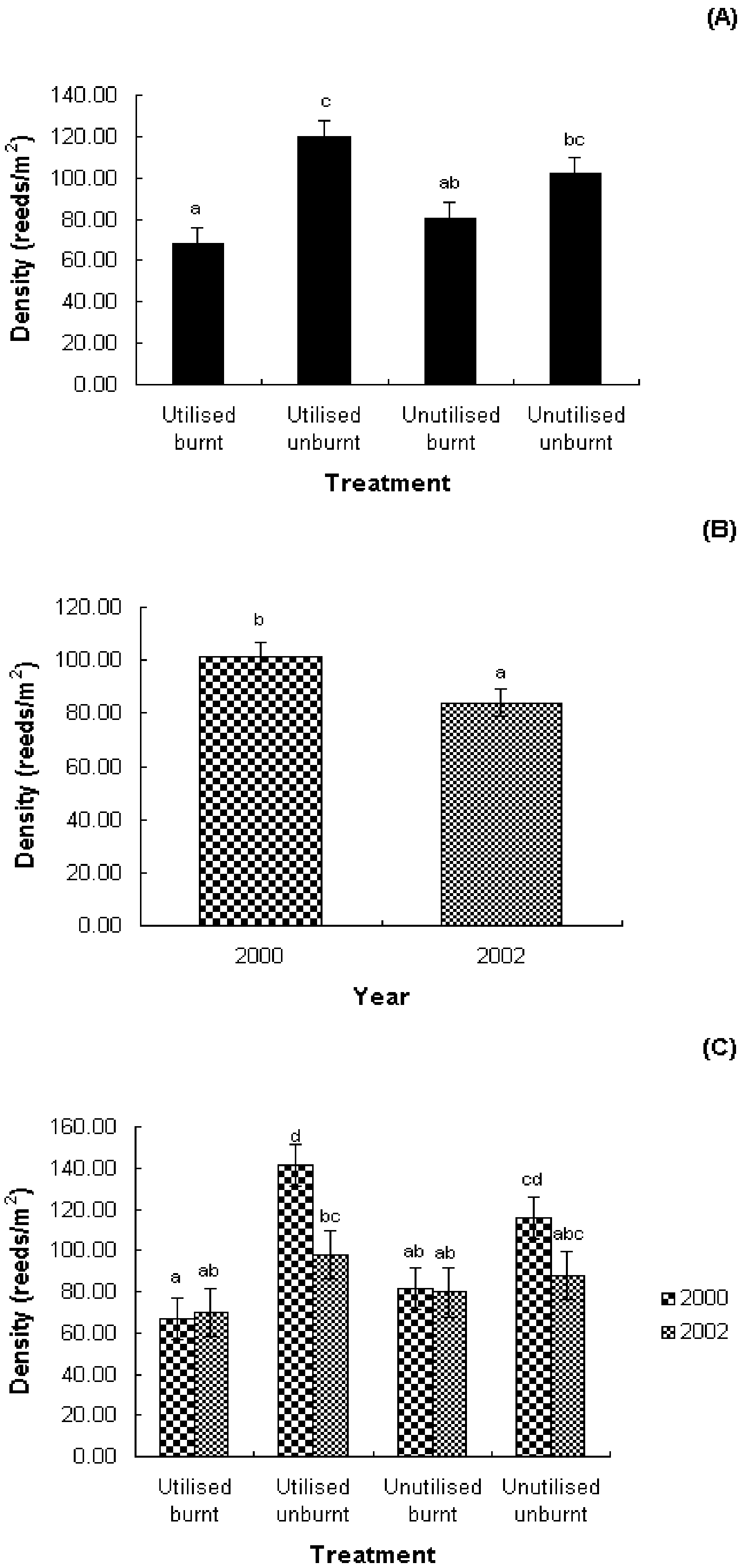


Fig. 5 Mean reed density under different utilisation and burning regimes in two years in the Muzi Swamp, Tembe Elephant Park. A. Marginal means for different treatment as main effect. B. Marginal means for year as main effect. C. Cell means for all combinations of treatment and year. Bars with the same superscripts do not differ significantly by Fisher's least significance test at α = 0.05.

Utilisation increases reed density through the reduction of apical dominance in individual reeds. This elicits a vegetative response from the reed in which an abundance of side shoots are produced. When a terminal bud is harvested, it stimulates the production of numerous side shoots from the nodes of the harvested or damaged reed, thereby increasing reed density (Haslam, 1970; Van Der Toorn & Mook, 1982). The combination of harvesting and burning reduces reed density and should not be done during the growing season because it could result in low numbers of reeds of a poor quality. When this process is repeated continually it could result in the ecological collapse of the system. Harvesting that is followed by burning should only be done when growth dormancy has set in and the translocation of nutrients from the above-ground, aerial parts to the rhizomes has been completed. One would expect then that the utilised reedbeds would have a significantly higher reed density than the unutilised reedbeds. This is not reflected in the results, however, and might be explained by the presence of dead but standing culms from previous seasons present in the unutilised areas.

It is not clear if a low reed density has a higher production rate than a high reed density in terms of good quality reeds. Good quality reeds are deemed to be of a uniform height, have a similar thickness and are relatively straight (Haslam, 1989; Ksenofontova, 1989). McKean (2001) describes a good quality, usable reed as being one that is taller than 2.5 m in height and more than 10 mm in diameter. Most of the European literature suggests that a lower reed density is optimal for the production of a better quality reed. However, there is little to suggest that this is valid for the tropics, where there are higher levels of solar irradiance and higher mean daily temperatures (Hocking, 1989). There was a significant difference between the mean number of reeds per m^2 in 2000 and 2002 (Fig. 5B). If the effects of the various treatments are removed from the data the density of reeds in 2000 (mean $\pm$ SE: 101.48 $\pm$ 5.08 reeds per m^2) is higher than in 2002 (mean $\pm$ SE: 83.92 $\pm$ 5.86 reeds per m^2). In an analysis of our data it was found that there was no significant ($P>0.05$) relationship between reed density and the number of reeds with a basal diameter thicker than 10 mm and a height greater than 2.5 m.

The analysis of variance for the combined effect of the two main effects was not significant. Therefore, direct conclusions about the significance of the main effects could be made. The results showing the combined effect of the two main treatments is presented in Fig. 5C.

Conclusions

The harvesting of reeds clearly affects mean reed height by reducing the number of taller reeds, with the remaining reeds being the shorter and thinner vegetative side shoots. Burning does not have a significant effect on reed height if it takes place at an innocuous time such as early in the growing season. When continual reed harvesting is combined with burning it results in short, poor quality reeds. The flooding of the Muzi Swamp in the 1999/2000 season resulted in an unusually high water level that may have caused structural damage to the reeds. The result was that the mean reed height in 2000 was less than that in 2002. Similar trends for main effects were found for reed diameter. The eventual reed height is linearly proportional to reed diameter. Therefore any trends in mean reed height will also be mirrored by reed diameter.

Utilisation within the Muzi Swamp negatively affects reed height and diameter. Unutilised areas in the reedbeds display improved reed quality in measurable proportions of reed height and basal diameter. There is no conclusive evidence that utilisation affects reed density. Fire has no effect on reed height and diameter when the area is utilised but does have a negative effect by reducing mean reed height and diameter when the area is not utilised. Fire considerably reduces reed density when applied in conjunction with utilisation, but has no significant effect in unutilised treatments.

Increased vigour and the production of better quality reeds in the Muzi Swamp can be attained by the correct management of the reedbeds. To accomplish this, winter harvests should be encouraged and each harvest should be followed by a resting period of 3 years. This approach will allow the complete replenishment of nutrient reserves to the rhizomes while still being able to harvest the standing crop of reeds from the growth of the previous 2 years.

Acknowledgments

The authors would like to thank Ezemvelo KwaZulu-Natal Wildlife (Tembe Elephant Park) for their logistic support, the Sibonisweni Community for their co-operation with and understanding of the necessity of the project. Dr H. Els, the Centre for Indigenous Knowledge and the Centre for Wildlife Management of the University of Pretoria for their financial support, and Mr R. J. Coertze of the Department of Animal and Wildlife Sciences of the University of Pretoria for help with the statistical analysis of the data set. This material is based upon work supported by the National Research Foundation under Grant Number 2047386.

References

ALLIRAND, J–M., & GOSSE, G. (1995) An above ground biomass production model for a common reed (*Phragmites communis* Trin.) stand. *Biom. Bioenerg.* **9,** 441-448.

ARMSTRONG, J., AFREEN-ZOBAYED, F., BLYTH, S. & ARMSTRONG W. (1999) *Phragmites australis*: effects of shoot submergence on seedling growth and survival and radial oxygen loss from roots. *Aquat. Bot.* **64,** 275-289.

BEGG, G.W. (1988) *The Wetlands of Natal*. Natal Town and Regional Planning Commission, Pietermaritzburg.

BROWNING, T.C. (2000) *Preliminary study of the socio-economic value of Phragmites reeds to the people neighbouring Tembe Elephant Park, KwaZulu-Natal*. BA (Hons) APL 770 Project Report, University of Pretoria, Pretoria.

BRUTON, M.N., SMITH, M. & TAYLOR, R.H. (1980) A brief history of human involvement in Maputaland. In: *Studies on the ecology of Maputaland.* (Eds M.N. BRUTON and K.H. COOPER). Rhodes University & Natal Branch of the Wildlife Society of Southern Africa, Durban.

CHAMBERS, R.M., MEYERSON, L.A. & SALTONSTALL, K. (1999) Expansion of *Phragmites australis* into tidal wetlands of North America. *Aquat. Bot.* **64,** 261-273.

COX, C.B. & MOORE, P.D. (1994) *Biogeography: an ecological and evolutionary approach.* Blackwell Scientific Publishing, Oxford.

CUNNINGHAM, A.B. (1985) *The resource value of indigenous plants to rural people in a low agricultural potential area.* PhD (Botany) thesis, University of Cape Town, Cape Town.

DEN HARTOG, C., KVĚT, J. & SUKKOP, H. (1989) Reed. A common species in decline. *Aquat. Bot.* **35,** 1-4.

GRANĒLI, W. (1989) Influence of standing litter on shoot production in reed, *Phragmites australis* (Cav.) Trin. ex Steudel. *Aquat. Bot.* **35,** 99-109.

GRUNDLING, P-L. (1996) *The implication of C^{14} and pollen derived peat ages on the characterisation of peat lands of the Zululand-Mozambique Coastal Plain, South Africa.* Council for Geoscience, Geological Survey (Report; no. 1996-0119.), Pretoria.

GRUNDLING, P-L. (1999) *Some characteristics of the Muzi Peatland, in the Tembe Elephant Park, northern KwaZulu-Natal, South Africa.* Council for Geoscience, Geological Survey (Report; no. 1999-0066), Pretoria.

HASLAM, S.M. (1969a) The development of shoots in *Phragmites communis* Trin. *Ann. Bot-London.* **33,** 695-709.

HASLAM, S.M. (1969b) The development and emergence of buds in *Phragmites communis* Trin. *Ann. Bot-London.* **33,** 289-301.

HASLAM, S.M. (1970) The development of the annual population in *Phragmites communis* Trin. *Ann. Bot-London.* **34,** 571-591.

HASLAM, S.M. (1989) Early decay of *Phragmites* thatch: an outline of the problem. *Aquat. Bot.* **35,** 129-132.

HOCKING, P.J. (1989) Seasonal dynamics of production, and nutrient accumulation and cycling by *Phagmites australis* (Cav.) Trin. *ex* Steudel in a nutrient-enriched swamp in inland Australia. I. Whole plants. *Austral. J. Mar. Freshwater Res.* **40,** 421-424.

KSENOFONTOVA, T. (1989) General changes in the Matsalu Bay reedbeds in this century and their present quality (Estonian SSR). *Aquat. Bot.* **35,** 111-120.

KWAZULU-NATAL NATURE CONSERVATION SERVICE. *Protected Area Management Plan. Part B: General description of the Tembe Ndumo Complex and key references.* Unpublished Report. KwaZulu-Natal Nature Conservation Services, Pietermaritzburg.

MATTHEWS, W.S., VAN WYK, A.E. VAN ROOYEN, N. & BOTHA, G.A. (2001) Vegetation of the Tembe Elephant Park, Maputaland, South Africa. *S. Afr. J. Bot.* **67,** 573-594.

MCKEAN, S.G. (2001) Productivity and sustainable use of *Phragmites* in the Fuyeni reed bed - Hluluwe-Umfolozi Park – Management guidelines for harvest. *S. Afr. J. Bot.* **67,** 274-280.

MOOK, J.H. & VAN DER TOORN, J. (1982) The influence of environmental factors and management on stands of *Phragmites australis* 2. Effects on yield and its relationship with shoot density. *J. App. Ecol.* **19,** 501-517.

SAMUELS, M.L. (1989) *Statistics for the life sciences*. Collier MacMillan, London.

STATISTICAL ANALYSIS SYSTEMS. (1994) *SAS User's Guide: Statistics Version 6.* SAS Institute Inc. Cary, NC., USA.

THOMPSON, D.J. & SHAY, J.M. (1985) The effects of fire on *Phragmites australis* in the Delta Marsh, Manitoba. *Can. J. Bot.* **63,** 1864-1869.

TARR, J.A., VAN ROOYEN, M.W. & BOTHMA, J. DU P. (2004) The response of *Phragmites australis* to harvesting pressure in the Muzi Swamp of the Tembe Elephant Park, South Africa. *Land Degrad. Dev.***15,** 1-11.

TOSH, C. (2000) *The effect of human harvesting on the height and diameter of Phragmites australis in Tembe Elephant Park.* Project, Department of Botany, University of Pretoria, Pretoria.

TROLLOPE, W.S.W. (1990) Veld management with special reference to game ranching in the grassland and savanna areas of South Africa. *Koedoe* **33,** 77-87.

VAN DER TOORN, J. & MOOK, J.H. (1982) The influence of environmental factors and management on stands of *Phragmites australis*. 1. Effects of burning, frost and insect damage on shoot density and shoot size. *J. App. Ecol.* **19,** 477-499.

VAN DER WERFF, M. (1991) Common Reed. In: *Ecological responses to environmental stresses.* (Eds. J. ROZEMA & J.A.C. VERKLEIJ). Kluwer Academic Publishers, Netherlands.

VAN ROOYEN, N. (2002) Veld management in the savannas. In: *Game Ranch Management.* (Ed. J. DU P. BOTHMA) J. L. van Schaik, Pretoria.

VAN WILGEN, B.W. & SCHOLES, R.J. (1997) The vegetation and fire regimes of southern hemisphere Africa. In: *Fire in southern African savannas*. (Eds. B.W. VAN WILGEN, M.O. ANDREA, J.G. GOLDAMMER and J.A. LINDESAY). Witwatersrand University Press, Johannesburg.