



# **WHAT ENVIRONMENTAL VARIABLES LIMIT *TYPHA* EXPANSION IN CAPE FLAT WETLANDS?**

by

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## ABSTRACT

The explosive expansion of *Typha capensis* into the wetlands of the Cape Flats has resulted in decreased species diversity and habitat value. Several initiatives to control this expansion have had varied success and management of wetlands dominated by *T. capensis* remains a challenge. For effective rehabilitation, one needs to understand what the problem is and its origin before any action can be taken. This study aims to determine whether there are any factors that limit the expansion of *T. capensis* that may be used in rehabilitation efforts, with the hypothesis being that the distribution of *T. capensis* is determined primarily by hydrology, salinity and nutrients such that wetlands with *T. capensis* or specific *T. capensis* stands will have stable hydrological regimes, moist soils, low salinities and high nutrients.

Six wetlands in Rondevlei with varying dominance of *T. capensis*, ranging from <sup>not having any</sup> not having any to being dominated by the plant, were examined. Wetlands were classified into types depending on their dominance of *T. capensis*, with *Typha* dominant, Mixed and No *Typha* wetland types. In each wetland soil cores were taken to represent the main vegetation types, focusing on *T. capensis*, *Ficinia nodosa* and *Isolepis rubicunda*. These three species comprise the dominant species of the three vegetation types that were measured, with *T. capensis* forming its own group and then rush-like and mat-like vegetation types respectively. Environmental variables like hydrology were observed by field visits at the end of summer and in winter/spring, and the soils were analyzed in the laboratory for salinity, pH and nutrients.

Using cluster and principle component analysis, it was found that sample areas separated according to vegetation type as appose to wetland type, such that *T. capensis* clustered separately from rush-like and mat-like vegetation types. Factors distinguishing *T. capensis* were significantly longer hydroperiods (H=18.57 (2, N=48), p=0.0001), lower soil salinity (H=7.826 (2, N=48), p=0.02), higher water salinity (H=22.974 (2, N=48), p=0.0000) and lower pH (H=8.201 (2, N=48), p=0.0166). From this, and other studies, it was concluded that of all the factors, hydrology and salinity were most important in limiting the occurrence of *T. capensis* as it affects seedling mortality and the degree to which this species has a competitive advantage over other species.

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# 1: INTRODUCTION

## 1.1: Background information

Wetlands are essential for the integrity of ecosystem functions in catchments in terms of service provision to both us and other living things (Hall 1993). Services include water purification, erosion control, groundwater recharge and moderating floods (Zedler 2000, Dallas et al 2006, Taylor & Cunningham 1983, cited in Hall 1993). These services account for 40% of total renewable ecosystem services which are provided for by a habitat that covers 1.5% of the earth's surface (Zedler 2000).

As this study is based on wetlands, it is appropriate to define wetlands as being, "... areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (UNESCO 1971). This definition is appropriate as it shows just how dynamic these environments can be.

In the past, South Africa's wetlands were poorly understood and therefore misused, but as research on wetlands has increased, their importance has become clear (Dallas et al 2006). This fact can be seen in the National Water Act of 1998, which recognizes the rights of aquatic ecosystems to water of adequate amount and quality, but this however does not stop wetlands still being threatened by our actions (Dallas et al 2006). Studies summarized by Hall (1993) show that over the country, huge percentages of wetlands have been lost in various basins, and that specifically in the Cape Peninsula, there are just a handful of pristine wetlands, the rest of which are classified as 'wastelands'. It has been my observation that many seasonal wetlands, such as the Khayelitsha area, are filled for development

and any permanent wetlands, like Rondevlei and Zeekoevlei have become polluted by being fed from storm water carrying canals.

Overall, there has been a loss in wetland biodiversity in the Cape Flat wetlands, at the same time, a relatively recent 'explosive expansion' of *Typha capensis* (Rohrb.) N.E.Br has begun to take over (Hall 1993). *Typha capensis* is an indigenous, monospecific, stand forming, emergent wetland species that outcompete other plants as changing environmental conditions are seen to benefit *T. capensis* over and above other indigenous species due to its adaptations which will be discussed in due course (Hall 1993). A study by Hall (1993) which looked at the distribution and spread of *T. capensis*, found that this species was restricted to areas with shallow bank gradients, low salinities, sediments that remain wet through summer and areas not subject to prolonged flooding in excess of 1.5m. However, the most important factor that coincided with *T. capensis* encroachment was stabilization of water levels which must therefore be the main focus in any management actions taken (Hall 1993).

### **1.1.1: About Rondevlei Nature Reserve**

This study focuses specifically on Rondevlei Nature Reserve which is situated on the False Bay coastline of Cape Town, South Africa, as seen in figure 1. This reserve was established in 1952 as a bird sanctuary and in 1986 it passed into the hands of the City of Cape Town as a nature reserve (E-Kapa 2008). Rondevlei Nature Reserve is host to 18 species of vulnerable to endangered flora with one endemic and rare bird species (Southern Waters Ecological Research and Consulting 2000). This reserve is divided into two main areas, the front section which includes the main wetland and the back section which contains smaller wetlands. The main wetland in the front section is a permanent wetland that is fed year round from two main canals which direct surface water from the residential and industrial areas of the Cape Flats, whereas the wetlands in the back section are mostly temporary,

receiving water from rainfall or groundwater. This region, like the rest of the South Western Cape, is classified as having a Mediterranean climate and falls within the winter rainfall region of South Africa. In terms of vegetation and soils, the front section of the reserve is Cape Flats sand fynbos and acid quartzitic soils and the back section is Cape Flats dune strandveld and calcareous alkaline soils (Mucina & Rutherford 2006). Rondevlei is managed for conservation, so although it is open to the public, human influence on the environment is kept as low as possible (Southern Waters Ecological Research and Consulting 2000). Consequently, only the front section is open to the public and has walking paths, bird hides and an environmental education centre, while the back section is kept pristine.

According to Middlemiss in 1974 (Cited in Hall 1993), in 1952 the invasion of *T. capensis* started with 15 plants in the south-eastern corner and is now completely ringed by *T. capensis*, which continues to extend into the centre of the wetland. The effects of this spread have resulted in blocked canals causing flooding, reduced free-flow causing siltation, loss of species, decreased habitat diversity and therefore a decline in bird species for which the reserve was originally created to protect (Hall 1993).

### **1.1.2: Variables and their effects on wetland dynamics**

Soil and water chemical environments are constantly changing as different variables interact with each other in an attempt to reach equilibrium (Winegardner 1996) and wetland plants are subject to these changes. In this study multiple variables were measured in both wetland soils and water, covering aspects of hydrology, pH, nutrients and salinity. These four factors were chosen based on the literature, which highlighted these factors as influencing *Typha* growth (Buele & Hine 1979, Hall 1993, Newman et al 1996 and Osland 2009) and because these variables are closely linked (Winegardner 1996).

Hydrology can be defined in three different ways; hydroperiod (duration of inundation and soil saturation), hydrodynamics (water movement) and water source (Reddy & DeLaune 2008). Hydrology controls many aspects of wetland ecosystems, from physical and chemical to even biological processes and it is not uncommon for this variable to change considerably over time (Reddy & DeLaune 2008).

The pH is a measure of  $H^+$  ions in water and is therefore a result of organic and inorganic acids and bases (Margesin & Schinner 2005). This is one of the most useful determinants of wetland health as pH affects many biogeochemical processes, for example the solubility and degradation of substances like pollution (Margesin & Schinner 2005) and pH is in turn affected by organic matter and salinity.

Soil organic matter consists of decaying plant and animal waste (Margesin & Schinner 2005) and is an important measure of soil quality as it influences soil nutrients, by providing nitrogen and phosphorus when decomposed by soil organisms (Wright & Hanlon 2009). Soil organic matter also affects pH as its decomposition results in the release of  $CO_2$  and ammonium which are acidic, but organic matter can also act as a buffer by absorbing  $H^+$  ions (Winegardner 1996). Soil organic content is in turn affected by hydroperiod (Wright & Hanlon 2009), as the degradation of organic matter depends on soil moisture by effecting oxygen supplies, such that soils with long hydroperiods will have a greater accumulation of organic matter (Miklovic & Galatowitsch 2005).

The two nutrients chosen in this study, nitrogen and phosphorus, are according to Margesin and Schinner (2005), the two most important nutrients used by plants and soil organisms in wetlands as both are seen to limit microbial decomposition and plant growth. These two nutrients also most characterize eutrophic water conditions and result in increased plant growth, which is a problem that Rondevlei Nature Reserve is currently facing (Southern Waters Ecological Research and Consulting 2000)

Lastly, is salinity, which was taken by measuring electrical conductivity as a measure of the amount of dissociated ions in solution. Salinity is an important variable as it determines community composition in both tidal and freshwater wetlands, where a study by Miklovic and Galatowitsch (2005) showed that increased salinity decreased species richness by affecting seedling success and plant growth. As stated, salinity also affects pH as the cation exchange capacity of the soil results in either basic or acidic ions being released into the water depending on the salts present (Winegardner 1996).

## 1.2: Purpose of the study

Effective wetland rehabilitation requires good legislation and a well researched guideline to wetland management, which Hall (1993) argues should focus on the manipulation of plant growth. Of all the threats to wetlands, alien invasion is the most threatening (Dallas et al 2006). As such, *T. capensis* has been the focus of many wetland studies, looking at varying factors like population dynamics and its role in wetland processes (Hall 1993), but there are few studies based on Cape Flat wetlands.

In response to this, this research project aims to contribute to the understanding of wetland ecosystems and wetland rehabilitation by increasing the knowledge base of how *T. capensis* and other wetland plants respond to varying environmental conditions. As it appears in many Cape Flats wetlands, *T. capensis* is expected to be able to inhabit a wide range of environmental conditions, yet it has patchy distributions. This study therefore seeks to investigate whether particular environmental conditions may limit where *T. capensis* occurs, relative to other vegetation types. My hypothesis is that wetlands with *T. capensis* or specific *T. capensis* stands exhibit similarities in terms of certain variables, such as hydrology, salinity and nutrients. These variables are then expected to differ from wetlands without *T. capensis* and that hydrology is especially important in determining the dynamics of *T. capensis* and where it may occur. *T. capensis* was the only *Typha* species found and will be referred to as *Typha*.

## 2: METHODS

### 2.1: Study site

Rondevlei Nature Reserve is a government run reserve, based in Cape Town along the False Bay coast as shown in figure 1.

Six wetlands were examined in Rondevlei Nature Reserve. Sites were chosen to sample three main types of wetlands depending on the presence of *Typha*, which were either dominated by *Typha* (Referred to as *Typha* dominant wetlands), had *Typha* present but which wasn't dominant (Referred to as Mixed wetlands) and sites that had no *Typha* at all (Referred to as No *Typha* wetlands), photos of these wetlands are provided in figure 2. In graphs and tables, the letters E, H, K, B, X and J refer to individual wetlands with varying *Typha* dominance, with *Typha* dominant wetlands in E & H, Mixed wetlands in B & K and No *Typha* wetlands in X & J. Three of these wetland sites (E, X and B) occur in the back section of Rondevlei while the other three (H, J and K) occur in the front section.

Within each of the wetlands, sample areas were chosen to represent three main vegetation types where possible. These three vegetation types were *Typha*, rush-like vegetation and mat-like vegetation with dominant species being *Typha capensis*, *Ficinia nodosa* (Rottb.) Goetgh, Muasya & D.A.Simpson and *Isolepis rubicunda* (Nees.)Kunth respectively. In graphs and tables, they are referred to as T, M and R. In the *Typha* dominant wetlands, samples were only taken from within *Typha* vegetation, in the No *Typha* wetlands, samples were only taken from within areas of mat-like and rush-like vegetation as no *Typha* is present and in the Mixed wetlands, samples were taken within areas of *Typha*, mat-like and rush-like vegetation.

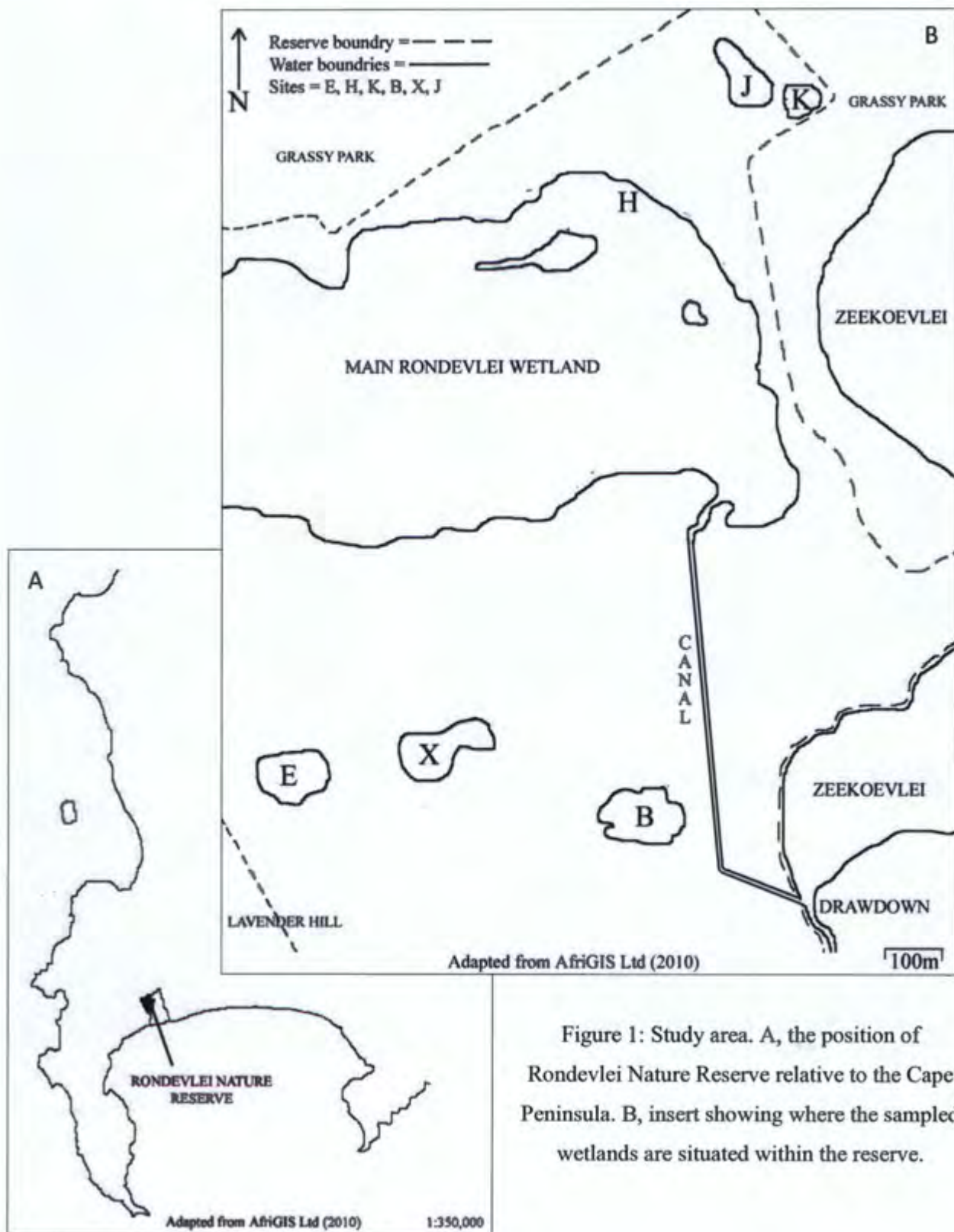


Figure 1: Study area. A, the position of Rondevlei Nature Reserve relative to the Cape Peninsula. B, insert showing where the sampled wetlands are situated within the reserve.



Figure 2: Wetland sites sampled in Rondevlei. Wetland types are *Typha* dominant (A & B) which has mostly *Typha*, Mixed wetlands (C & D) which have *Typha*, rush and mat-like vegetation and No *Typha* wetlands (E & F), which only have rush and mat-like vegetation (For specific species, see table 2).

Table 1: 6 wetland sites with sample areas (Indicated by an X) taken from each of the three vegetation types where appropriate and 4 replicates per sample area. GPS coordinates included.

Site #	Wetland type	Sample			GPS coordinates
		<i>Typha</i> (T)	Mat-like (M)	Rush-like (R)	
E	<i>Typha</i> dominant	X			34°04'10.93"S 18°29'43.27"E
H	<i>Typha</i> dominant	X			34°03'33.45"S 18°30'03.93"E
K	Mixed	X	X	X	34°03'28.11"S 18°30'16.04"E
B	Mixed	X	X	X	34°04'12.76"S 18°30'06.14"E
X	No <i>Typha</i>		X	X	34°04'08.26"S 18°29'52.94"E
J	No <i>Typha</i>		X	X	34°03'27.27"S 18°30'12.85"E

## 2.2: Data collection

### 2.2.1: Field work

From each wetland (E, H, K, B, X and J), vegetation types of interest (*Typha*, mat-like and rush-like) were sampled and within each vegetation type, four replicate soil core samples and four replicate water chemistry measures were taken. Table 1 shows the samples that were taken and from where.

Soil cores: A standard hand held auger was used to collect samples from the first 50cm of the soil.

Samples were then bagged to reduce moisture loss and kept in the fridge to reduce any chemical processes that may alter the natural state of the soil until it could be analyzed in the lab.

Water chemistry measures: two hand held probes were used, the EC 320 set and the pH 320 set.

Electrical conductivity (EC), total dissolved solids (TDS), NaCl and temperature were measured using the first probe, while pH and a second temperature measure were taken from the second probe.

Hydrology: This involves a rough indication of inundation period of the vegetation. To do this, vegetation types from where the core samples were taken were classified in one of three ways depending on level of inundation over the period of time in which I visited the reserve, which spanned

the end of summer (May 2010) to early spring (September 2010). Samples classed as 1, were dry the entire time, samples classed as 3 were wet the entire time and samples classed as 2 were wet in winter but dry in summer.

### **2.2.2: Lab work:**

Soil pH: To measure this, the method described by Margesin and Schinner (2005) was followed. 5 grams of field moist samples from each core were measured off and placed into glass sample bottles with five times the amount of water. The sample bottles were then closed and placed in a mechanical shaker for one hour. While the samples were still in the shaker, pH was measured using the same pH probe that was used for the water chemistry measures.

Salinity: Measures of soil salinity, sodium chloride (NaCl), electrical conductivity (EC) and total dissolved solids (TDS) were taken using the same probes as for the water chemistry measurements. To measure these, the method for measuring soil pH described by Margesin and Schinner (2005) was used and measurements of NaCl, EC and TDS were taken at the same time and from the same samples as what was used to measure soil pH.

Hydrology: For soil moisture, the methods described by Margesin and Schinner (2005) were followed. This involved weighing crucibles ( $m_0$ ) and measuring off 30g of field moist samples into these crucibles and weighing them again ( $m_1$ ) before placing them into a drying oven. Soil samples were then dried at 105°C overnight until constant mass was achieved and then cooled in a desiccator before being reweighed ( $m_2$ ). To calculate the moisture content, the following equation was used:

$$(1) W_{\text{H}_2\text{O}} = (m_1 - m_2) / (m_2 - m_0) \times 100$$

$W_{\text{H}_2\text{O}}$ : Water content

Nutrients: Soil organic content, total nitrogen and phosphorus were measured. For nitrogen and phosphorous, soil samples from each of the cores were air dried and approximately 200g measured off and sent to a commercial laboratory (Bemlab) for analysis. For soil organic content, the Loss on Ignition (LOI) method was used as described by Margesin and Schinner (2005). The soils used for the soil moisture measure were reweighed in the same crucibles to determine the dry mass ( $m_s$ ) and fired in a muffle furnace at 550°C for three hours to burn off any organic matter. The samples were then cooled in a desiccator and reweighed twice ( $m_c + m_t$ ). Calculating organic content used the equations:

$$(2) \Delta m = (m_s + m_t) - (m_c + m_t) = m_s - m_c \quad \Delta m: \text{ loss of mass of the soil after ignition}$$

$$(3) \text{LOI (\%)} = \Delta m / m_s \times 100$$

### 2.3: Statistical analysis

The data was analyzed from three different perspectives (Sites, vegetation type and wetland type), focusing on the main variables hypothesized to influence wetland vegetation (Salinity, hydrology and nutrients) including an overall view of the data.

Using the program Primer (Primer-E 2006): Cluster analysis and principle component analysis (PCA) were used to analyze all of the data together to determine which sample areas were similar and why.

The cluster analysis used was Euclidean distance and Group Average.

Using the program Statistica (Statsoft 2009): Histograms were made for each variable to test for normality. On concluding that the data were not normally distributed, nonparametric Kruskal-Wallis analysis was used to determine if variables differed significantly between the samples. This was done from a number of perspectives, namely testing differences in variables between wetland types (*Typha*, Mixed, No *Typha*), vegetation types (*Typha*/T, mat-like/M, rush-like/R) and sites (E, H, X, J, B, K).

### 3: RESULTS

#### 3.1: Considering how sample areas are grouped

The first three groups represent the species that form the three main vegetation types sampled and group 4 represents extra species that were not considered in the statistical analyses, but which may help in distinguishing one site from another. *Isolepis rubicunda* is common to all wetlands, while rush-like vegetation does not occur in *Typha* dominant wetlands. Of the group 4 species, wetland E is the only one with *Cladium strobilifera* while wetland J has *Sarcocornia natalensis* and *Bolboschoenus maritimus*.

Table 2: Species in wetlands and wetland vegetation and soil type. Underlined, bold x indicates dominant species in wetlands. E/H=*Typha* dominant, K/B=Mixed, J/X=No *Typha*, CFDS=Cape Flats Dune Strandveld, CFSF=Cape Flats Sand Fynbos, 1=calcareous alkaline soils, 2=acid quartzitic soils.

Species (Germishuizen & Meyer 2003)	Wetland site					
	E	H	B	K	X	J
<b><i>Typha</i></b>						
<i>Typha capensis</i> (Rohrb.)N.E.Br	<u>x</u>	<u>x</u>	x	x		
<b>Rush-like</b>						
<i>Ficinia nodosa</i> (Rottb.) Goetgh., Muasya & D.A.Simpson			x	x	x	x
<i>Elegia tectorum</i> (L.f.) Moline & H.P.Linder			x			x
<i>Juncus kraussii</i> Hochst.			<u>x</u>	x	x	
<b>Mat-like</b>						
<i>Isolepis rubicunda</i> (Nees.)Kunth	x	x	x	<u>x</u>	<u>x</u>	<u>x</u>
<i>Isolepis venustula</i> Kunth					x	
<b>Group 4</b>						
<i>Cladium mariscus</i> (L.)Pohl	x					
<i>Cliffortia strobilifera</i> L.	x					
Algae			x			
<i>Bolboschoenus maritimus</i> (L.)Palla						x
<i>Sarcocornia natalensis</i> (Bunge ex Ung.-Sternb.)A.J.Scott						x
<i>Schoenoplectus litoralis</i> (Schrad.)Browning		x				
<b>Vegetation type</b> (Mucina & Rutherford 2006)	CFDS	CFSF	CFDS	CFSF	CFDS	CFSF
<b>Soil type</b> (Mucina & Rutherford 2006)	1	2	1	2	1	2

The cluster analysis in figure 3 shows that replicates in sample areas generally cluster together and that at a distance of 3.7, sample areas separate into six main groups. Sample area TE is the most unique, then MJ, then RK and finally MB. The rest of the sample areas are divided into two groups whereby *Typha* vegetation (T) are clustered together and sample areas related to mat-like (M) and rush-like (R) vegetation are clustered together. (Refer to table 1 for a summary of sample areas in wetland sites).

not true!

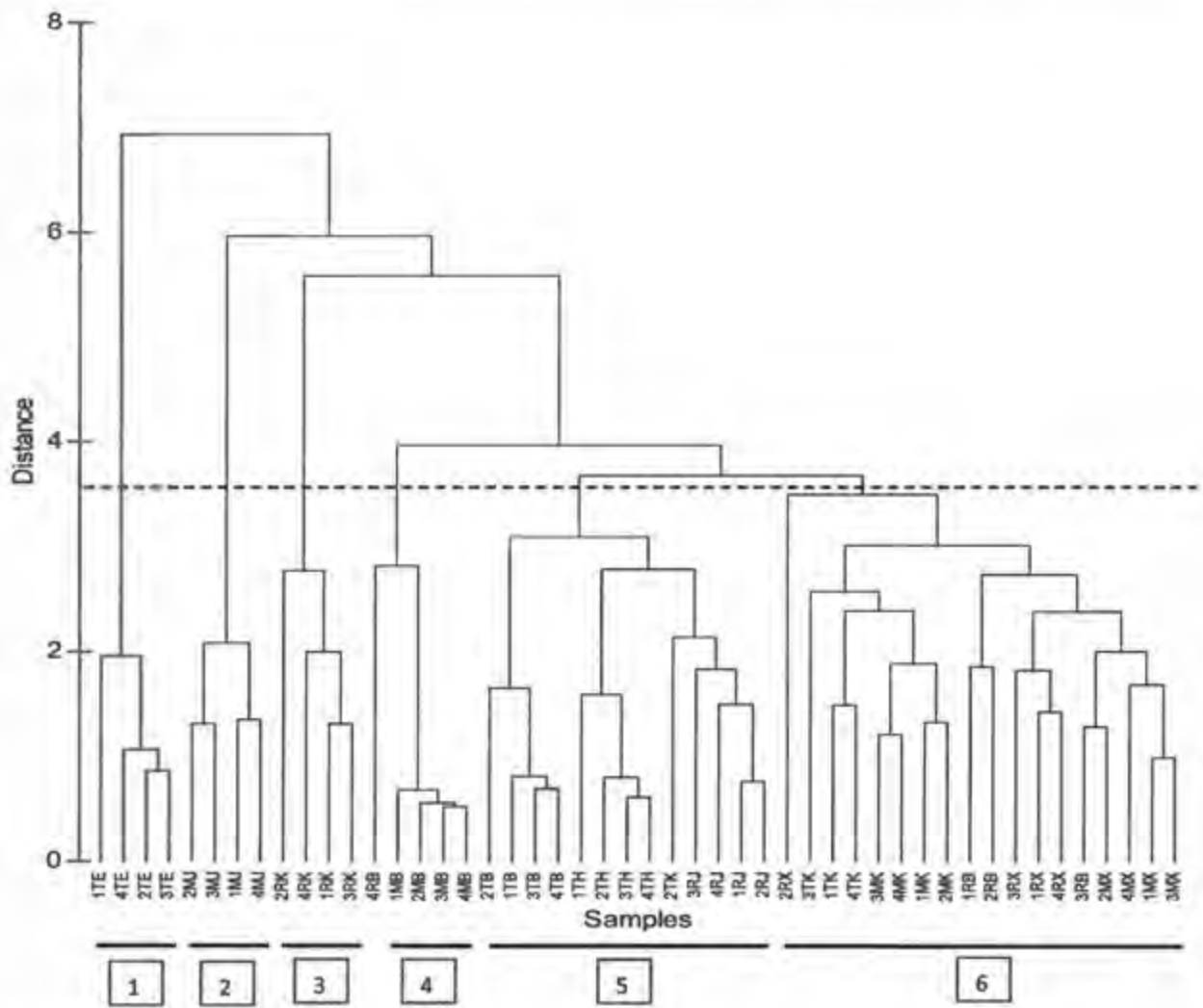


Figure 3: Cluster analysis based on Euclidean distance and group average cluster mode. This cluster includes all sample areas and variables shown in appendices 7.2. T=*Typha*, M=mat-like, R=rush-like. E/H=*Typha* dominant, K/B=Mixed, J/X=No *Typha*

A Principal components analysis (PCA) was used to evaluate whether the five clusters observed at Euclidian distance 3.7 (Figure 3) are supported and to identify what variables contribute to the pattern (Figure 4). Outlying values (TE, MJ, RK and MB) cluster the remaining sample areas together, making it difficult to pick out the same pattern. Most notable of these are MJ, which differs in terms of soil electrical conductivity (S.EC), MB, which differs in terms of water pH (W.pH) and soil pH (S.pH) and TE, which differs in terms of water electrical conductivity (W.EC).

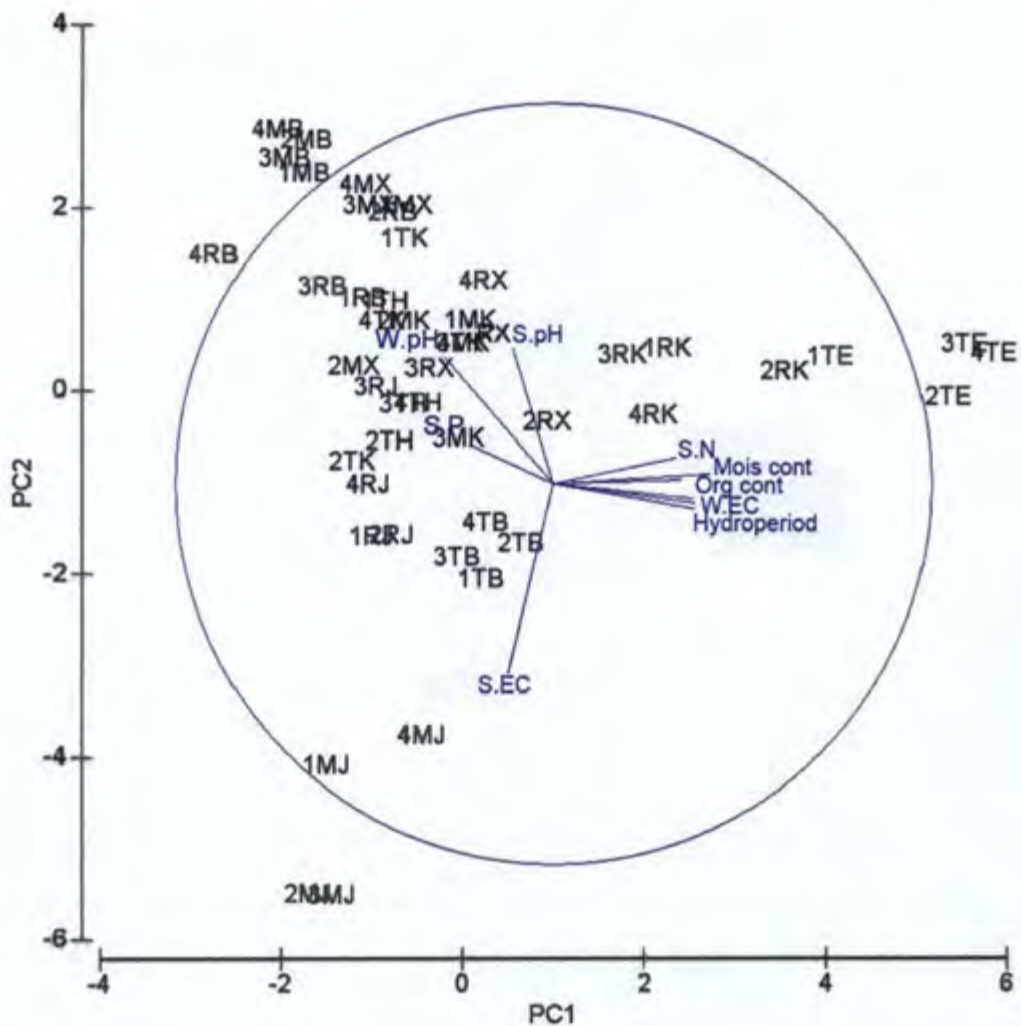


Figure 4: Principle Component Analysis (PCA), which include all variables and sample areas shown in appendices 7.2. T=*Typha*, M=mat-like, R=rush-like. E/H=*Typha* dominant, K/B=Mixed, J/X=No *Typha*

For the largest cluster (Figure 3, 2TB to 3 MK), Principle Component Analysis (PCA) plot shows that the sample areas separate into two main groups (figure 5). The one group includes mainly mat-like (M) and rush-like (R) sample areas from two wetlands sampled (K and X). The other group includes mainly *Typha* (T) sample areas from another two wetlands sampled (B and H). These two groups differ according to hydroperiod, and to a lesser extent soil and water electrical conductivity (W.EC), soil pH (S.pH) and possibly also soil nitrogen (S.N).

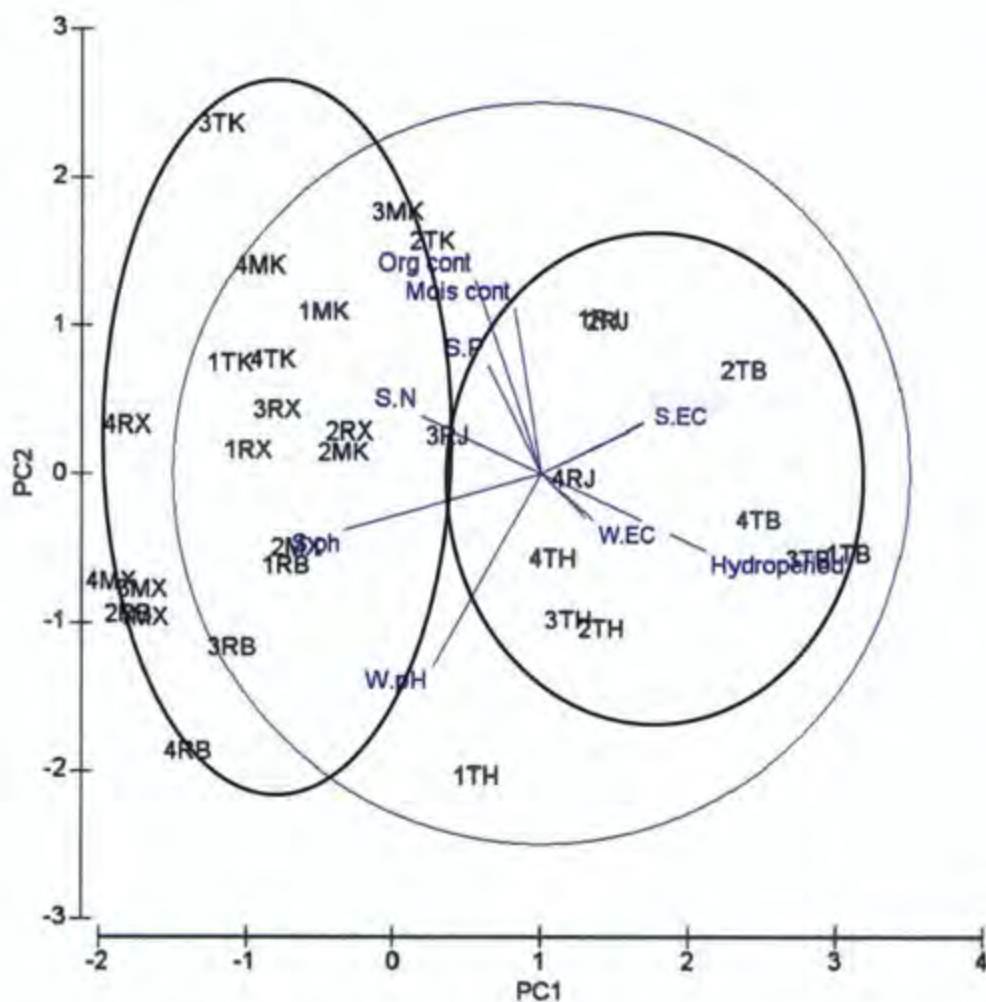


Figure 5: Principle Component Analysis (PCA), including all the variables shown in appendices 7.2, while excluding outlying sample areas, TE, MJ, RK and MB, identified in figure 3 to show how the rest of the areas cluster according to the different variables. T=*Typha*, M=mat-like, R=rush-like. E/H=*Typha* dominant, K/B=Mixed, J/X=No *Typha*

### 3.2: Considering variables and their affects on the vegetation

According to vegetation type (Figure 6A), *Typha* vegetation has significantly longer hydroperiod compared with mat-like vegetation ( $H=18.57$  (2,  $N=48$ ),  $p=0.0001$ ). In terms of wetland type (Figure 6B, C, D), *Typha* dominant wetlands have significantly longer hydroperiods ( $H=19.306$  (2,  $N=48$ ),  $p=0.0001$ ) and significantly lower soil electrical conductivity ( $H=7.826$  (2,  $N=48$ ),  $p=0.02$ ) than No *Typha* wetlands, and significantly higher water electrical conductivity than Mixed wetlands and No *Typha* wetlands ( $H=22.974$  (2,  $N=48$ ),  $p=0.0000$ ).

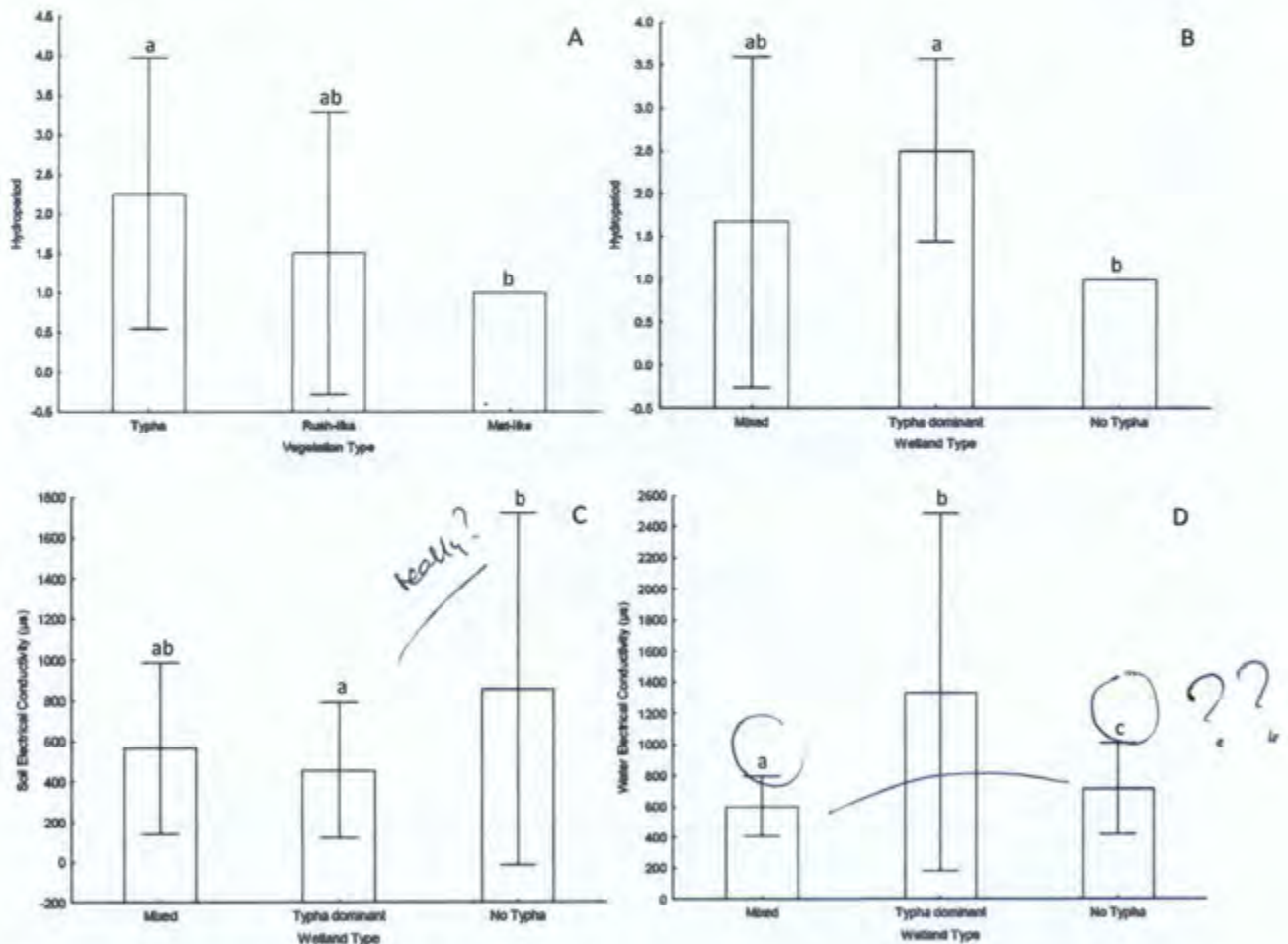


Figure 6: Hydroperiod for vegetation type (A) and wetland type (B). Soil electrical conductivity (C) and water electrical conductivity (D) for wetland type. (Mean value,  $\pm 1$  SD, means with different letters are significantly different (Kruskal Wallis, Multiple comparisons,  $p < 0.05$ ))

*Very confusing layout of fig either veg type or wetland type. Ambiguity!*

According to vegetation type (Figure 7A and C), *Typha* vegetation has significantly lower soil pH than rush-like vegetation ( $H=8.201$  (2,  $N=48$ ),  $p=0.0166$ ) and rush-like vegetation has significantly higher soil nitrogen than mat-like vegetation ( $H=6.365811$ (2,  $N=48$ ),  $p=0.0415$ ). In terms of wetland type (Figure 7B and D), *Typha* dominant wetlands have significantly lower soil pH than the other wetland types ( $H=8.265$  (2,  $N=48$ ),  $p=0.0160$ ), and Mixed wetlands have significantly higher soil phosphorus than *Typha* dominant wetlands ( $H=9.784$  (2,  $N=48$ ),  $p=0.0075$ ).

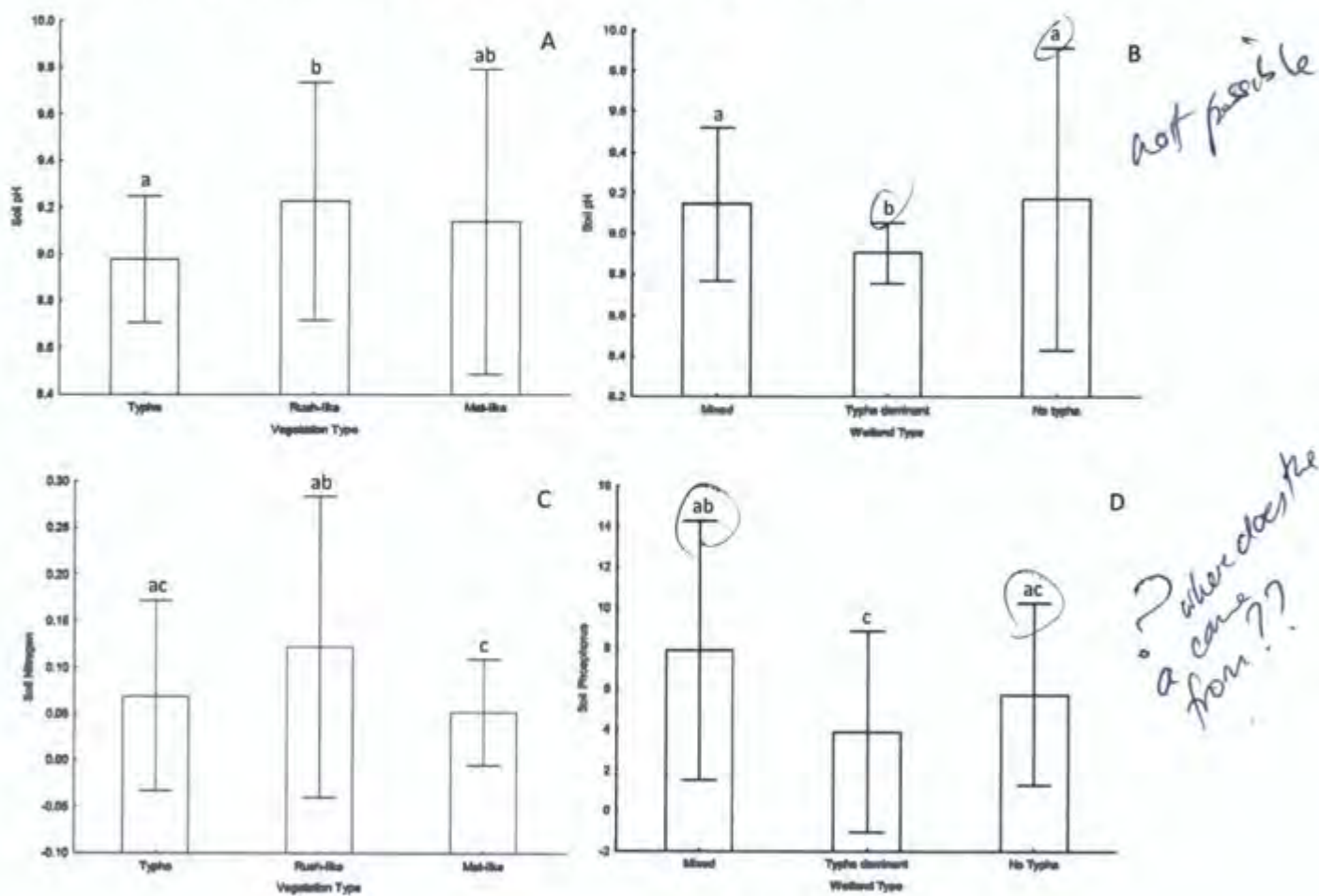


Figure 7: Soil pH for vegetation type (A) and wetland type (B). Soil nitrogen (C) and soil phosphorus (D) for wetland type. (Mean value,  $\pm 1$  SD, means with different letters are significantly different (Kruskal Wallis, Multiple comparisons,  $p < 0.05$ ))

*very ~~low~~ sparse statistical outliers!*

## 4: DISCUSSION

This study evaluated the effects of various environmental variables on wetland plant communities to determine if any were responsible for limiting the occurrence of *Typha*. The study chose to focus on measures of hydroperiod, salinity, nutrients and pH and compared these across wetland type and vegetation type. This discussion will now use these findings to answer the study question and hypothesis by getting an overall impression of how the sample areas are separated according to dominant species and environmental variables and then taking environmental variables of interest and looking at how vegetation and wetland types respond to them to try to determine why *Typha* occurs where it does and whether any of these variables are responsible for limiting *Typha*.

### 4.1 Considering how sample areas are grouped

From the cluster analysis (Figure 3) and Principle Component Analysis (PCA) plots (Figures 4 and 5), it appears that sample areas are arranged according to vegetation type, such that samples are divided into one group consisting of *Typha* associated sample areas and another group consisting of rush-like and mat-like sample areas. There are however a number of outlying sample areas (TE, MJ, RK and MB) and what is most notable of these sample areas is that they do not represent a specific vegetation or wetland type and each has a different set of variables that distinguishes it from the rest of the sample areas (note; specific values of all environmental variables can be found in the appendices 7.1 and 7.2).

Focusing first on the outlying sample areas, in order of decreasing dissimilarity, the No *Typha* wetland, MJ, differs by having twice as high soil conductivity as any other sample area (Figure 4), while the *Typha* dominant wetland, TE, has almost double the levels of water electrical conductivity (Figure 4). In terms of plant species, sample area MJ has *Sarcocornia natalensis* which is associated with highly saline conditions (Naidoo & Rughunanan 1990), but sample area TE does not have any plants that

would indicate saline conditions. Sample areas RK and MB do not show as much dissimilarity from the rest of sample areas as MJ and TE do, but RK does have higher organic content, moisture content and soil nitrogen (Figure 4) and sample area MB has higher water pH levels (Figure 4). In terms of the rest of the sample areas, the *Typha* cluster is distinguished from the rush-like and mat-like cluster in terms of longer hydroperiod and to a lesser extent, lower soil electrical conductivity, higher water conductivity and lower soil pH (Figure 5).

From this it appears that hydroperiod, electrical conductivity, and pH play a role in separating sample areas and that plant composition responds to these variables. This agrees with a study by Rolon and Maltchik (2006), which showed that macrophyte composition and species richness are influenced by hydrology, water chemistry (nitrogen, phosphorus and electrical conductivity), wetland size and altitude, although in this study, wetland size and altitude were not considered (Wetlands were all at the same altitude). The discussion will now move onto analyzing specific environmental variables in light of these groupings and the study hypothesis.

*Joined.*

## 4.2 Considering variables and their affects on the vegetation

As an effective invader and competitor (Hall 1993), *Typha* is able to inhibit a wide range of environmental conditions like water level, salinity, pH and nutrients, but studies have shown that they prefer stable water levels, low salinity and high nutrients (Hall 1993 and Newman et al 1996). What is seen in this study is that nutrients show no clear trend (Figure 7C & D), but that *Typha* vegetation is limited to areas with long hydroperiods (Figures 6A & B), low pH (Figures 7A & B) and peculiarly, low soil salinity, but high water salinity (Figures 6C & D).

Of these variables, studies in Wisconsin (Beule & Hine 1979) and Rondevlei (Hall 1993) show that hydrology is most important in determining the occurrence of *Typha* as these macrophytes are

especially adapted to living in stable, flooded conditions (Hall 1993 and Newman et al 1996) where other macrophytes may not survive as well, giving *Typha* a competitive edge. In Rondevlei, there is the opinion that *Typha* encroachment accelerated when the wetland was connected to the canals that carry storm water, thereby maintaining constant, flooded water levels in the wetland (Allan, T, personal communication, 2010). This same trend was seen in the American Everglades where a study by Newman et al (1996) concluded that the construction of drainage canals stabilized the hydrological regime and resulted in *T.dominegensis*, also a natural species, encroachment in the area.

Studies show that stable, flooded conditions results in increased growth rates and biomass accumulation (Newman et al 1996 and Hall 1993), an observable result being that *T.latifolia* and *T.angustifolia* grow taller in deeper water, giving *Typha* a competitive advantage as it accumulates a lot of above ground biomass which shades out other species (Hall 1993). The degree of flooding affects the oxygen content of soils, as pore spaces become filled with water, resulting in anoxic soils, the degree of which affects macrophyte composition as soil oxygen is important for microbial and plant root respiration (Reddy and DeLaune 2008). A study by Newman et al (1996) highlighted how *Typha* continues to respire in flooded conditions by using the leaves, of which 50% of its volume is reserved for gas space, to transport air to the roots, thereby allowing aerobic respiration.

However, *Typha* are not confined to these environments, as hydrological conditions are more important for the early stages, as mature plants are more tolerant of unstable hydrological conditions (Beule and Hine 1979). This may have allowed *Typha* to colonize the temporary wetlands (wetlands E, B and K) which have hydroperiods long enough to allow *Typha* to establish itself from seed, but not long enough to allow it to outcompete other macrophytes. I propose that if these temporary wetlands were closer to the main wetland, they would soon become overrun with *Typha*, as resource sharing would allow the plant to develop beyond the capacity of the temporary wetlands.

Salinity is influenced by hydrology as the water source brings in different types of salts and changing water levels will either dilute or concentrate salts in the water, especially in the soils as water evaporates (Blaylock 1994). Salinity has a strong influence on macrophyte composition (Miklovic and Galatowitsch 2005) as it has a variable effect on different species due to their different salinity preferences (Rolon & Maltchik 2006). The reason salinity has this influence is because it affects plant osmosis by reducing plant available water, forcing plants to expend more energy to absorb water, thereby affecting productivity and growth (Blaylock 1994). Figure 6C and D show electrical conductivity as a measure of salinity, and that for soil salinity, wetlands associated with *Typha* have statistically lower salinity than wetlands without *Typha* ( $H=7.826$  (2,  $N=48$ ),  $p=0.02$ ), and that wetlands with *Typha* present, but not dominant, have intermediate salinity. This agrees with other studies, which conclude that *Typha* prefers areas of low salinity, especially in the developing stages (Hall 1993 and Zedler et al 1990). High salinity increases *Typha* seedling mortality and in adult plants it decreases the growing season and it is because of these factors that for *Typha* to successfully invade an area, it needs low salinity to establish and then outgrow the competition (Zedler et al 1990).

However, what is unusual is that although *Typha* dominant wetlands have the lowest soil salinity, they have significantly the highest water salinity ( $H=22.974$  (2,  $N=48$ ),  $p=0.0000$ ) (Figure 6C & D). In wetland H, which is on the main Rondevlei, water salinity is understandably high as water flows through this wetland from canals which divert water from farmlands and road runoff and the water does not remain in the area for long enough to effect soil salinity, but wetland E (which contributes most to this anomalous result) is an isolated, temporary wetland and so soil salinity would be expected to be the same as water salinity. My suggestion is that this is a temporary phenomenon and if measurements were retaken at another time, they would show both low water and soil salinity for wetland E.

The last variable that may influence where *Typha* occurs is pH, which is influenced by soil and water in terms of the types of salt in solution and the source of water. It appears from the data (Figures 7A & B) that *Typha* vegetation and wetlands associated with *Typha* show significantly low pH ((2, N=48),  $p=0.0166$ ) and (2, N=48),  $p=0.0160$ ) respectively) compared with non-*Typha* vegetation and wetlands without *Typha*; however, all sample areas are still considered to have basic pH as all are above 7. In sample areas dominated by *Typha*, pH could be either low or high as high growth rates means higher organic matter which feeds microbes that release CO<sub>2</sub> forming acids as they decompose this organic matter, but at the same time, organic matter decreases pH as it contains carboxyl and hydroxyl ions that act as buffers. According to studies by Zedler et al (1990), *Typha* does not function well under low pH as this reduces nutrient uptake, and it was seen that maximum absorbance of nitrogen occurred just below neutral pH as this is where competition between cations and H<sup>+</sup> ions (at low pH) and between anions and OH<sup>-</sup> ions (at high pH) are lowest (Brix et al 2002).

An unexpected finding in the results is related to nutrients. As mentioned, *Typha* is generally found in high nutrient environments due to its adaptations and high nutrient requirements as a result of high growth and leaf turnover rates (Newman et al 1996). However, this is not seen in the results as for both nitrogen and phosphorus, *Typha* vegetation or wetlands with *Typha* do not show significantly high levels of either nutrient and what is most surprising is that even the nutrients in the main wetland are not especially high. Admittedly, I am uncertain as to the reason for this and could suggest that it is due to seasonal variations in nutrient levels in relation to plant growth cycles.

In conclusion it would appear that the presence of *Typha* in wetlands is to a certain extent controlled by water and soil chemistry, especially in terms of salinity, but that hydrology is the main factor limiting the occurrence of *Typha*. Both of these factors are especially important for *Typha* establishment and give mature *Typha* the competitive advantage as other plants are less well adapted to these conditions.

## 5: ACKNOWLEDGMENTS

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## 6: REFERENCES

- Beule JD, Hine RL (1979). *Control and management of cattails in south-eastern Wisconsin wetlands* (Technical bulletin. (Wisconsin Dept. of Natural Resources), No. 112). Wisconsin Department of Natural Resources, pp: 39
- Blaylock AD (1994). *Soil Salinity, Salt Tolerance and Growth Potential of Horticultural and Landscape Plants*. [Online], accessed: <http://ces.uwyo.edu/PUBS/Wy988.pdf>, [02/09/10]
- Brix H, Dyhr-Jensen K, Lorenzen B (2002). *Root-zone acidity and nitrogen source affects *Typha latifolia* L. growth and uptake kinetics of ammonium and nitrate*. *Journal of Experimental Botany*, 53(379), pp: 2441-2450
- Dallas H, Seymour C, Snaddon K, Ewart-Smith J (2006). *Identification and collation of existing information on the wetlands of the Western Cape*. The Freshwater Consulting Group, Freshwater Research Unit, University of Cape Town, pp: 112
- E-Kapa (2008). *South Nature Reserves*. [Online], accessed: <http://ekapa.ioisa.org.za/module6/reserves/rondevleireserve.htm>, [25/08/10]
- Germishuizen G, Meyer NL (eds) (2003). *Plants of southern Africa: an annotated checklist*. *Strelitzia* 14, Pretoria, National Botanical Institute, pp: 1231

- Hall DJ (1993). *The Ecology and Control of Typha capensis in the Wetlands of the Cape Flats, South Africa*. Bsc Doctoral thesis, University of Cape Town, pp: 249
- Margesin R, Schinner F (2005). *Manual of Soil Analysis: Monitoring and Assessing Soil Bioremediation*. Springer, Germany, pp: 366
- Miklovic S, Galatowitsch SM (2005). *Effect of NaCl and Typha angustifolia on Marsh Community establishment: a Greenhouse Study*. *Journal of Wetlands*, 25(2), pp: 420-429
- Mucina L, Rutherford MC (eds) (2006). *The Vegetation of South Africa, Lesotho and Swaziland*. *Strelitzia* 19. South African National Biodiversity Institute, Pretoria, pp: 816
- Naidoo G, Rughunanan R (1990). *Salt Tolerance in the Succulent, Coastal Halophyte, Sarcocornia natalensis*. *Journal of Experimental Biology*, 41(4), pp: 497-502
- Newman S, Grace JB, Koebel JW (1996). *Effects of Nutrients and Hydroperiod on Typha, Cladium, and Eleocharis: Implications for Everglades Restoration*. *Ecological Applications*, 6(3), pp: 774-783.
- Osland MJ (2009). *Managing Invasive Plants during Wetland Restoration: The Role of Disturbance, Plant Strategies, and Environmental Filters*. Unpublished dissertation towards a Doctor of Philosophy in the Department of Ecology in the Graduate School of Duke University, pp: 181
- Primer-E (2006). Primer 6, version 6.1.5, licensed to the Botany Department, University of Cape Town
- Reddy KR, De Laune RD (2008). *Biogeochemistry of Wetlands, Science and Applications*. CRC Press, United States of America, pp: 774
- Rolon AS, Maltchik L (2006). *Environmental factors as predictors of aquatic macrophyte richness and composition in wetlands of southern Brazil*. *Hydrobiologia*, 556, pp: 221-231
- National Water Act (1998). Government Gazette, 19182, Act 38, Pretoria, South Africa
- Southern Waters Ecological Research and Consulting (2000). *Zeekoevlei/Rondevlei rehabilitation study, unpublished report*. [Online], accessed: <http://www.southernwaters.co.za/downloads/aplan.pdf>, [12/06/10]

Statsoft (2009). Statistica, version 9.0, licensed to the University of Cape Town

UNESCO: United Nations Educational, Scientific and Cultural Organization (1971). *Convention on Wetlands of International Importance especially as Waterfowl Habitat*. [Online], accessed: [http://www.ramsar.org/cda/en/ramsar-documents-texts-convention-on/main/ramsar/1-31-38^20671\\_4000\\_0](http://www.ramsar.org/cda/en/ramsar-documents-texts-convention-on/main/ramsar/1-31-38^20671_4000_0), [21/09/10]

Winegardner D (1996). *An Introduction to Soil for Environmental Professionals*. CRC Lewis Publishers, United States of America, pp: 270.

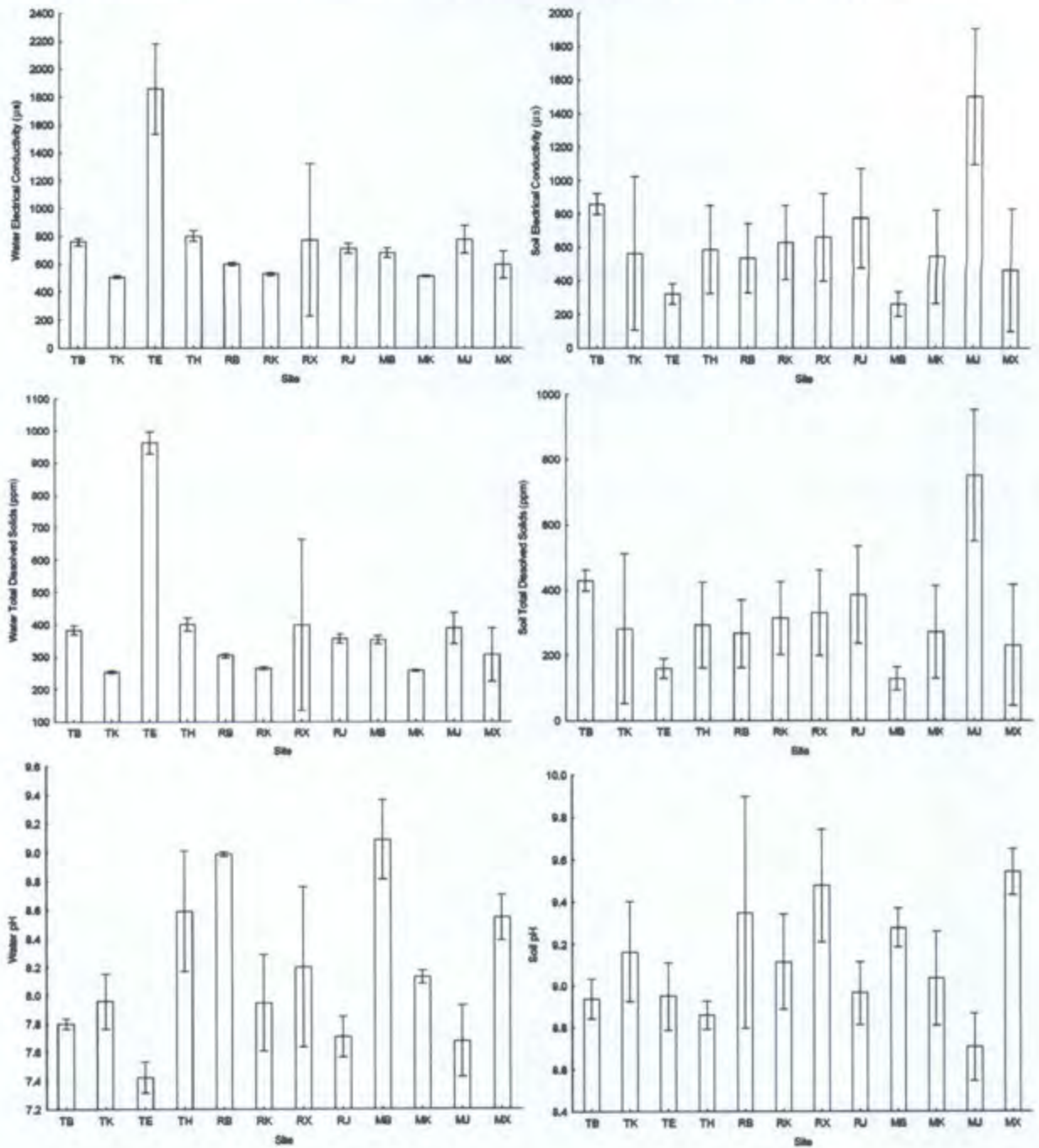
Wright A, Hanlon E (2009). *Measuring Organic Matter in Everglades Wetlands and the Everglades Agricultural Area*. [Online], accessed: <http://edis.ifas.ufl.edu/ss498>, [20/08/10]

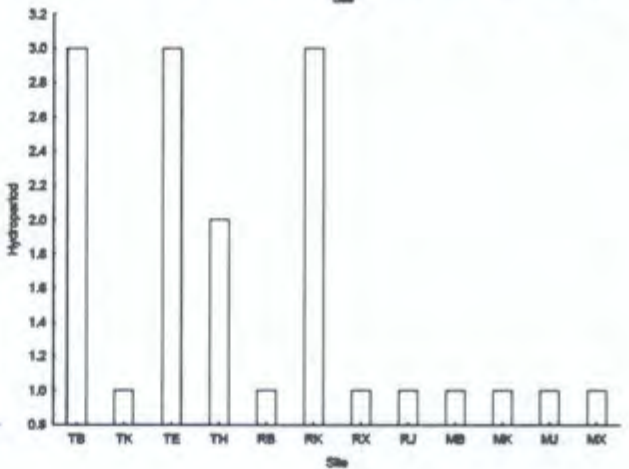
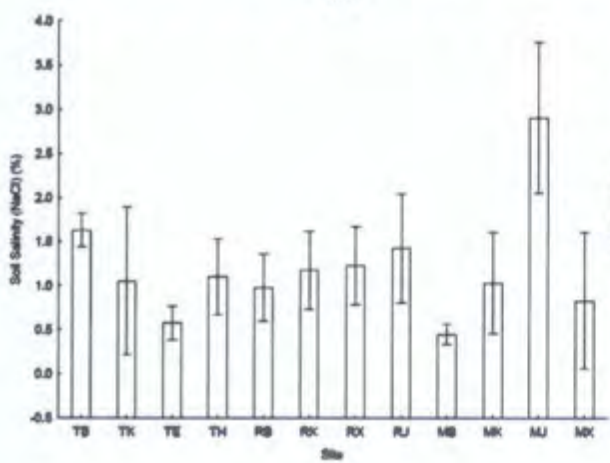
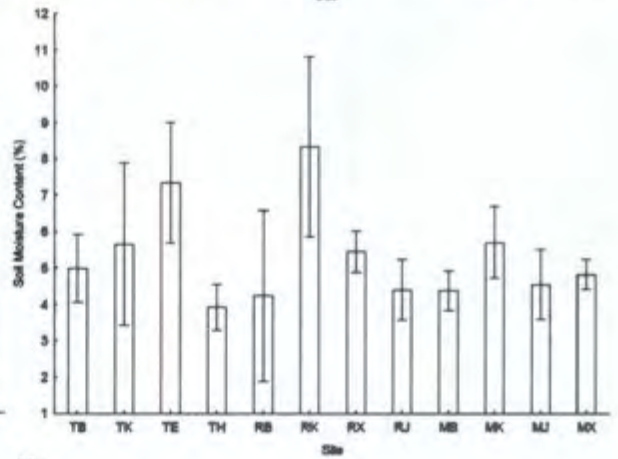
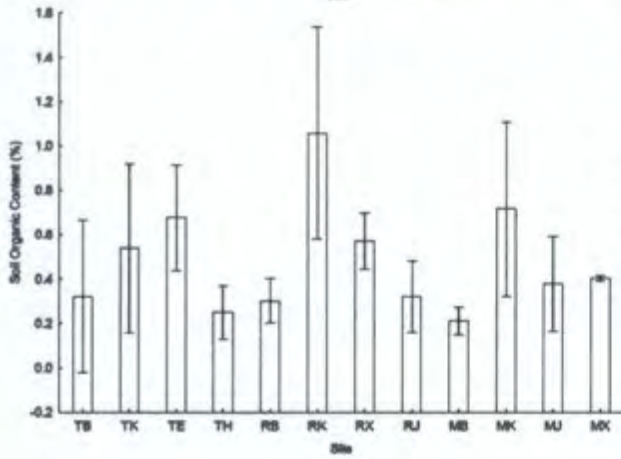
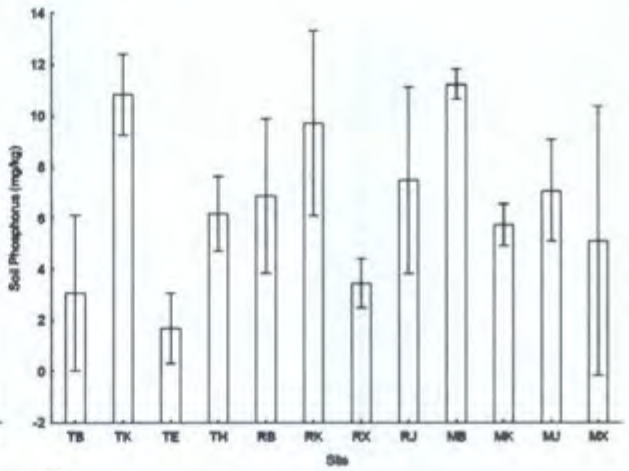
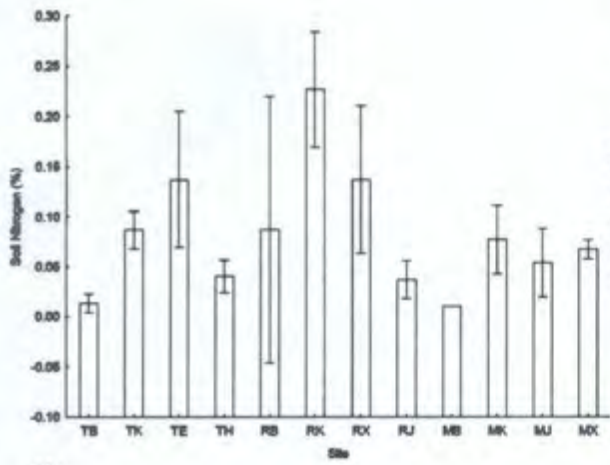
Zedler JB, Paling E, McComb A (1990). *Differential responses to salinity help explain the replacement of native *Juncus kraussii* by *Typha orientalis* in Western Australian salt marshes*. Australian Journal of Ecology, 15(1), pp: 57-72

Zedler JB (2000). *Progress in wetland restoration ecology*. TREE 15(10), pp: 402-407

## 7: APPENDICES

**7.1: Summarized data in graphs.** Environmental variables by sample area (Mean value,  $\pm 1$  SD, T=*Typha*, M=mat-like, R=rush-like. E/H=*Typha* dominant, K/B=Mixed, J/X=No *Typha*).





**7.2: Complete data.** Environmental variables by sample area (T=*Typha*, M=mat-like, R=rush-like. E/H=*Typha* dominant, K/B=Mixed, J/X=No *Typha*; water electrical conductivity=W.EC, water pH=W.pH, water total dissolved solids=W.TDS, soil moisture=S.Moisture, soil organic content=S.Organic, soil pH=S.pH, soil total dissolved solids=S.TDS, soil sodium chloride=S.NaCl, soil electrical conductivity=S.EC, soil nitrogen=S.N, soil phosphorus=S.P).

	W.EC	W.pH	W.TDS	S.Moisture	S.Organic	S.pH	S.TDS	S.NaCl	S.EC	S.N	S.P	Hydroperiod	% Cover
1TB	780	7.79	380	4.74	0.23	8.87	443.0	1.7	885.0	0.01	1.20	3	53.8
2TB	756	7.78	387	5.51	0.58	8.94	433.0	1.6	866.0	0.02	4.94	3	53.8
3TB	760	7.81	391	4.48	0.21	8.96	436.0	1.7	871.0	0.01	3.01	3	53.8
4TB	748	7.82	375	5.21	0.27	8.98	406.0	1.5	812.0	0.01	3.05	3	53.8
1TK	512	7.90	256	4.90	0.48	9.08	137.4	0.5	274.6	0.08	10.85	1	50.0
2TK	516	7.85	254	5.21	0.44	9.06	412.0	1.5	824.0	0.08	11.77	1	50.0
3TK	506	8.04	253	7.31	0.82	9.32	317.0	1.2	636.0	0.09	10.82	1	50.0
4TK	503	8.04	252	5.16	0.42	9.19	261.0	1.0	522.0	0.10	9.83	1	50.0
1TE	1619	7.50	949	6.19	0.56	9.00	164.0	0.6	328.0	0.09	2.63	3	100.0
2TE	1929	7.38	967	7.43	0.64	8.85	180.0	0.7	361.0	0.15	1.40	3	100.0
3TE	1917	7.39	952	7.58	0.67	9.03	152.0	0.5	304.0	0.17	1.02	3	100.0
4TE	1974	7.42	987	8.17	0.84	8.92	145.9	0.5	291.7	0.14	1.68	3	100.0
1TH	830	8.88	414	3.51	0.18	8.90	206.0	0.8	411.0	0.03	5.48	2	100.0
2TH	803	8.61	406	3.98	0.24	8.85	364.0	1.3	730.0	0.04	5.81	2	100.0
3TH	798	8.42	395	3.96	0.24	8.87	296.0	1.2	594.0	0.04	6.15	2	100.0
4TH	784	8.45	392	4.27	0.33	8.82	308.0	1.1	616.0	0.05	7.17	2	100.0
1RB	599	8.99	307	5.34	0.31	9.06	267.7	1	535.3	0.09	6.85	1	37.5
2RB	613	9.00	307	4.35	0.33	9.19	194.0	0.7	388.0	0.18	6.89	1	37.5
3RB	604	8.98	302	4.66	0.34	9.47	305.0	1.1	610.0	0.05	4.98	1	37.5
4RB	603	8.99	300	2.59	0.23	9.67	304.0	1.1	608.0	0.03	8.69	1	37.5
1RK	538	7.76	269	7.63	0.88	9.12	269.0	1.0	538.0	0.23	9.26	3	12.5
2RK	528	7.85	264	10.18	1.41	9.00	295.0	1.1	590.0	0.23	9.69	3	12.5
3RK	529	8.06	264	7.92	0.93	9.07	300.0	1.1	601.0	0.19	12.08	3	12.5
4RK	528	8.12	264	7.60	1.00	9.27	396.0	1.5	792.0	0.26	7.72	3	12.5
1RX	796	8.30	392	5.24	0.57	9.38	305.0	1.1	609.0	0.14	3.66	1	20.0
2RX	1141	8.50	587	5.83	0.64	9.35	414.0	1.5	827.0	0.14	3.43	1	20.0
3RX	676	7.83	293	5.22	0.49	9.62	345.0	1.3	691.0	0.09	3.86	1	20.0
4RX	491	8.17	324	5.47	0.57	9.56	259.0	1.0	517.0	0.18	2.77	1	20.0
1RJ	738	7.62	365	4.74	0.34	8.98	444.0	1.7	890.0	0.03	8.77	1	80.0
2RJ	719	7.75	359	4.76	0.42	8.86	438.0	1.6	878.0	0.04	7.45	1	80.0
3RJ	695	7.68	349	4.08	0.26	9.04	284.0	1.0	567.0	0.05	8.71	1	80.0
4RJ	709	7.78	355	3.98	0.25	8.98	381.0	1.4	763.0	0.03	4.86	1	80.0
1SB	672	8.89	343	4.46	0.20	9.23	133.0	0.5	265.4	0.01	10.79	1	40.0
2SB	675	9.14	354	4.65	0.25	9.25	118.2	0.4	236.7	0.01	11.19	1	40.0
3SB	679	9.12	359	4.36	0.22	9.33	154.0	0.5	309.0	0.01	11.49	1	40.0
4SB	711	9.21	353	4.00	0.18	9.30	114.0	0.4	228.6	0.01	11.29	1	40.0
1SK	519	8.11	260	5.99	0.70	8.93	210.0	0.8	420.0	0.07	5.75	1	6.3
2SK	516	8.11	258	4.97	0.44	9.04	227.0	0.8	454.0	0.06	5.18	1	6.3
3SK	516	8.14	258	6.01	0.87	8.98	366.0	1.4	729.0	0.08	5.71	1	6.3
4SK	514	8.16	257	5.80	0.84	9.19	287.0	1.1	574.0	0.10	6.20	1	6.3
1SJ	718	7.85	362	4.31	0.31	8.70	692.0	2.7	1383.0	0.05	7.05	1	95.0
2SJ	769	7.66	379	4.10	0.28	8.66	820.0	3.2	1640.0	0.03	5.77	1	95.0
3SJ	786	7.55	394	4.53	0.39	8.82	854.0	3.3	1708.0	0.07	8.16	1	95.0
4SJ	840	7.65	420	5.20	0.52	8.64	642.0	2.4	1283.0	0.06	7.23	1	95.0
1SX	614	8.46	309	5.06	0.41	9.62	190.0	0.6	379.0	0.06	2.76	1	5.0
2SX	597	8.51	299	4.66	0.41	9.51	370.0	1.4	738.0	0.07	3.72	1	5.0
3SX	531	8.58	257	4.89	0.40	9.50	181.0	0.7	363.0	0.07	5.08	1	5.0
4SX	650	8.64	358	4.64	0.40	9.54	183.0	0.6	370.0	0.07	8.75	1	5.0