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Aquatic Macrophytes Metal and Nutrient Concentration Variations, with Implication for Phytoremediation Potential in a Subtropical River System

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Abstract: Human activities have resulted in an increase in metal pollution within aquatic ecosystems, with most of these metals ending up being taken by macrophytes. Thus, these macrophytes provide an opportunity to study metal pollution dynamics and the role that macrophytes play in potentially translocating and accumulating these metals. Here, we studied three macrophyte species, namely *Phragmites australis*, *Schoenoplectus corymbosus*, and *Typha capensis*, and assessed their potential to be utilized in the phytoremediation of metals in an Austral subtropical river across three seasons. We measured P, K, Ca, Mg, B, Fe, Zn, Cu, and Mn concentrations in macrophyte roots, stems, and leaves, and we further quantified the metal bioconcentration factor (BCF). The N, Ca, and Mg concentrations were generally high in *P. australis* leaves across all seasons. In general, high Na, Mg, and Ca concentrations were observed in *T. capensis* across seasons. The bioconcentration factor (BCF) values were generally low (<1) in most macrophyte parts for most metals during the cool-dry season, with the exception of Na, which had high BCF values > 1 (i.e., accumulators) across the different macrophyte parts. We found that *P. australis* and *S. corymbosus* have the potential to accumulate metals such as B, Na, Mg, Ca, and N and also have high phytoremediation potential for the studied metals. We found that the studied macrophytes were good at phytoremediation within the river system; however, for any treatment of polluted systems, it is better to use a combination of different macrophytes, as some were better at translocating certain metals than others.

Keywords: bioconcentration factor; phytoremediation; *Phragmites australis*; *Schoenoplectus corymbosus*; *Typha capensis*; translocation factor

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1. Introduction

Macrophytes are aquatic plants that are emergent, submerged, and/or free-floating and that grow in or near aquatic ecosystems [1–4]. In addition, they are an important mode for the transfer of contaminants from the bottom sediment to tertiary consumers [3,4]. These macrophytes are crucial for food provision, as microhabitats for organisms, primary production, and nutrient cycling within aquatic environments [4–6]. Macrophytes have the potential to accumulate metals in aquatic ecosystems and can be used for testing ecological processes such as nutrient and metal cycling [7]. Various studies, e.g., [8–10], have indicated that macrophytes can potentially accumulate metals.

Environmental pollution, particularly by metals, has been heightened by rapid industrialization and urbanization, severely impacting aquatic ecosystems. Recent studies, e.g., [11,12] have shown that aquatic metal pollution is a significant contributor to ecological degradation. These metals can pose a significant threat to human health due to their persistence in the ecosystem and potential to bioconcentrate as they move through the food chain [13,14]. Manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), and cadmium (Cd) are some of the most common metal pollutants in aquatic ecosystems and tend to accumulate to dangerous levels within the aquatic environment through food-chain biomagnification, and these metals are of great particular concern. Thus, macrophytes can absorb some of these metals and store them in various macrophyte parts such as roots, stems, and leaves before releasing them back to the aquatic environment when they die off and decompose [15,16]. Furthermore, various macrophyte species tend to respond differently to varying metal concentrations; hence, this has implications for potential metal uptake [17].

Metal removal using living organisms has recently received a lot of public interest and research and development funding [17–19]. Thus, several studies have recommended phytoremediation as an environmentally friendly and cost-effective method for removing pollutants from aquatic ecosystems [20,21]. Research on phytoremediation in aquatic ecosystems is ongoing, but a number of studies have been promising, identifying a variety of aquatic macrophytes, such as duckweed, i.e., [22,23], and water hyacinth, i.e., [24,25], being effective in removing metals from water and sediments. Thus, research on finding new aquatic hyperaccumulators that can be used to remediate specific contaminants, such as heavy metals, nutrients, and organic compounds, has been ongoing, e.g., [17,26–28]. Therefore, to understand the mechanisms of phytoremediation in aquatic ecosystems, studies need to be conducted that assess the different ways in which aquatic macrophytes remove pollutants from water, and this includes investigating the role of roots, stems, leaves, and microorganisms in phytoremediation [27]. This will aid in the development of new and improved approaches to phytophytoremediation, and according to Rai [29] and Sinclair et al. [30] biological processes for metal removal in aquatic environments are cheaper when compared to conventional technologies.

Therefore, the present study aimed to examine the potential metal uptake and phytoremediation by three commonly found macrophyte species (i.e., *Phragmites australis*, *Schoenoplectus corymbosus*, and *Typha capensis*) found within a subtropical river system across three seasons (i.e., cool-dry, hot-dry, and hot-wet) in South Africa. This study further determined whether different macrophyte parts (i.e., roots, leaves, and stems) are good accumulators of metals. We hypothesized that *T. capensis* will have low phytoremediation potential since *T. capensis* is an emergent macrophyte that permanently grows in water, whereas *P. australis* and *S. corymbosus* may grow in areas without much water or on riverbanks, making them ideal phytoremediation taxa.

2. Materials and Methods

2.1. Study Area

Sampling of macrophytes for metal determination was carried out across three (3) seasons (i.e., cool-dry season (June 2019), hot-dry season (September 2019), and hot-wet season (February 2020)) from five (5) randomly selected sites along a tributary of the Luvuvhu River, i.e., the Mvudi River, that represented the different land-use patterns (Figure 1). The Mvudi River is a perennial river system found in the Vhembe District, Limpopo Province, South Africa, draining the rural town of Thohoyandou and various villages [31]. The area receives a mean annual rainfall of 400–800 mm. The temperatures can reach 40 °C (October–March) during the hot-wet season, and the cool-dry season temperatures range from 12–22 °C. The region is characterized by red loam soils due to the presence of high concentrations of iron oxides [32]. The Mvudi River system is significantly affected by various land uses such as agricultural activities (i.e., mostly subsistence farming), car washing, water abstraction, and brick-making activities along the river shorelines/banks [31,33]. Polluted water discharged from Thohoyandou and Sibasa towns, mainly from waste drainage spills and road runoff, is a common occurrence [34].

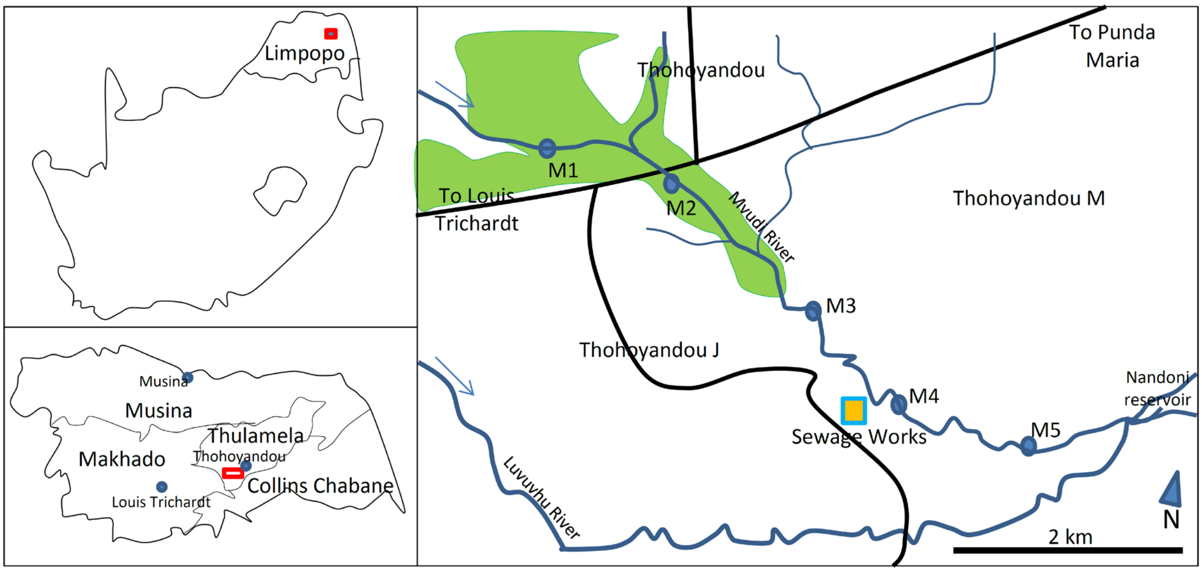

Figure 1. The location of the sampling sites is along the Mvudi River, Vhembe Distric, South Africa. Red is the location of the river system relative to the province and municipality, and the green shaded area is a wetland.

2.2. Macrophytes Sampling and Processing

Three dominant macrophyte species (i.e., *P. australis*, *S. corymbosus*, and *T. capensis*) (n = 10–25 per season [*P. australis* found at 5 sites (n = 25 individual macrophytes per season), *S. corymbosus*—3 sites (n = 15 individual macrophytes per season), and *T. capensis*—2 sites (n = 10 individual macrophytes per season)] were randomly collected at each site per season by uprooting the macrophyte plant using a digging fork while carefully ensuring that all roots were not damaged and properly preserved. The macrophytes were then washed with river water thoroughly to remove epiphyton and sediments. Afterwards, the macrophytes were cut into three (3) sections (i.e., leaves, steams, and roots) and placed into three separate polyethylene Ziplock bags. Macrophyte parts from young (sprouting) and old (withering) macrophytes were eliminated due to the fact that young macrophytes devote most of their energy to growth, while old macrophytes collect chemical metabolites [35].

In the laboratory, the roots, stems, and leaves were further washed in a Teepol solution, rinsed with deionized water, and oven dried at 70 °C for 72 h. For the determination of metals and nutrients, the dried leaves were crushed to a small size (~40 μm particle size), combusted in a furnace at 480 °C, and then mixed with HCl (32%) in a 50:50 solution before being extracted using a Whatman filter paper [36]. Metals (i.e., K, Ca, Mg, Na) and metal cations (i.e., B, Cu, Mn, Zn, Fe) concentrations of each macrophyte taxa part extract were quantified using an ICP-OES optical emission spectrometer (Varian) against standards. Total nitrogen concentrations of the ground macrophyte components (i.e., leaves, stems, and roots) were determined using the total combustion in a Leco N-analyser.

3. Data Analysis

The macrophyte concentration data were first tested for homogeneity of variances and normality in SPSS. The data were found to meet all the assumptions for conducting a parametric test. Therefore, a three-way analysis of variance (ANOVA) was used to examine the effect of seasons (i.e., cool-dry, hot-dry, and hot-wet), macrophyte species (i.e., *P. australis*, *S. corymbosus*, and *T. capensis*), and macrophyte part/location (i.e., roots, stems, and leaves) on the measured metal concentrations and bioconcentration factors (BCF). For models considering translocation factors (TF), a two-way ANOVA was used. Tukey HSD tests were performed for multiple pairwise comparisons, where the data were found to be significant, i.e., $p < 0.05$.

To determine the macrophyte's ability to accumulate metals from the river sediments, two metrics were used: the BCF and TF values as indicators based on Barron [37] and

Ghosh and Singh [38]. The BCF was determined for B, Cu, Fe, Mn, Na, and Zn, which we quantified in mg kg^{-1}. In brief, a large BCF value (>1) means a better accumulation capability and is therefore considered an accumulator, while a BCF value < 1 indicates an excluder [37]. Translocation factors measure the capability to move metals from roots to leaves, and they are determined based on the leaf-to-root ratio of metal concentration [38]. A large TF value (>1) indicates a high translocation capability.

4. Results

The metal concentration differed among macrophytes, with metal concentrations being highly variable (Figure 2, Table S1). The N, Ca, and Mg concentrations were generally high in *P. australis* leaves across all seasons. In general, high Na, Mg, and Ca concentrations were observed in *T. capensis* across seasons (Figure 2, Table S1). For example, B concentrations showed a decrease from *T. capensis* roots to stems, whereas in *S. corymbosus*, metal concentrations were high in roots before decreasing in stems and then increasing leaves across seasons (Figure 2). Using ANOVA, N, Ca, Mg, Na, and B concentrations showed significant differences ($p < 0.05$) across species, whereas all metal parameters except for Mn showed significant differences ($p < 0.05$) across macrophyte locations (i.e., roots, stems, and leaves) (Table 1). Furthermore, macrophyte species × location showed significant differences (ANOVA, $p < 0.05$) in N, K, Ca, Mg, Na, Cu, and B concentrations (Table 1), with macrophyte location being a major driver. However, the interaction of macrophyte species × location × season only indicated significant differences for Cu concentrations, with macrophyte species and seasons being major drivers (Table 1).

Table 1. Three-way analyses of variance (ANOVA) based on significant ($p < 0.05$) variables only for macrophyte metal concentration and bioconcentration factors across different species (i.e., *P. australis*, *S. corymbosus*, and *T. capensis*), location (i.e., roots, stems, and leaves), and seasons (i.e., cool-dry, hot-dry, and hot-wet).

Variables	D*f*	F	*p*	Variables	D*f*	F	*p*
Metal Concentrations							
Species				**Season**			
N	2	9.206	<0.001	Cu	2	7.707	0.001
Ca	2	65.126	<0.001	B	2	10.53	<0.001
Mg	2	70.452	<0.001	**Species × Location**			
Na	2	58.734	<0.001	N	4	7.123	<0.001
B	2	11.452	<0.001	K	4	4.872	0.002
Location				Ca	4	9.615	<0.001
N	2	53.067	<0.001	Mg	4	4.98	0.002
P	2	26.549	<0.001	Na	4	4.666	0.003
K	2	30.387	<0.001	Cu	4	5.102	0.001
Ca	2	21.065	<0.001	Zn	4	2.281	0.072
Mg	2	5.251	0.008	B	4	10.788	<0.001
Na	2	10.645	<0.001	**Species × Location × Season**			
Fe	2	14.197	<0.001	Cu	8	4.216	0.001
Cu	2	23.159	<0.001				
Zn	2	5.232	0.008				
B	2	33.227	<0.001				
Bioconcentration factors							
Species				**Species × Location**			
Na	2	24.721	<0.001	B	4	10.327	<0.001
Mn	2	6.089	0.004	**Species × Season**			
Zn	2	2.979	0.059	Mn	4	3.222	0.019
B	2	17.342	<0.001	Zn	4	3.049	0.024
Location				B	4	7.268	<0.001
Na	2	5.342	0.008	**Location × Season**			

Table 1. *Cont.*

Variables	Df	F	p	Variables	Df	F	p
Fe	2	36.821	<0.001	Fe	4	10.575	<0.001
Cu	2	37.569	<0.001	Cu	4	6.539	<0.001
Zn	2	3.762	0.030	Zn	4	2.866	0.032
B	2	25.134	<0.001	B	4	9.604	<0.001
Season				**Species × Location × Season**			
Na	2	8.461	0.001	B	8	4.378	<0.001
Mn	2	7.082	0.002				
Fe	2	17.335	<0.001				
Cu	2	13.889	<0.001				
Zn	2	7.563	0.001				
B	2	79.260	<0.001				

The BCF values were generally low (<1) in most macrophyte parts for most metals during the cool-dry season, with the exception of Na, which had high BCF values > 1 (i.e., accumulators) across the different macrophyte parts (Table 2). During the same season, stems were better accumulators of metals for the three macrophyte species (Table 2). The BCF values were high during the hot–dry season for all species, with most parts tending to be accumulators. The change in BCF values was hot–dry > hot–wet > cool–dry seasons, with stems being major accumulators (Table 2). The Mn concentration showed high accumulation in roots (BCF > 2) for *T. capensis* across all seasons, whereas in *P. australis* and *S. corymbosus* it was in stems (BCF > 1). Significant BCF differences ($p < 0.05$) were observed for all metals with the exception of Fe (F = 0.336, $p = 0.716$), Cu (F = 0.133, $p = 0.876$), and Cu (F = 2.979, $p = 0.059$) for species, whereas for location only Mn was not significant (F = 1.372, $p = 0.262$) (Table 2). All metal BCFs were found to be significantly different ($p < 0.01$) across seasons (Table 2).

Table 2. Mean ± standard deviation of bioconcentration factor values in different macrophyte species across various macrophyte locations (i.e., roots, stems, leaves) amongst three seasons. Bold indicate values that had high BCF for that particular metal across different macrophyte parts for the season; green = BCF < 1 (i.e., excluder), and orange = BCF > 1 (i.e., accumulator).

Variables	Cool–Dry			Hot–Dry			Hot–Wet		
	Roots	Stem	Leaves	Roots	Stem	Leaves	Roots	Stem	Leaves
					Phragmites australis				
Na	1.39 ± 0.66	4.89 ± 1.57	**5.35 ± 2.66**	4.21 ± 0.46	22.88 ± 7.15	**23.28 ± 12.37**	4.51 ± 2.11	19.61 ± 9.61	**19.71 ± 8.63**
Mn	0.96 ± 1.26	**5.10 ± 8.02**	0.58 ±0.61	5.60 ± 1.26	**7.17 ± 7.03**	1.39 ± 2.44	0.47 ± 1.26	**1.06 ± 0.34**	0.44 ± 0.20
Fe	0.04 ± 0.03	**1.11 ± 0.57**	0.04 ± 0.03	7.38 ± 0.03	**170.7 ± 136.6**	4.60 ± 5.63	4.57 ± 0.03	**84.48 ± 8.86**	13.46 ± 2.87
Cu	0.11 ± 0.05	**0.86 ± 0.33**	0.12 ± 0.06	0.74 ± 0.05	**6.40 ± 3.12**	0.61 ± 0.49	0.28 ± 0.05	**3.19 ± 2.40**	0.66 ± 0.56
Zn	0.73 ± 0.43	**1.22 ± 0.46**	0.57 ± 0.25	6.24 ± 0.43	**15.46 ± 6.57**	4.62 ± 4.07	6.35 ± 0.43	**10.78 ± 10.77**	10.03 ± 11.96
B	0.21 ± 0.13	**1.54 ± 0.80**	0.12 ± 0.07	16.54 ± 0.13	**92.60 ± 19.90**	5.54 ± 5.42	10.76 ± 0.13	**43.42 ± 15.72**	10.09 ± 2.92
					Schoenoplectus corymbosus				
Na	1.21 ± 0.39	4.09 ± 2.91	**5.53 ± 5.98**	8.35 ± 5.38	35.50 ± 19.41	**51.70 ± 32.00**	6.65 ± 4.89	25.25 ± 12.83	**35.75 ± 19.4**
Mn	0.55 ± 0.11	**1.96 ± 1.32**	0.59 ± 0.48	3.00 ± 3.87	4.26 ± 3.04	**4.45 ± 6.01**	1.70 ± 1.53	**6.23 ± 5.58**	4.57 ± 5.93
Fe	0.07 ± 0.06	**0.59 ± 0.52**	0.06 ± 0.05	25.13 ± 23.28	**181.9 ± 111.5**	20.68 ± 28.66	10.75 ± 6.63	**103.59 ± 23.22**	9.03 ± 4.01
Cu	**1.77 ± 1.51**	0.51 ± 0.60	0.12 ± 0.08	1.49 ± 0.68	**4.54 ± 2.87**	0.90 ± 0.38	0.84 ± 0.49	**3.73 ± 0.93**	0.48 ± 0.27
Zn	**0.70 ± 0.13**	0.68 ± 0.12	0.53 ± 0.28	11.40 ± 2.10	**11.58 ± 3.72**	7.18 ± 1.69	7.74 ± 2.97	**9.68 ± 1.37**	4.78 ± 2.22
B	**1.14 ± 1.05**	0.79 ± 0.65	0.22 ± 0.19	**145.0 ± 70.2**	105.76 ± 7.98	23.14 ± 2.73	**58.94 ± 16.40**	50.79 ± 18.93	19.95 ± 8.07
					Typha capensis				
Na	38.96 ± 21.19	18.48 ± 10.23	**54.88 ± 25.41**	81.92 ± 96.63	83.43 ± 73.99	**130.7 ± 152.5**	66.04 ± 24.11	40.23 ± 14.99	**118.8 ± 50.5**
Mn	**2.99 ± 1.34**	1.28 ± 0.51	1.58 ± 1.00	**34.49 ± 45.55**	28.14 ± 36.14	10.14 ± 11.45	**9.59 ± 3.82**	7.59 ± 4.70	4.48 ± 2.47
Fe	0.02 ± 0.02	**0.64 ± 0.35**	0.06 ± 0.01	5.80 ± 4.82	**167.7 ± 66.0**	24.80 ± 18.39	4.44 ± 1.93	**135.9 ± 2.45**	16.89 ± 2.71
Cu	0.09 ± 0.01	**1.68 ± 1.52**	0.15 ± 0.03	0.66 ± 0.04	**4.74 ± 0.66**	1.50 ± 0.33	0.45 ± 0.19	**3.31 ± 0.75**	0.90 ± 0.38
Zn	0.56 ± 0.34	**1.18 ± 0.12**	1.08 ± 0.68	7.80 ± 3.88	**114.7 ± 143.5**	24.35 ± 8.02	4.77 ± 2.26	**10.02 ± 0.03**	8.93 ± 7.01
B	0.36 ± 0.10	**0.89 ± 0.23**	0.30 ± 0.02	23.58 ± 5.67	**86.3 ± 14.5**	40.82 ± 30.05	29.28 ± 10.72	**52.77 ± 10.23**	33.21 ± 9.05

The TF values were >1 for Na in all macrophyte species across the three seasons, with *T. capensis* having high TF values (Figure 3). For *P. australis*, most of the TF values for Mn, Fe, Cu, Zn, and B were <1 across all seasons, apart from Mn (hot–dry) and Zn (cool–dry, hot–wet) (Figure 3a). For *S. corymbosus*, most metals had TF values > 1 across seasons with the exception of Fe (hot–dry, hot–wet) and Cu (hot–wet) (Figure 3b), and lastly, Fe (all seasons), Cu (all seasons), and B (cool–dry; hot–dry) were below <1 for *T. capensis* (Figure 3c). Significant TF differences were observed for B (F = 11.435, $p = 0.001$) on the three macrophyte species, and no significant seasonal differences ($p > 0.05$) were observed. The Tukey's posthoc analysis indicated significant differences for *P. australis* vs. *S. corymbosus* ($p < 0.001$), and *S. corymbosus* vs. *T. capensis* ($p = 0.042$).

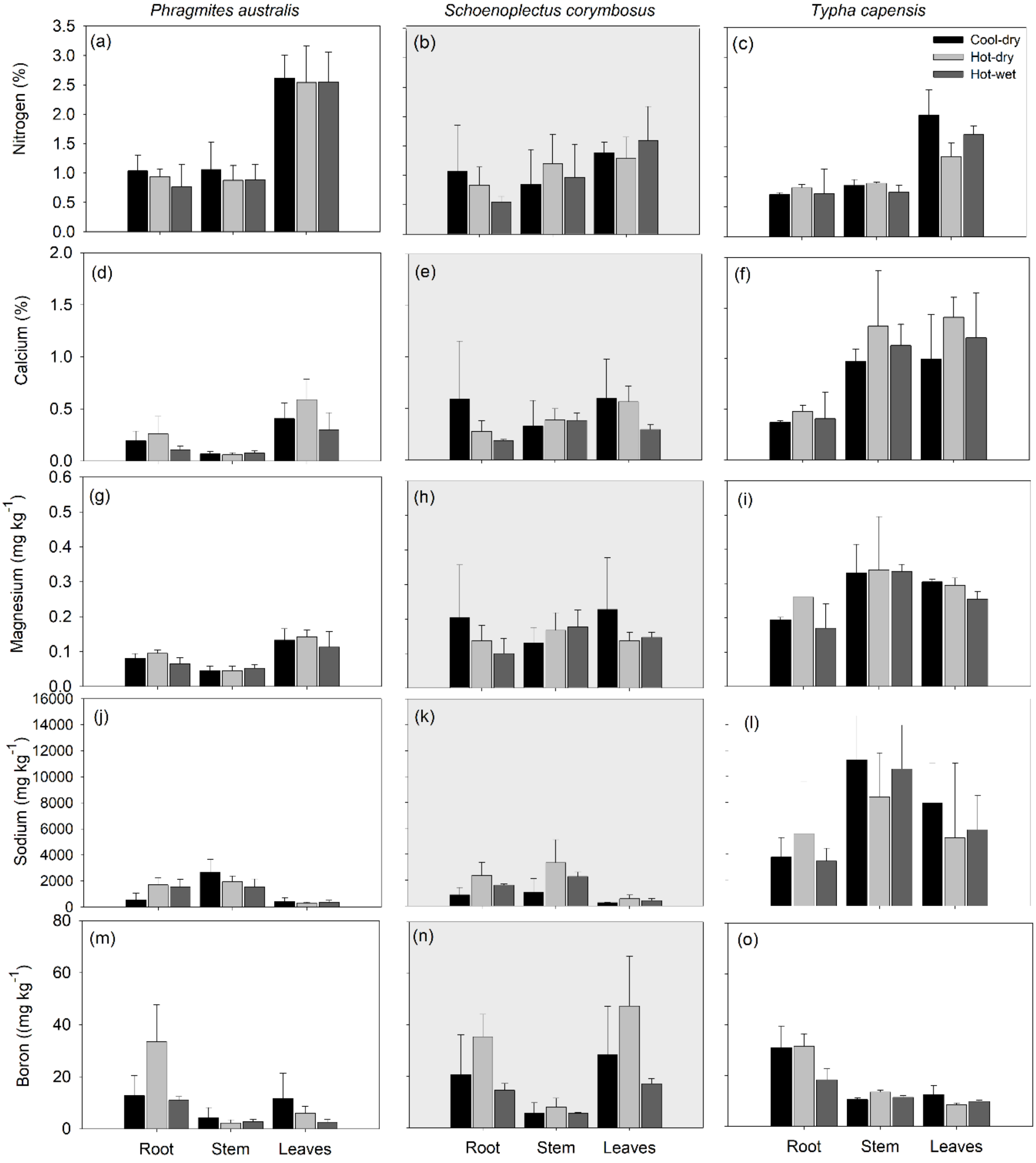

Figure 2. Mean (±standard deviation) of significant metal concentration variation in macrophyte parts (i.e., roots, stems, and leaves) of different macrophytes (i.e., *Phragmites australis*, *Schoenoplectus corymbosus*, and *Typha capensis*) species across various seasons (i.e., cool–dry, hot-dry, and hot–wet) sampled from Mvudi River, South Africa; (**a**–**c**) nitrogen (N), (**d**–**f**) calcium (Ca), (**g**–**i**) magnesium, (**j**–**l**) sodium (Na) and (**m**–**o**) boron (B) for the respective macrophyte species at the top.

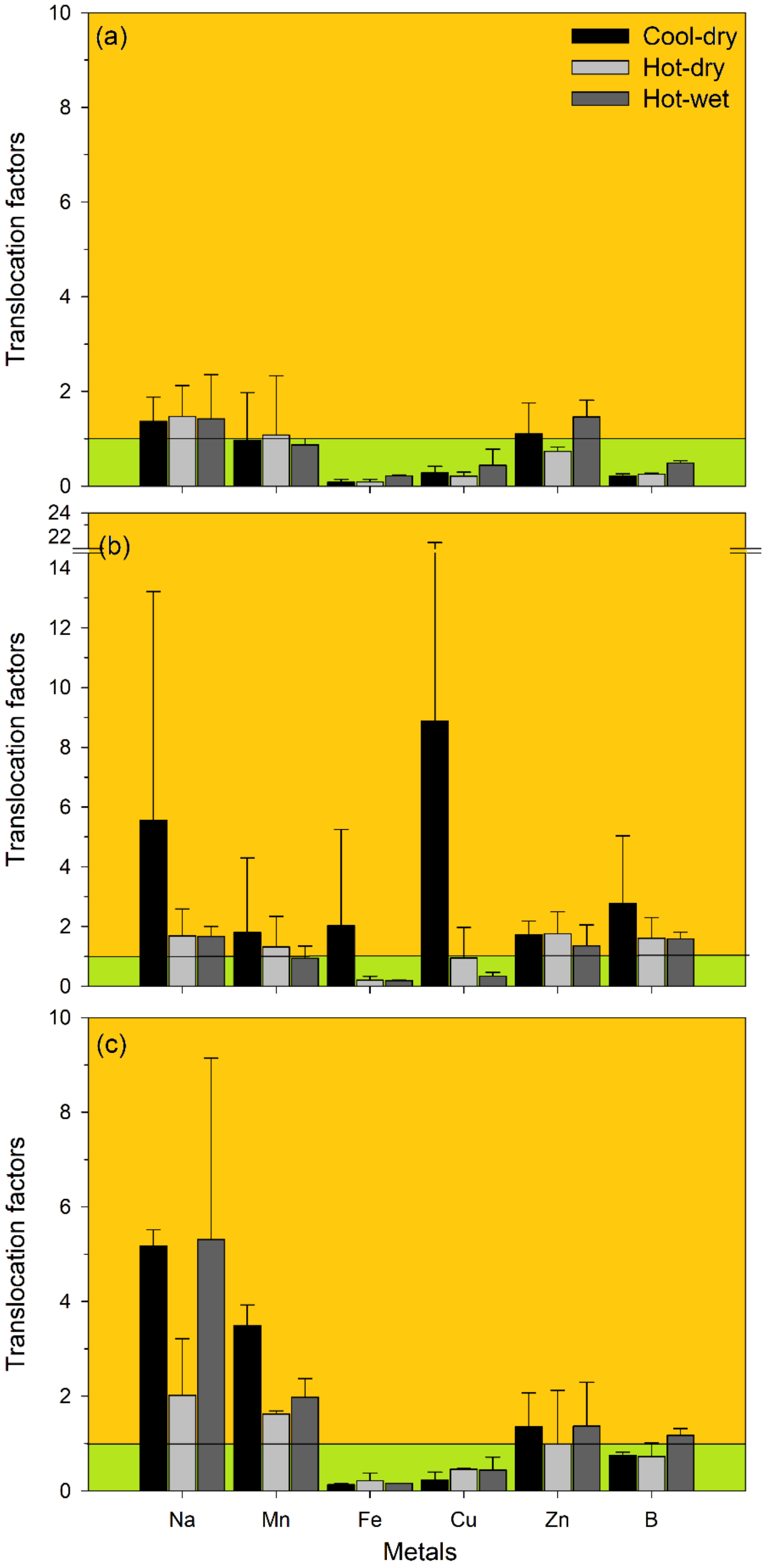

Figure 3. Mean (± standard deviation) translocation factors (TF) of (**a**) *Phragmites australis*, (**b**) *Schnoenoplectus corymbosus*, and (**c**) *Typha capensis* were sampled from the Mvudi River, South Africa. The orange color indicates TF value (>1) = high translocation capability, and the green color TF < 1 = low translocation capability. Note differences in scale for (**b**) *Schnoenoplectus corymbosus* for the TFs.

5. Discussion

This study found that macrophyte metal concentrations differed among macrophyte locations within the Mvudi River system, with *S. corymbosus* having high phytoremediation potential as compared to *P. australis* and *T. capensis*. However, *T. capensis* was better at translocating and accumulating certain metals (i.e., Na, Mn) compared to other macrophyte taxa. This could have potential due to (i) differences in water quality among this study sites within the system and/or (ii) different macrophytes having specific potential to adsorb and uptake metals from water [39]. Macrophyte taxa accumulated most of the metals within their stems across seasons, with Na and Mn being highly accumulative in the leaves, and these two metals showed high translocation capability. *Phragmites australis* was the least effective in translocating metals, although it showed accumulation of metals during the hot–dry and hot–wet seasons. Similarly, studies by Kassaye et al. [40] and Netshiongolwe et al. [19] observed that *P. australis* has an absorptive ability for heavy metals and tends to accumulate these metals within the roots. Furthermore, Kassaye et al. [40] highlighted that *S. corymbosus* has the potential to absorb heavy metals from soils, and they mostly accumulate in its leaves.

Previous studies, e.g., [14,41–43], have indicated that toxic metals are released into the environment as a result of mining activities, industrial activities, and domestic and agricultural usage of metals and metal–containing compounds. In the current study area, these activities have had a detrimental impact on aquatic ecosystems, resulting not only in the deterioration of water and sediment quality but may also lead to fish kills, posing a serious risk to inhabitants around Thohoyandou who use the river water for domestic purposes [44]. The presence of aquatic macrophytes such as *P. australis*, *T. capensis*, and *S. corymbosus* in the Mvudi River is important as they help in reducing and mitigating the impacts of metals entering the system from agriculture and urban sewer burst pipes. For instance, *T. capensis*, which is an emergent macrophyte, has been shown to be a good accumulator of metals [45]. However, in the current study, it was not a good accumulator, as other macrophyte species fared much better. The present study further demonstrated that seasonality plays a significant role in metal accumulation within a river system, and this is highlighted by this study results, which indicated seasonal variability of metals and their bioaccumulative capacity within different macrophytes. According to Emenike et al. [46], high metal concentrations were observed during the hot-dry season; similarly, our study showed a similar finding where some metal concentrations peaked during the hot-dry season, suggesting that accumulation and concentration occur as the river recedes and evaporation significantly increases, whereas the pollutants/contaminants entering the system remain constant. In support of our findings, Netshiongolwe et al. [19] also observed similar patterns in metal concentrations. In contrast with this study findings, Edokpayi et al. [33] found that metal concentrations were high during the hot–wet season in the Mvudi River, which was attributed to changes in human activities across different seasons. The metal concentration in the river could be associated with hydrological flow, which is dependent on precipitation received during the hot-wet season [47].

All metals (i.e., K, Ca, Mg, B, Fe, Zn, Cu, and Mn) studied in the present study, including those assessed by Edokpayi et al. [33] and Netshiongolwe et al. [19], showed high levels that increased from the roots to the leaves and tended to vary across seasons. Lambers et al. [48] highlighted that Mn had a high BCF value and metal concentration within the leaves for all macrophytes, indicating better accumulation for that macrophyte part. Similarly, the present study revealed that Mn levels in the leaves of all the investigated macrophyte species were always higher than in other macrophyte parts (i.e., roots and stems). Furthermore, this study revealed that macrophyte parts (i.e., roots, leaves, and stems) were good predictors of metal concentrations in sediment.

Although studies have indicated that most macrophytes tend to accumulate metals within their roots, thereby preventing the metals from reaching sensitive macrophyte parts [49,50]. However, most of the macrophytes in the current study accumulated metals within the stems across all seasons, although one or two metals might have accumulated in the roots. For example, *P. australis* releases certain compounds from its roots into the surrounding soil, which can bind to or chelate heavy metals, reducing their toxicity and mobility.

All three macrophytes, *S. corymbosus*, *T. capensis*, and *P. australis*, were good for phytoremediation, but they had different strengths and weaknesses, which were highlighted in the current study, where *S. corymbosus* was identified as a better accumulator and translocator of metals. For instance, studies have shown that *S. corymbosus* is very effective at removing metals from water and sediments, is also very tolerant of high salinity, and can grow in a variety of conditions [51]. *Schnoenoplectus corymbosus* has an extensive root system that allows it to reach deep into the soil and absorb pollutants that are not accessible to other macrophytes. However, it is not as effective at removing organic pollutants as *T. capensis* and *P. australis* [52]. *Phragmites australis*, although a very versatile macrophyte that can be used for phytoremediation in both wetlands and terrestrial environments as it is very effective at removing a wide range of pollutants, including heavy metals, organic pollutants, and nutrients, was found not to be as effective as *S. corymbosus* [53]. Therefore, based on this study results, the best macrophyte for phytoremediation is dependent on the specific pollutants that will need to be removed and the environmental conditions at the site. In general, it is important to note that all three of these macrophytes can be invasive in some areas.

6. Conclusions

The ability of macrophytes to accumulate metals makes them very essential, especially for the treatment of sewage water and industrial effluents that enter streams. The current study highlights the phytoaccumulation metal potential of macrophytes, with a focus on *P. australis*, *S. corymbosus*, and *T. capensis* as promising phytoremediation agents. The BCF and TF values indicated that certain macrophyte species were better at accumulating certain metals; hence, for any phytoremediation to be successful, these taxa might need to be grown together. *Schnoenoplectus corymbosus* was better at translocating and accumulating most metals compared to the other macrophytes, with *T. capensis* being a better translocator and accumulator of Na and Mn. However, according to Zhu et al. [54], a good metal accumulator has the ability to bioconcentrate metals with a BCF value of >1000 and accumulate >5000 mg kg^{-1} metal concentration, thus all macrophytes studied here fell far short of the expected threshold. Thus, more studies should be implemented focusing on a wide range of metals and macrophyte taxa to clearly identify a better macrophyte taxa that can be used for phytoremediation purposes [55]. Furthermore, although metal contamination emanates from anthropogenic activities occurring in the catchment, further studies must be undertaken to assess the water quality and impact of these metals on aquatic biota.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su152014933/s1, Table S1: Mean ± standard deviation of metal concentration for various macrophyte species parts among seasons.

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