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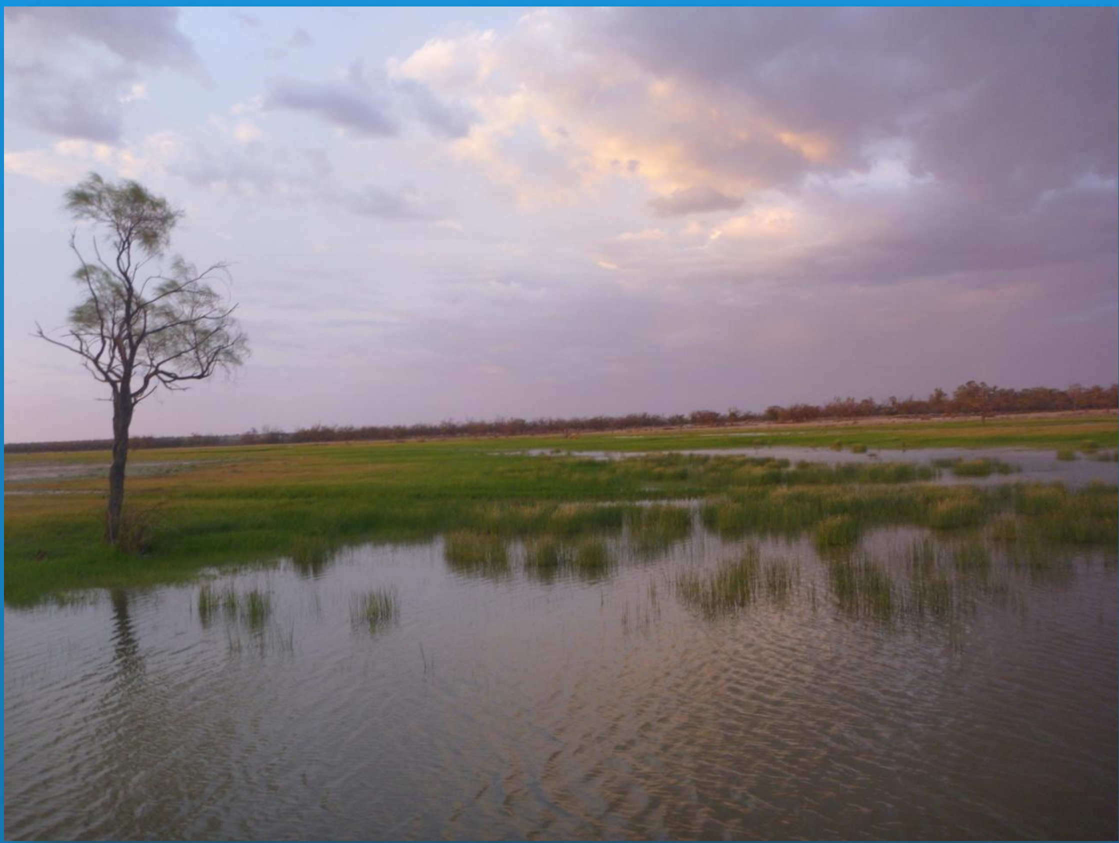
Chowilla Icon Site – Floodplain Vegetation Condition Monitoring

2012 Interim Report



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Executive Summary

The Chowilla Floodplain is the largest remaining area of undeveloped floodplain habitat in the lower Murray-Darling system. It was designated as one of The Living Murray (TLM) initiative's icon sites and management actions are being undertaken to attain the following resource condition targets: improve the area and diversity of grass and herblands (Target 5), improve the area and diversity of flood dependent understorey vegetation (Target 6), maintain or improve the area and diversity of grazing sensitive plant species (Target 8) and limit the extent of invasive (increaser) species, including weeds (Target 9). The aim of this study was to monitor and assess vegetation condition (across a range of open habitats subjected to a wide range of flood frequencies) against the TLM resource condition targets used for the Chowilla icon site. A network of vegetation survey sites was established in areas of herbland and grassland in 2006. These sites were used to provide baseline vegetation data in 2006, and were re-surveyed in 2007, 2008, 2009, 2010, 2011 and 2012. This quadrat network has been used to monitor medium-term vegetation changes and to assess the aforementioned resource condition targets. In 2010/11, an overbank flood resulted in inundation of more than 60% of the floodplain. Overall, species richness recorded in 2011 was higher compared to previous survey years (66 species), but by 2012 species richness had decreased to 51 species (although this was the second highest species richness recoded over the past seven years), from 22 families across the 73 sites surveyed. The five most abundant taxa were *Atriplex* spp., *Sclerolaena stelligera, Ammannia multiflora*, *Carpobrotus rossii* and *Sporobolus mitchelli*. Cluster analysis comparing the plant community of the 73 sites distinguished six significantly different groups:

1. "*Sclerolaena stelligera*" sites were predominantly characterised by salt tolerant, dryland species such as *Sclerolaena stelligera* and *Sclerolaena brachyptera* and (38.4% of sites),

2. "*Atriplex/Sporobolus*" sites were characterised by desiccation tolerant species such as *Atriplex* sp. and *Sporobolus mitchelli* (35.5%),

3. "*Carpobrotus/Pachycornia*" sites were relatively high elevation sites with salt tolerant species such as *Carpobrotus rossii* and *Pachycornia triandra* (11.0%),

4. "Bare soil" were predominantly characterised by empty cells (11.0%),

5. "Flood Responders" sites were characterised by floodplain, amphibious and terrestrial species such as *Alternanthera denticulata*, *Centipeda minima*, *Conyza bonariensis*, *Eleocharis acuta*, *Glinus lotoides*, *Heliotropium europaeum*, *Persicaria lapathifolia* and *Polygonum plebeium* (2.7 % of sites),

6. "Calotis/Sclerolaena" site was characterised by *Sclerolaena divaricata* and *Calotis hispidula* (1.4%).

Despite the decline in abundance of flood dependent and amphibious species in 2012, species richness was the second highest recorded with the abundance of salt tolerant species and bare soil the second lowest recorded. The response of the understorey plant community to flooding is usually short lived due to the annual life cycles of most flood dependent species; however this strategy allows species to reach maturity in a short time and replenish the seed bank. Further decreases in the abundance of floodplain and amphibious species and a corresponding increase in the abundance of salt tolerant and terrestrial species and bare soil are expected in the absence of flooding or watering. However, increases in the abundance of flood dependent and amphibious species and a corresponding decrease in salt tolerant and terrestrial taxa and bare soil are expected if there is another overbank flood or watering.

Prior to 2010, icon site Targets 5, 6 and 8 were not met without management intervention (namely watering). Whilst watering did result in the aforementioned targets being met, the spatial extent was limited and significant increases in the abundance of pest plants resulted in Target 9 not being met. The overbank flood in 2010/11 resulted in increased recruitment of flood dependent and amphibious species (including grazing sensitive species) and minimal weed recruitment. Therefore, all of the TLM targets for the Chowilla icon site were met in 2011. In the year following flooding (2012) Targets 5 and 6 were met because the abundance and area of grass and herblands and flood dependent species were the second highest recorded (even in years where there was watering). Grazing sensitive species were abundant; hence, Target 8 was met and there was no increase in invasive species; therefore, Target 9 was met.

1. Introduction

The Chowilla Floodplain, located on the lower River Murray at the borders of South Australia, New South Wales and Victoria, is the largest remaining undeveloped area of floodplain habitat in the lower Murray-Darling system. It is unique both for its large area of contiguous floodplain habitat and for the wide variety of aquatic environments including fast and slow flowing anabranches, temporary billabongs and permanent backwaters (O'Malley and Sheldon 1990). The area supports a large range of species across many taxonomic groups and has been recognised as a wetland of international significance under the RAMSAR convention (O'Malley and Sheldon 1990).

Vegetation on the Chowilla Floodplain includes a range of vegetation types including *Eucalyptus largiflorens* (black box) woodlands, *Eucalyptus camaldulensis* var. *camaldulensis* (river red gum) woodlands, *Atriplex* spp. (saltbush) shrublands and a range of aquatic and riparian vegetation types associated with the various temporary and permanent wetlands (O'Malley and Sheldon 1990). The majority of vegetation studies of the Chowilla Anabranch system prior to 2005 have focussed on the *Eucalyptus camaldulensis* and *Eucalyptus largiflorens* overstorey communities with an emphasis on the impact of groundwater depth and salinity on tree condition (Jolly *et al.* 1993; Jolly, *et al.* 1994; McEwan *et al.* 1995; Walker *et al.* 1996; Akeroyd *et al.* 1998; Doble *et al.* 2004; Overton and Jolly 2004). In the last 20 years there have been sporadic investigations of the understorey vegetation of the system; O'Malley (1990) undertook an extensive vegetation survey of the floodplain and Roberts and Ludwig (1990) of the permanently inundated wetlands in 1988 and there has been a series of monitoring and scientific investigations in Pilby Creek (e.g. Stone 2001; Siebentritt 2003). This project represents the longest continuous monitoring program of the understorey plant community on the Chowilla Floodplain or any floodplain in the South Australian River Murray Corridor.

The Asset Environmental Management Plan (AEMP) for the Chowilla Floodplain (DWLBC 2006) identified a number of targets for management of the various components of the Chowilla Floodplain ecosystem that were later revised (Murray Darling Freshwater Research Centre 2010) and more recently have been presented in the Chowilla Floodplain Environmental Water Management Plan (MDBA 2012). Four targets were identified for understorey vegetation, namely, "improve the area and diversity of grass and herblands" (Target 5), "improve the area and diversity of flood dependent understorey vegetation" (Target 6), "maintain or improve the area and diversity of grazing sensitive plant species" (Target 8) and "limit the extent of invasive (increaser) species, including weeds" (Target 9). Evaluation of the progress towards achieving these targets requires both baseline data and ongoing monitoring, particularly after large flood events or interventions.

In February 2006, a series of sites were established in areas of herbland and grassland across the Chowilla Floodplain, which provided baseline data for the study. These sites were re-surveyed in February 2007, 2008, 2009, 2010, July 2011 and 2012 to monitor the condition of floodplain understorey vegetation with reference to the icon site targets. This interim report describes the methods used to establish the monitoring sites, including survey quadrat design, results from six years of surveys, plus the quantitative and qualitative comparisons of the changes in floristic composition between the 2006 and 2012 surveys.

Flows to the Chowilla Floodplain

Prior to river regulation there was greater variability in flow (and in turn water level) and the Chowilla Floodplain was inundated more frequently (usually every year), for longer duration and greater depth (Maheshwari *et al.* 1995). Since river regulation commenced early last century, small to medium sized floods have generally been lost from the lower Murray resulting in floodplain inundation occurring less frequently, for shorter periods with lower flood peaks (Maheshwari *et al.* 1995).

From 1996 to 2010, the Murray-Darling Basin (MDB) experienced the most severe drought in recorded history (MDBA 2011). Below average stream flows, coupled with upstream extraction and river regulation, resulted in reduced inflows to South Australia (Timbal and Jones 2007), which prior to August 2010 were insufficient to inundate the floodplain (MDBA 2011) (Figure 1).

In early 2010, inflows into the River Murray were anticipated to be very low and the drought in the southern MDB was expected to continue. However, from June 2010 to May 2011 total inflow volumes were among the highest on record and the patterns of inflows were atypical compared to historical flows (MDBA 2011). Until the end of November 2010, inflows were the highest since 2000, but not unusual compared to historical flows. However, inflows during summer 2010-11 were the highest on record (~6,700 GL), more than double the previous highest record of ~2,980 GL in the summer of 1992-93 (MDBA 2011).

The increase in inflows in the summer of 2010-11 resulted in widespread flooding across the MDB. In the River Murray system, the extent of flooding varied considerably due to the pattern of rainfall and the nature of the floodplain. By the end of May 2011, the total annual flow into South Australia was ~14,000 GL, which was the highest total since 1975-76. During this period, flow into South Australia peaked at 93,000 ML day^{-1}, in February 2011. Flows of a magnitude between 90,000 to 100,000 ML day^{-1} (in combination with increased local rainfall) are estimated to inundate between 62.7–74.6% (11,100–13,200 ha) of the floodplain area (Sharley and Huggan 1995, cited in Cale 2009; see Figure 2), where the delineation between floodplain and highland is based upon the extent of the 1956 flood (Overton and Doody 2010). Large flows with maximums of ~100,000 ML day^{-1} typically last for about three months as unregulated events (Sharley and Huggan 1995), but the 2010/11 high flows and floodplain inundation persisted for about 11 months. Hence for the first time in ten years, flows not only watered red gum (*Eucalyptus camaldulensis*) woodland and wetland areas, but also reached some black box (*Eucalyptus largiflorens*) communities (MDBA 2011).

Flows remained high throughout winter and spring 2011 peaking at 41,000 ML day^{-1} in August 2011 and remained above 15,000 ML day^{-1} throughout the summer. These flows were confined to the channel and were insufficient to inundate large areas of floodplain; hence none of the condition monitoring sites were inundated since the 2011 survey. Nevertheless, low lying temporary wetlands were flooded.

The monitoring undertaken in early 2012 builds upon data collected from 2006 to 2011 and provides information regarding the change in plant communities across that time. The survey period includes a period of record low inflows, targeted environmental watering and an unregulated River Murray flow (following watering and flooding) periods. Therefore, this monitoring program collected information regarding the change in floodplain understorey vegetation communities in response to desiccation, targeted environmental watering and increased water levels due to natural flooding. This study also provides an insight into the recovery of floodplain systems under hydrological restoration.

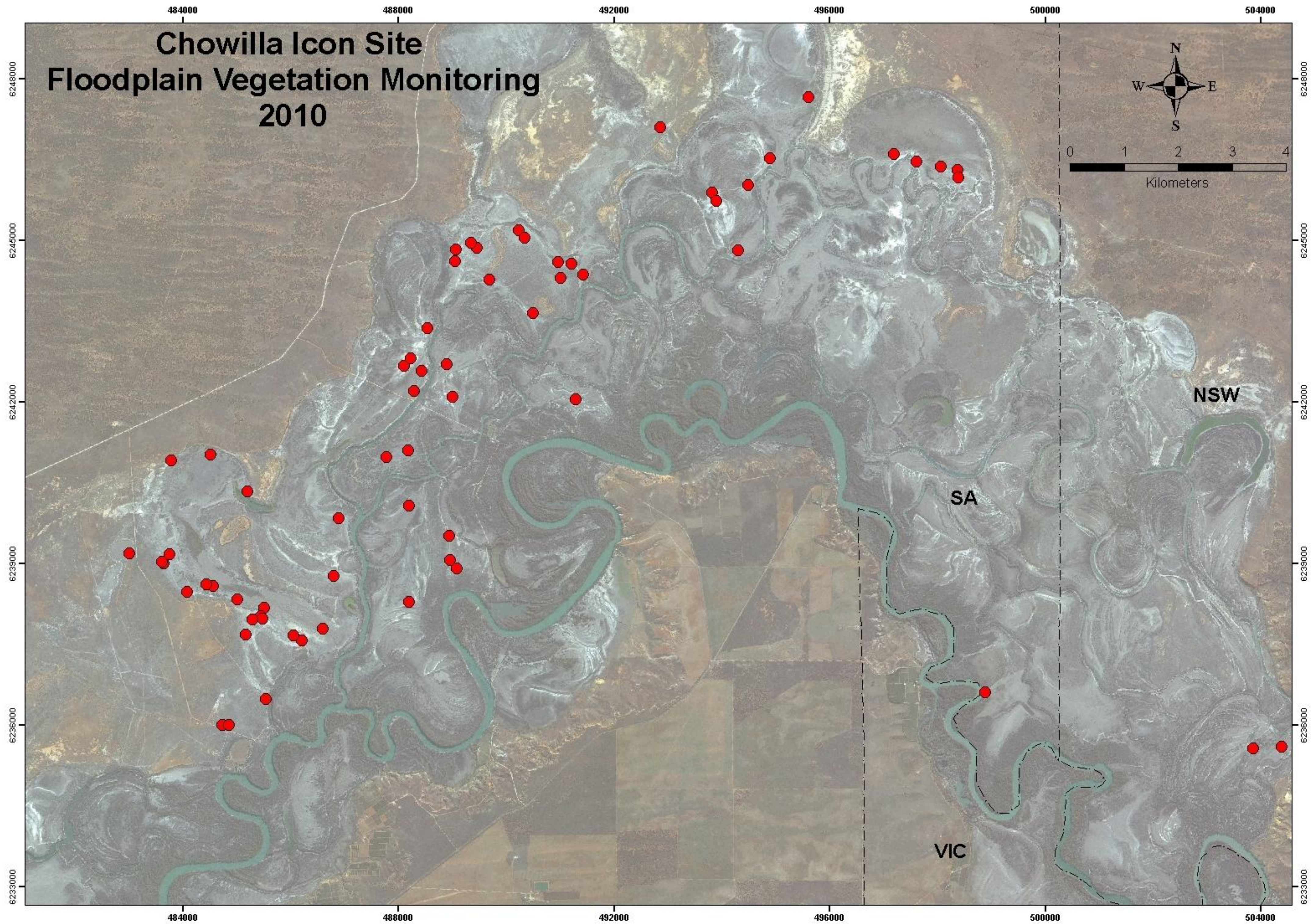

Figure 1: Aerial photograph of the Chowilla Floodplain in February 2010, during drought conditions. Red dots indicate floodplain vegetation monitoring sites. Map sourced from ArcGIS version 9.3.1 (Department of Heritage server: http://imagemapsa.deh.sa.gov.au).

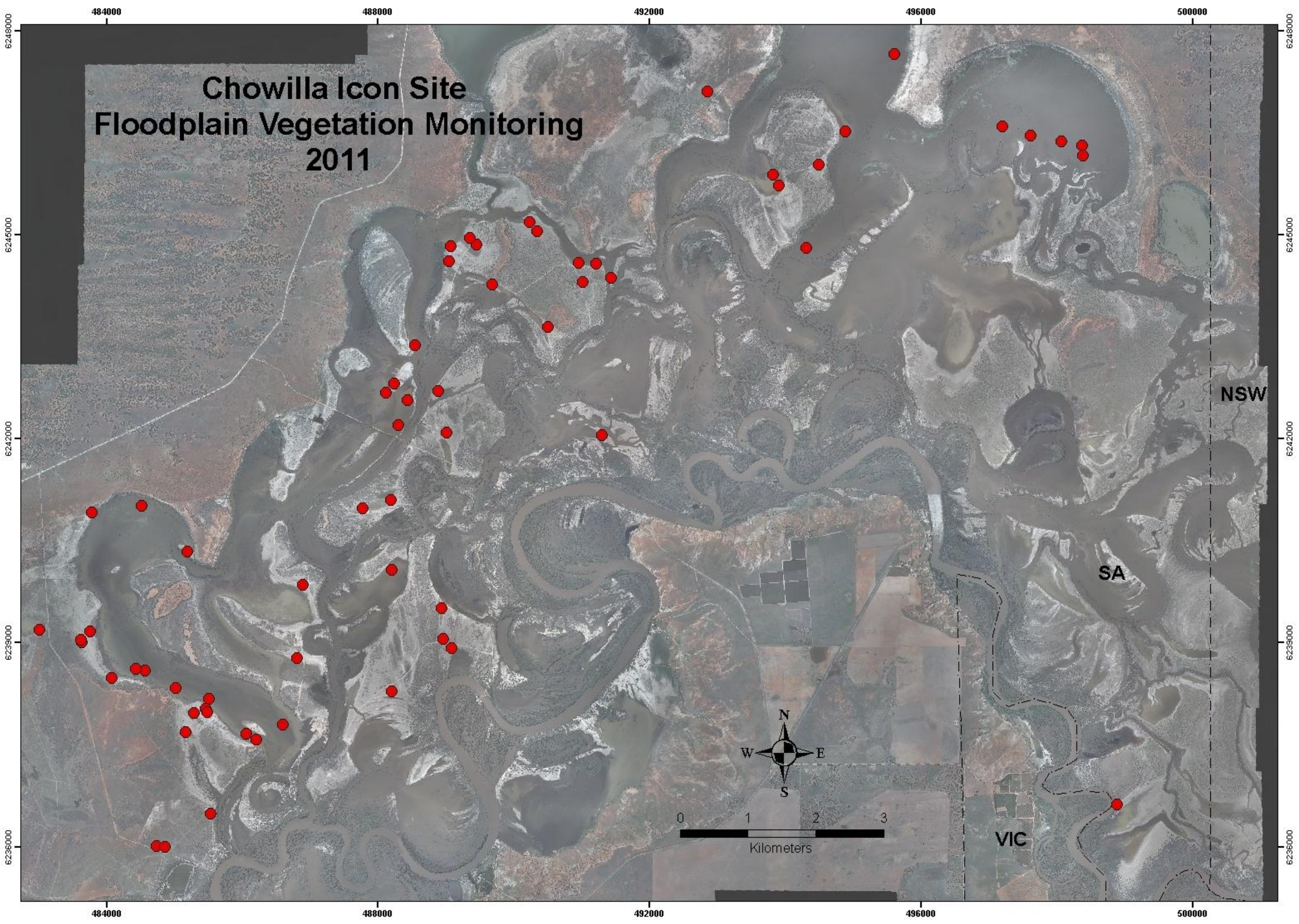

Figure 2: Aerial photograph of the Chowilla Floodplain showing inundation during unregulated flow conditions of 2010/11. Map sourced from ArcGIS version 9.3.1 (Department of Heritage server: http://imagemapsa.deh.sa.gov.au). Please note that date when photograph was taken has not been verified and therefore may not represent full extent of flooding. Red dots indicate floodplain vegetation monitoring sites (excluding sites 83 and 84, which are located in New South Wales).

2. Methods

Vegetation survey methods were the same as those used for other vegetation monitoring projects in the Chowilla icon site, namely Environmental Watering (Nicol *et al.* 2010) and Chowilla Aquatic Macrophyte Works and Measures understorey vegetation surveys (Zampatti *et al.* 2011). The maintenance of consistent methods and ongoing monitoring will facilitate comparison of data across studies to enable a greater understanding of vegetation dynamics.

The February 2006 "baseline" survey involved quantitative vegetation surveys at 79 sites located in open areas across the Chowilla Floodplain. Sites were chosen such that they:

- were located in areas that would be inundated by overbank flows
- had no tree overstorey
- were accessible by 4WD vehicle during dry conditions
- covered a range of vegetation types and grazing histories.

Sites were re-surveyed in February 2007, 2008, 2009, 2010 and 2012. Due to the 2010/11 overbank flood, access to the Chowilla Floodplain was not possible until July 2011. In 2008, three additional sites on the outer islands and New South Wales section of the floodplain were added. Two sites established in 2006 (53 and 54) were excluded from 2009 onwards as the construction of a fence made them inaccessible. In 2010, 2011 and 2012, sites on Punkah Island were inaccessible due to high water levels in Punkah Creek and in 2011 a total of 16 sites (including the sites on Punkah Island) were inaccessible due to high river levels.

At each site three 15 m x 1 m quadrats were surveyed. Quadrats were arranged in a straight line parallel to elevation contours 50 m apart. Each quadrat was divided into 15 1 m x 1 m cells. The presence of each species that had live plants rooted within each cell was recorded to give a total score out of 15 for each quadrat. Cells containing no live plants were given a bare ground score of one.

Plants were identified using keys in Cunningham *et al.* (1981), Jessop and Toelken (1986) and Jessop *et al.* (2006). In some cases, due to immature individuals or lack of floral structures, plants were identified to genus only. Nomenclature used follows Barker *et al.* (2005).

For each survey the vegetation communities present (a snapshot for each year) were compared using Group Average clustering (McCune *et al.* 2002) performed on pooled data (species scores were averaged from the three quadrats at each site). A cut-off score of 30% similarity was used to determine the cluster groups and each year five distinct groups were produced (except 2011 and 2012 when there were seven and six groups, respectively) based on species presence and their abundances. To identify the representative species for each group, Indicator Species Analysis (Dufrene and Legendre 1997) was performed on the unpooled data using the groupings of sites derived from the cluster analysis. All multivariate analyses used Bray-Curtis (1957) similarities to construct the similarity matrices and were undertaken using the package PCOrd 5.12 (McCune and Mefford 2006). Finally, the locations of the quadrats were mapped to allow presentation of the spatial distribution of the vegetation groups, as well as their distribution in relation to environmental variables such as elevation/inundation frequency.

Maps of flood inundation for October flood events modelled to simulate flood return frequencies of between three and 13 years (the maximum permitted by the model) under regulated conditions were generated using the GIS model FIM III (Overton *et. al.* 2004). This allowed the "natural" flood return frequency for each site to be determined. Sites were assigned to one of three flood types based on their flood return frequency: "Often", for sites flooded at least one in five years; "Sometimes", for sites flooded between one in five and one in 13 years; and "Rarely" for sites not flooded under the highest flow permitted by the model (102,000 ML day^{-1}). The cut off points for the groups were chosen to reflect the tri-modal nature of the flood frequency distribution (Figure 5). A Fisher's Exact Test for Count Data was performed on the vegetation group vs. flood frequency contingency table using R (R Development Core Team 2006).

The change in floristic composition from 2006 to 2012 was analysed using NMS ordination, two-factor PERMANOVA (Anderson 2001; Anderson and Ter Braak 2003) and Indicator Species Analysis (Dufrene and Legendre 1997). Sites were categorised on the basis of inundation history (watered, watered + flooded, flooded and unflooded) and year. In addition, plants were classified into functional groups based on the framework developed by Nicol *et al.* (2010) and the proportion of broad functional groups (terrestrial, salt tolerant, floodplain, amphibious and bare soil) present each year were plotted.

3. Results

3.1. 2006 Survey

Figure 3 shows the spatial distribution and vegetation communities based on groupings identified from cluster analysis (Figure 4) of the 79 survey sites across the Chowilla Floodplain in 2006.

Twenty-eight taxa from 13 families were observed across the 79 sites. The five most frequently encountered taxa (accounting for 73% of quadrat presences) were *Atriplex* spp., *Sclerolaena brachyptera*, *Sclerolaena divaricata*, *Carpobrotus rossii* and *Maireana* spp. All but *Carpobrotus rossii* (Aizoaceae) are members of the Chenopodiaceae.

Cluster analysis separated the sites into 5 groups at 30% similarity (Figure 4). This produced a manageable number of groups and reflected the major differences between sites.

Indicator Species Analysis produced a list of representative taxa for each grouping (Table 1). These species lists were used to name the five groups according to their characteristic taxa:

1. "Bare soil" characterised by empty cells (14% of sites)

2. "*Atriplex*" sites characterised by high abundances of *Atriplex* spp. and *Sclerolaena brachyptera* (64%)

3. "Salt Tolerant" sites characterised by salt tolerant species such as *Carpobrotus rossii*, *Halosarcia pergranulata* ssp. *pergranulata*, and *Pachycornia triandra* (9%)

4. "Flood responders" sites characterised by taxa that typically establish in response to flood events such as *Alternanthera denticulata, Cyperus gymnocaulos, Eragrostis australasica, Euphorbia drummondii, Glinus lotoides, Heliotropium europaeum* and *Sporobolus mitchelli* (3%)

5. "*Sclerolaena*" characterised by the shrub *Sclerolaena divaricata* (10%).

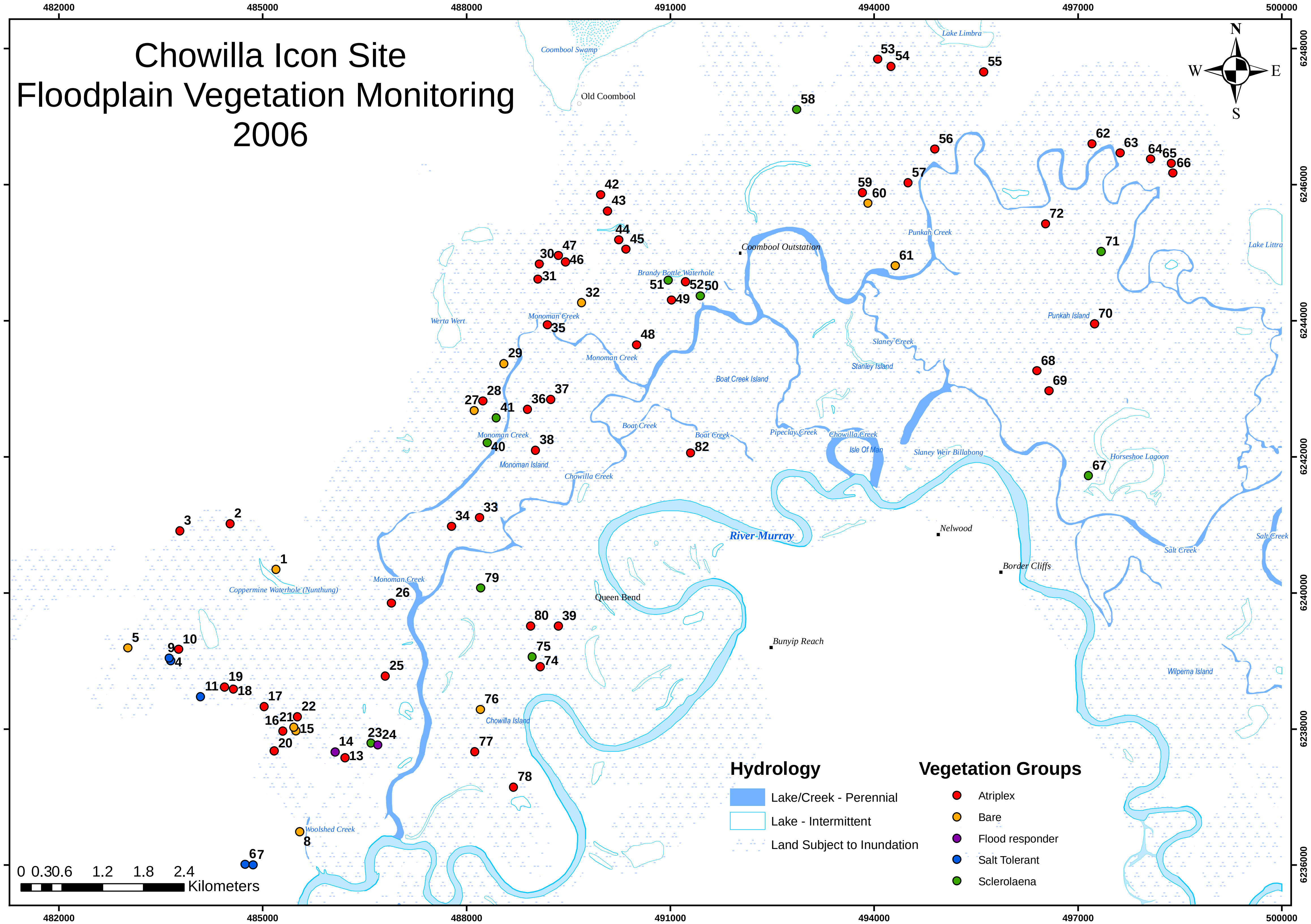

Figure 3: Spatial distribution and vegetation communities of the 79 survey sites across the Chowilla Floodplain for the 2006 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

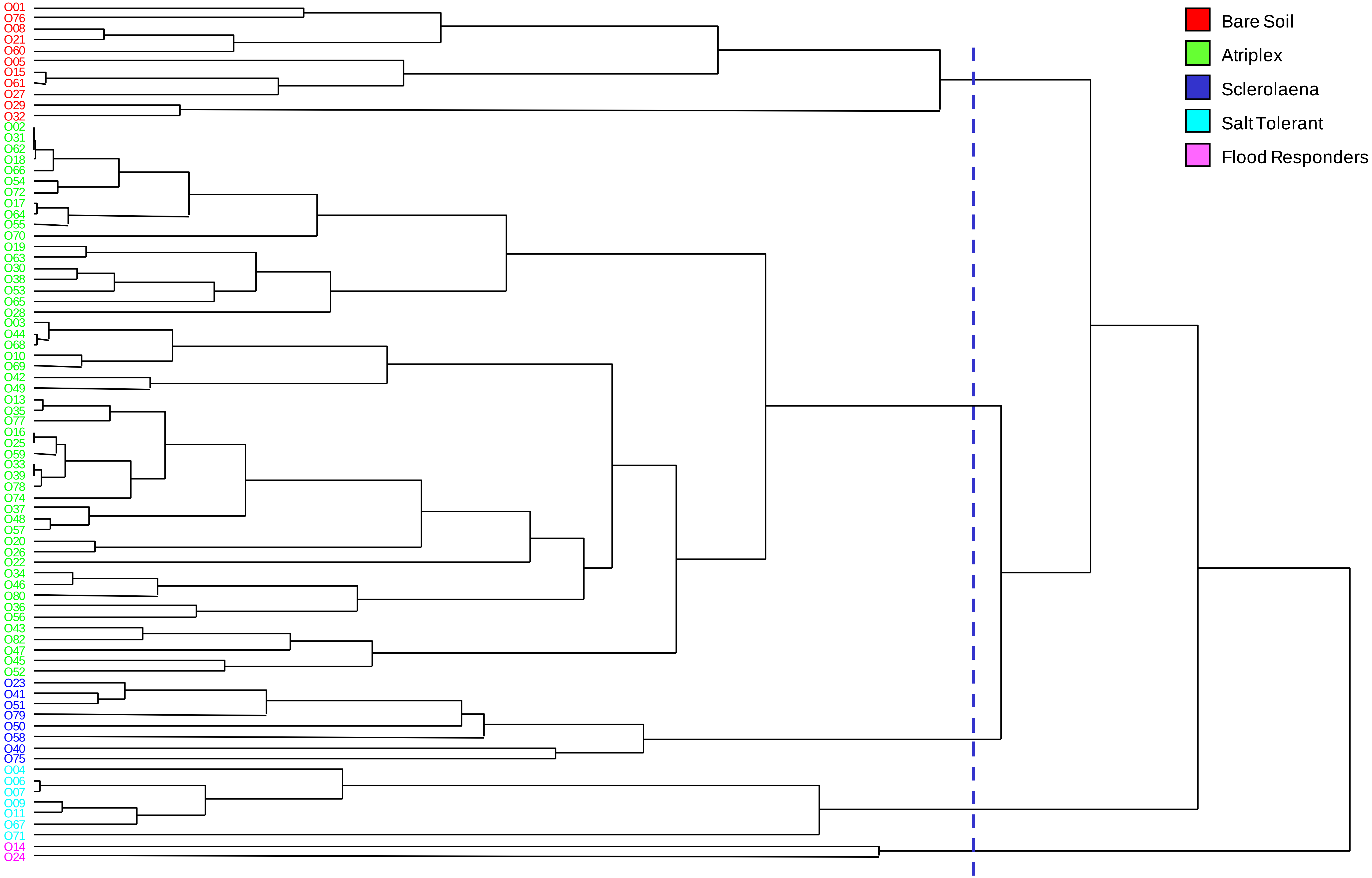

Figure 4: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2006 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 1: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=237) from the 2006 vegetation survey. Max. Group indicates group in which taxon had highest indicator value. P-value derived from Monte-Carlo test of significance (permutations=10,000). Significant (p<0.05) taxa are highlighted (*denotes exotic species).

Taxon	Max. Group	P-value
Alternanthera denticulata	Flood Responders	0.0252
Atriplex spp.	*Atriplex*	0.0001
Bare soil	Bare Soil	0.0001
Brachyscome basaltica	*Atriplex*	1.0000
Calotis hispidula	*Atriplex*	1.0000
Carpobrotus rossii	Salt Tolerant	0.0001
Centaurea sp.*	*Sclerolaena*	0.2781
Centipeda minima	Flood Responders	0.0004
Chenopodium nitrariaceum	*Atriplex*	1.0000
Craspedia chrysantha	*Sclerolaena*	0.1105
Cyperus gymnocaulos	Flood Responders	0.0007
Enchylaena tomentosa	*Sclerolaena*	0.3048
Eragrostis australasica	Flood Responders	0.0001
Euphorbia drummondii	Flood Responders	0.0001
Glinus lotoides	Flood Responders	0.0007
Halosarcia pergranulata ssp. *pergranulata*	Salt Tolerant	0.0585
*Heliotropium europaeum**	Flood Responders	0.0001
Maireana sp.	*Atriplex*	0.2817
Morgania floribunda	*Sclerolaena*	0.2144
Muehlenbeckia florulenta	Flood Responders	0.0835
Sclerolaena brachyptera	*Atriplex*	0.0001
Pachycornia triandra	Salt Tolerant	0.0001
Plantago turrifera	*Sclerolaena*	0.0672
*Polygonum aviculare**	*Sclerolaena*	0.2153
Sclerolaena divaricata	*Sclerolaena*	0.0001
*Solanum nigrum**	*Sclerolaena*	0.2173
Sporobolus mitchelli	Flood Responders	0.0001
Tetragonia tetragonioides	*Sclerolaena*	0.0687
Unknown daisy	Bare Soil	0.0788

The distribution of sites across the flood frequency gradient is shown in Figure 5. The distribution forms three easily identifiable modes, for classification of sites into flood frequency classes.

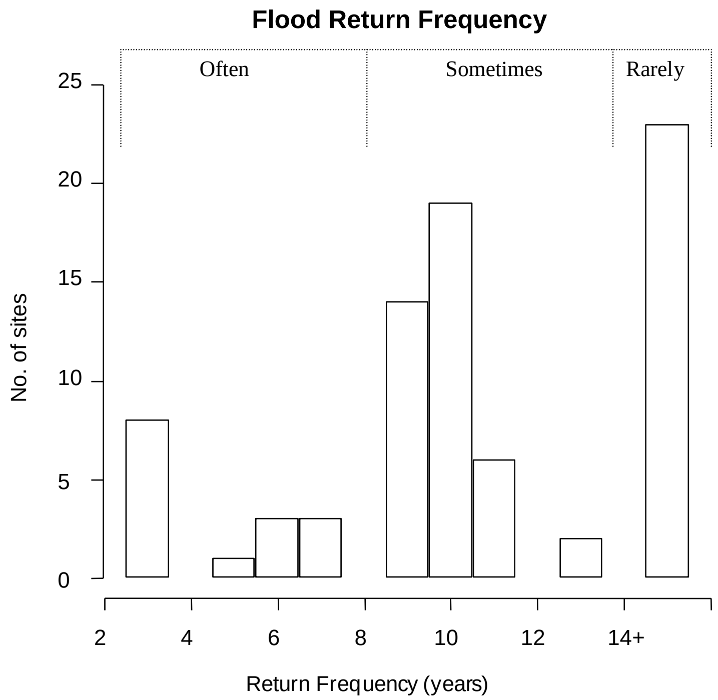

Figure 5: Distribution of all vegetation survey sites according to flood return frequency. Groupings show division into flood frequency classes used for contingency analysis.

The distribution of the sites according to their vegetation group and flood frequency class is summarised in Table 2. The Fisher's Exact Test for Count Data performed on this contingency table returned a P-value of 0.0237 allowing rejection of the null hypothesis of no relationship between flood frequency and vegetation type. The contingency plot (Figure 6) graphically summarises the results of this test. The positive association of "Salt Tolerant" sites with rarely flooded areas is the source of the deviation from the null hypothesis.

Table 2: Vegetation group distribution according to flood return frequency. Values indicate number of sites (*n*=79).

Vegetation Group	Flood Frequency		
	Often (1 in ≤ 5 years)	Sometimes (between 1 in 5 and 1 in 13 years)	Rarely (less often than 1 in 13 years)
Atriplex	7	35	9
Bare soil	1	5	5
Flood Responders	0	2	0
Salt Tolerant	0	1	6
Sclerolaena	1	4	3

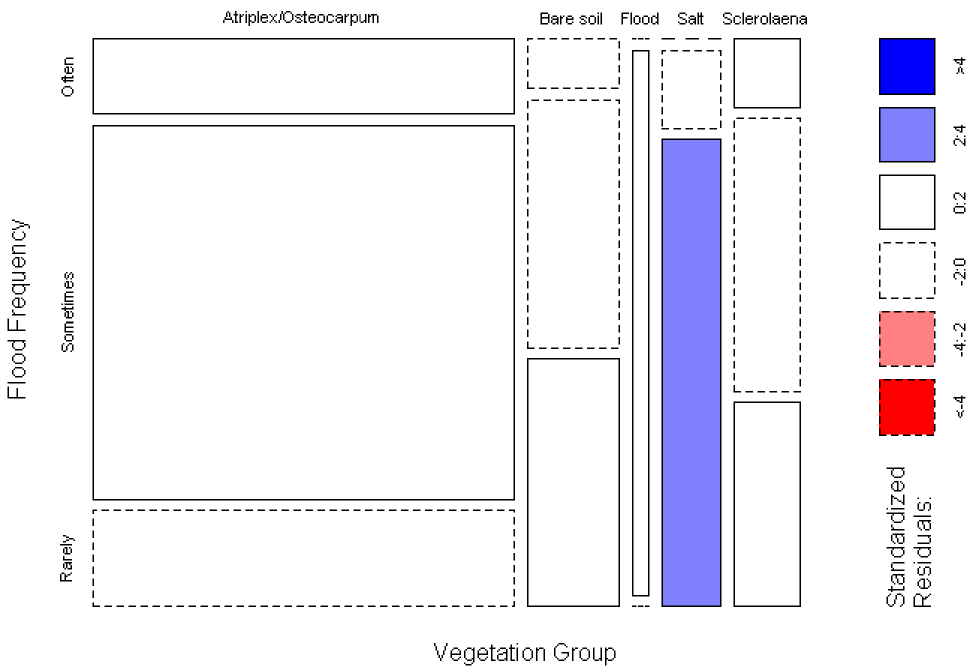

Figure 6: Contingency plot for Vegetation Group by Flood Frequency. Width of columns is proportional to group size; box size represents proportion of dendrogram group within each flood frequency class. Box outline and colour indicates standardised residuals from chi-squared style test. Residuals indicate the difference between observed values and those expected under H_0.

3.2. 2007 Survey

Figure 7 shows the spatial distribution and vegetation communities based on groupings identified from cluster analysis (Figure 8) of the 79 survey sites across the Chowilla Floodplain in 2007.

In 2007 a total of 48 taxa from 20 families were recorded across the 79 sites. The five most encountered taxa (accounting for 59% of all quadrat presences) were *Sclerolaena brachyptera*, *Atriplex* spp., *Carpobrotus rossii*, *Sclerolaena divaricata* and *Craspedia chrysantha.* All but *Carpobrotus rossii* (Aizoaceae) and *Craspedia chrysantha* (Asteraceae) are members of the Chenopodiaceae.

Cluster analysis separated sites into 5 groups at 30% similarity (Figure 8). This produced a manageable number of groups and reflected the major differences between sites. Indicator species analysis (Table 3) produced a list of representative taxa for each group, which were used to name the five groups according to their characteristic taxa:

1. "Bare soil" characterised by empty cells (14% of sites).
2. "*Sclerolaena brachyptera*" sites characterised by high abundances of *Sclerolaena brachyptera, Carpobrotus rossii* and *Pachycornia triandra* (64%).
3. "*Heliotropium*" sites characterised by *Heliotropium curassavicum*, and *Solanum esuriale* (4%).
4. "Flood responders" characterised by taxa that establish in response to flood events, including *Alternanthera denticulata, Ammannia multiflora, Atriplex* spp., *Centipeda minima, Cyperus gymnocaulos, Eleocharis acuta, Epaltes australis, Euphorbia drummondii, Goodenia gracilis, Heliotropium europaeum, Isolepis hookeriana, Marsilea angustifolia, Mimulus repens, Phyllanthus lacunaris* and *Sporobolus mitchelli* (10%). These sites were all inundated by pumping in spring 2006.
5. "*Sclerolaena*" sites characterised by the shrubs *Sclerolaena divaricata* and *Salsola kali* var. *kali* (8%).

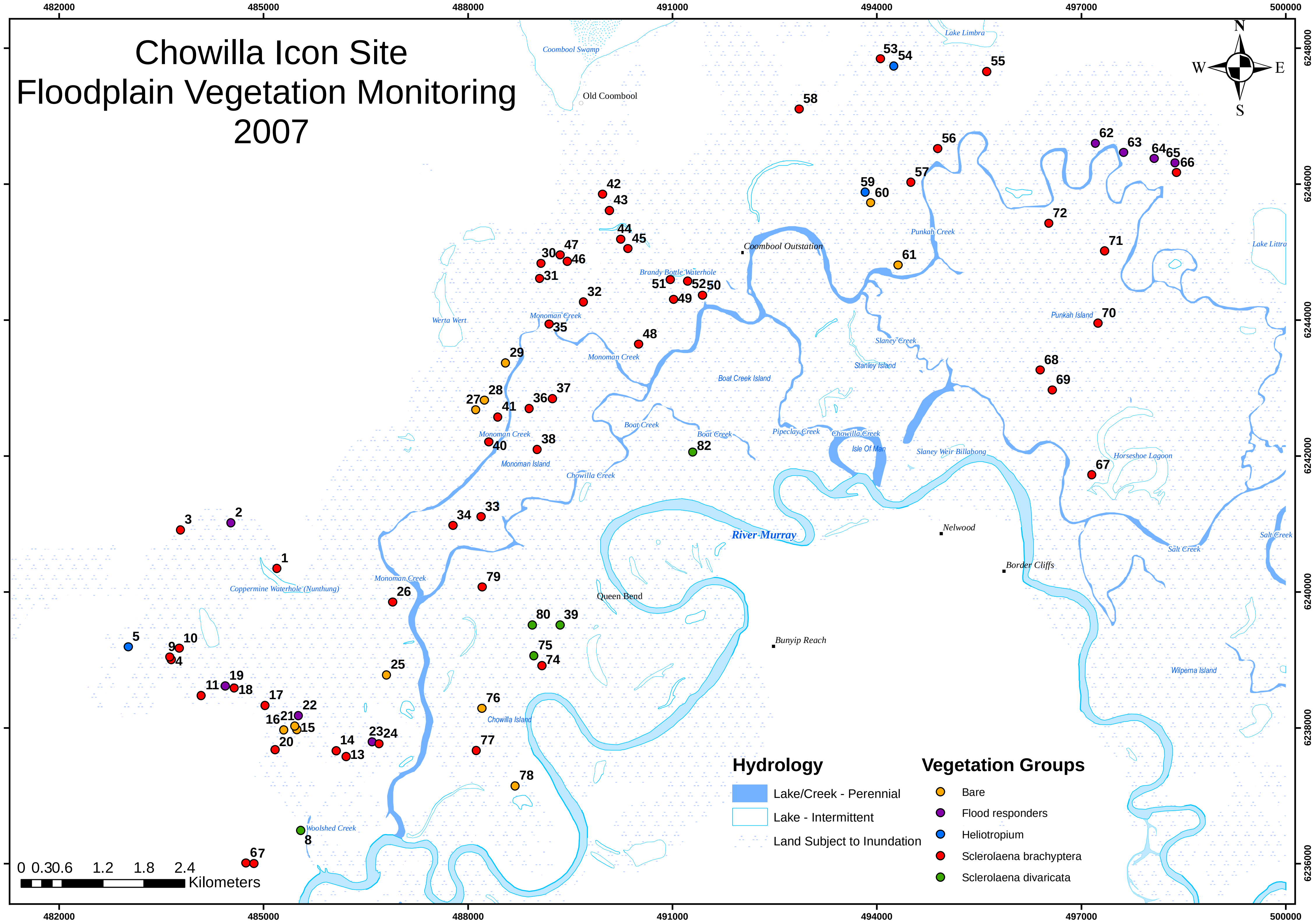

Figure 7: Spatial distribution and vegetation communities of the 79 survey sites across the Chowilla Floodplain for the 2007 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

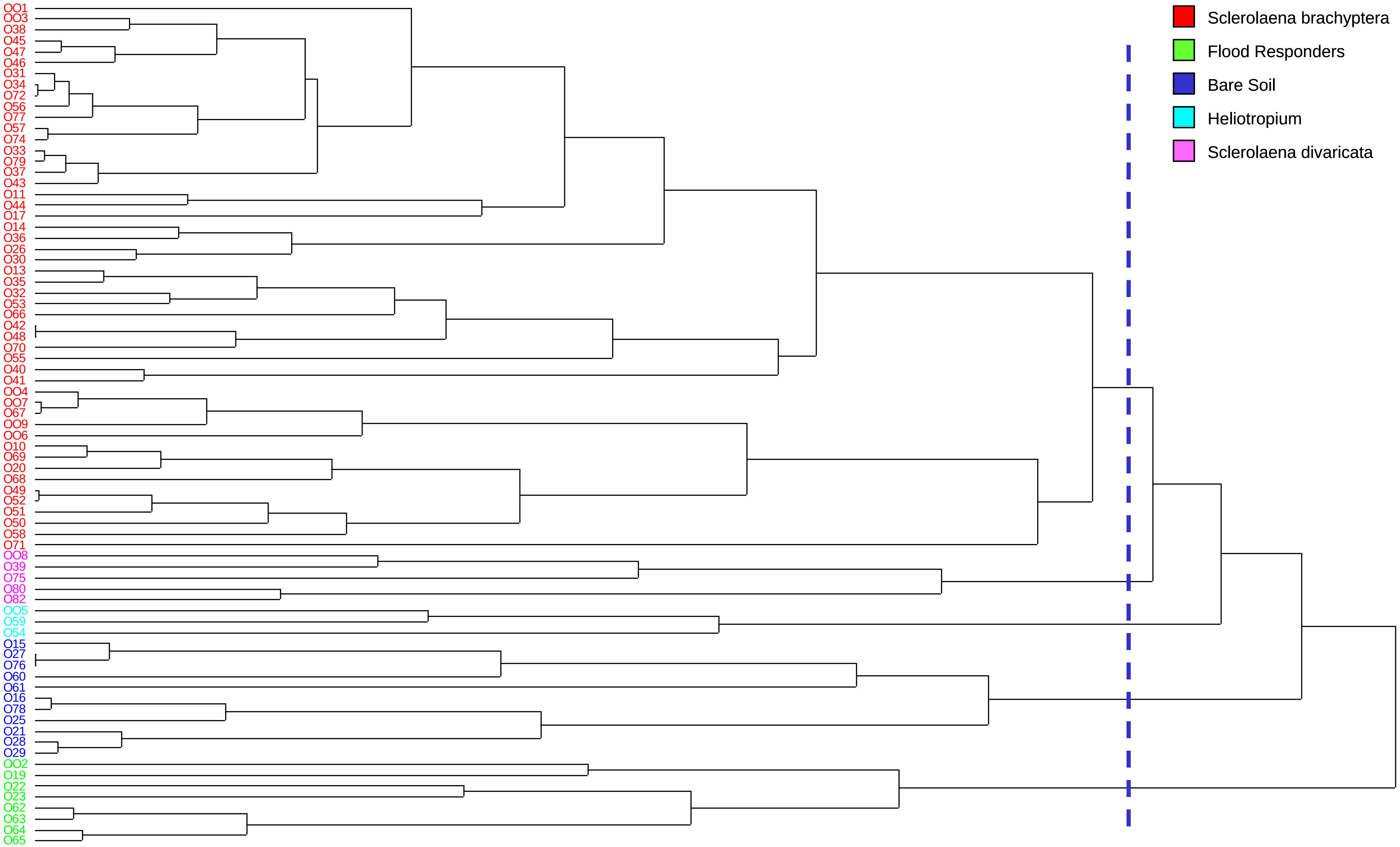

Figure 8: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2007 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 3: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=237) from the 2007 vegetation survey. Max. Group indicates group in which taxon had highest indicator value. P-value derived from Monte-Carlo test of significance (permutations=10,000). Significant ($p<0.05$) taxa are highlighted (*denotes exotic species).

Taxon	Max. Group	P-value
Alternanthera denticulata	Flood Responder	0.0002
Ammannia multiflora	Flood Responder	0.0002
Atriplex spp.	Flood Responder	0.0002
Bare soil	Bare Soil	0.0002
Brachyscome basaltica	Flood Responder	0.4585
Calotis hispidula	Flood Responder	0.2501
Carpobrotus rossii	*Sclerolaena brachyptera*	0.0008
Centipeda minima	Flood Responder	0.0002
Chenopodium nitrariaceum	*Sclerolaena brachyptera*	1
Chenopodium pumilio	Flood Responder	0.2142
*Citrullus lanatus**	Flood Responder	0.2094
Craspedia chrysantha	*Sclerolaena brachyptera*	0.2725
Cyperus gymnocaulos	Flood Responder	0.0002
Eleocharis acuta	Flood Responder	0.0108
Epaltes australis	Flood Responder	0.009
Eremophila scoparia	Flood Responder	0.8726
Euphorbia drummondii	Flood Responder	0.0244
Glinus lotoides	Flood Responder	0.1256
Goodenia gracilis	Flood Responder	0.004
Grass 1	*Sclerolaena brachyptera*	1
Haloragis aspera	*Heliotropium*	0.0564
Halosarcia pergranulata ssp. *pergranulata*	*Sclerolaena brachyptera*	0.7111
*Heliotropium amplexicaule**	*Heliotropium*	0.0682
*Heliotropium curassavicum**	*Heliotropium*	0.0372
*Heliotropium europaeum**	Flood Responder	0.0112
Isolepis hookeriana	Flood Responder	0.0004
Ixiolaena brevicompta	*Sclerolaena brachyptera*	1
Lachnagrostis filiformis	*Sclerolaena divaricata*	0.2114
Maireana sp.	*Sclerolaena divaricata*	0.1304
*Malva parviflora**	*Sclerolaena brachyptera*	1
Marsilea angustifolia	Flood Responder	0.0038
Mimulus repens	Flood Responder	0.009
Mollugo cerviana	Flood Responder	0.0076
Muehlenbeckia florulenta	*Heliotropium*	0.1514
Pachycornia triandra	*Sclerolaena brachyptera*	0.0516
Phyllanthus lacunaris	Flood Responder	0.0178
Plantago turrifera	Flood Responder	0.2022
*Polygonum aviculare**	Flood Responder	0.1998
Salsola kali var. *kali*	*Sclerolaena divaricata*	0.0032
Scleroblitum atriplicinum	Bare Soil	0.1898
Sclerolaena brachyptera	*Sclerolaena brachyptera*	0.0002
Sclerolaena divaricata	*Sclerolaena divaricata*	0.0002
Solanum esuriale	*Heliotropium*	0.0384
Solanum oligacanthum	Flood Responder	0.811
Sporobolus mitchelli	Flood Responder	0.0002
Tetragonia tetragonioides	*Sclerolaena brachyptera*	0.9136
Unknown Brassicaceae	*Sclerolaena brachyptera*	1
Unknown daisy	*Sclerolaena divaricata*	0.5247
*Xanthium occidentale**	Flood Responder	0.1976

3.3. 2008 Survey

Figure 9 shows the spatial distribution and vegetation communities based on groupings identified from cluster analysis (Figure 10) of the 82 survey sites across the Chowilla Floodplain in 2008.

A total of 21 taxa from eight families were recorded across the 82 sites. The five most frequently encountered taxa (accounting for 73% of all quadrat presences) were *Sclerolaena brachyptera*, *Atriplex* spp., bare soil, *Sclerolaena stelligera* and *Carpobrotus rossii* All but *Carpobrotus rossii* (Aizoaceae) and bare soil are members of the Chenopodiaceae.

Cluster analysis separated sites into 5 groups at 30% similarity (Figure 10), which reflected the major differences between sites. Indicator Species Analysis (Table 4) produced a list of representative taxa for each group, which were used to name the five groups according to their characteristic taxa:

1. "Bare soil" characterised by empty cells (24% of sites).
2. "*Sclerolaena brachyptera*" sites characterised by high abundances of *Sclerolaena brachyptera* and *Sclerolaena stelligera* (34%).
3. "*Atriplex*" sites characterised by *Atriplex* spp. and *Sporobolus mitchelli* (16%).
4. "Salt Tolerant" sites characterised by the salt tolerant taxa *Carpobrotus rossii* and *Pachycornia triandra* (23%).
5. "*Sclerolaena*" sites characterised by the shrubs *Sclerolaena divaricata* and *Enchylaena tomentosa* (3%).

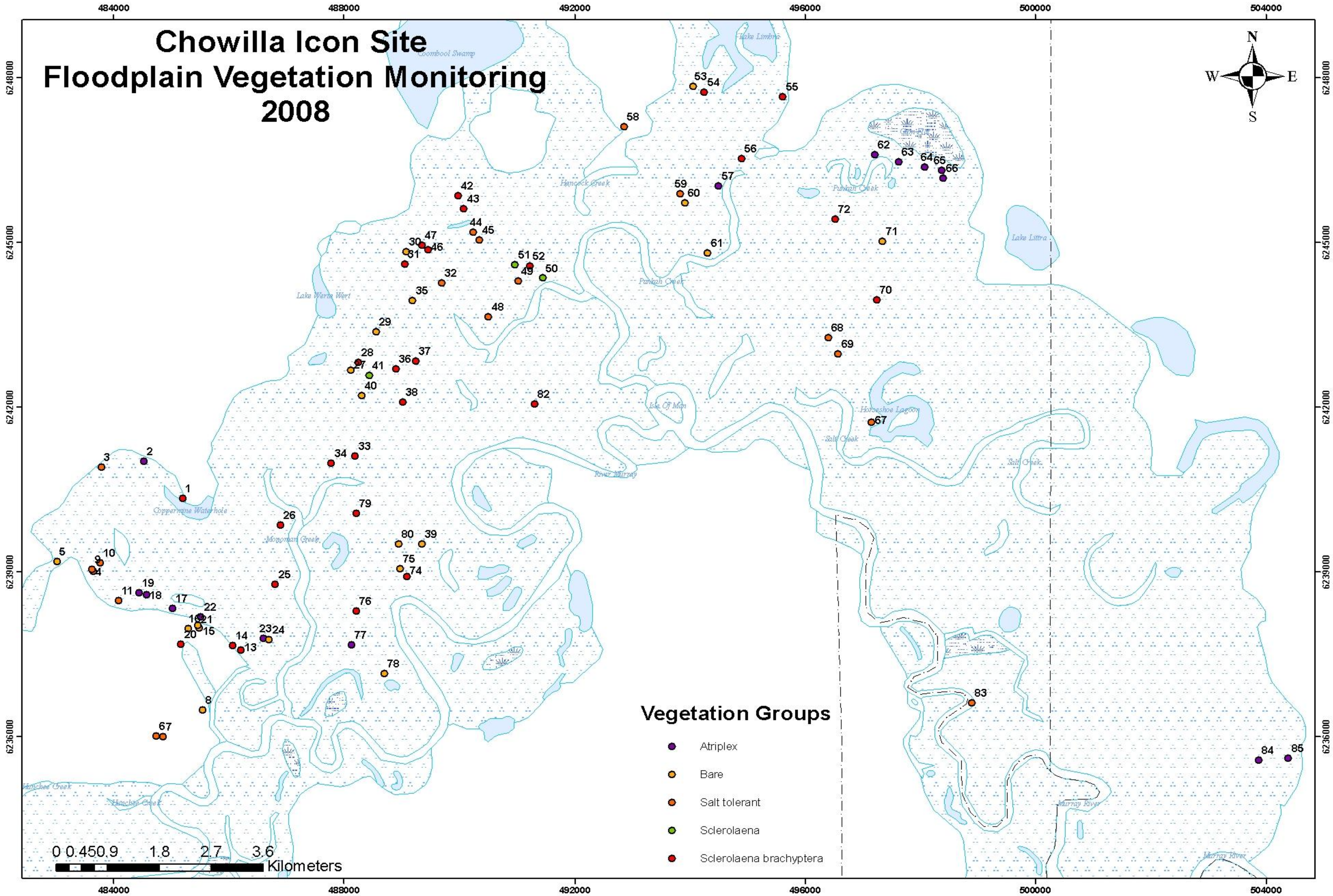

Figure 9: Spatial distribution and vegetation communities of the 82 survey sites across the Chowilla Floodplain for the 2008 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

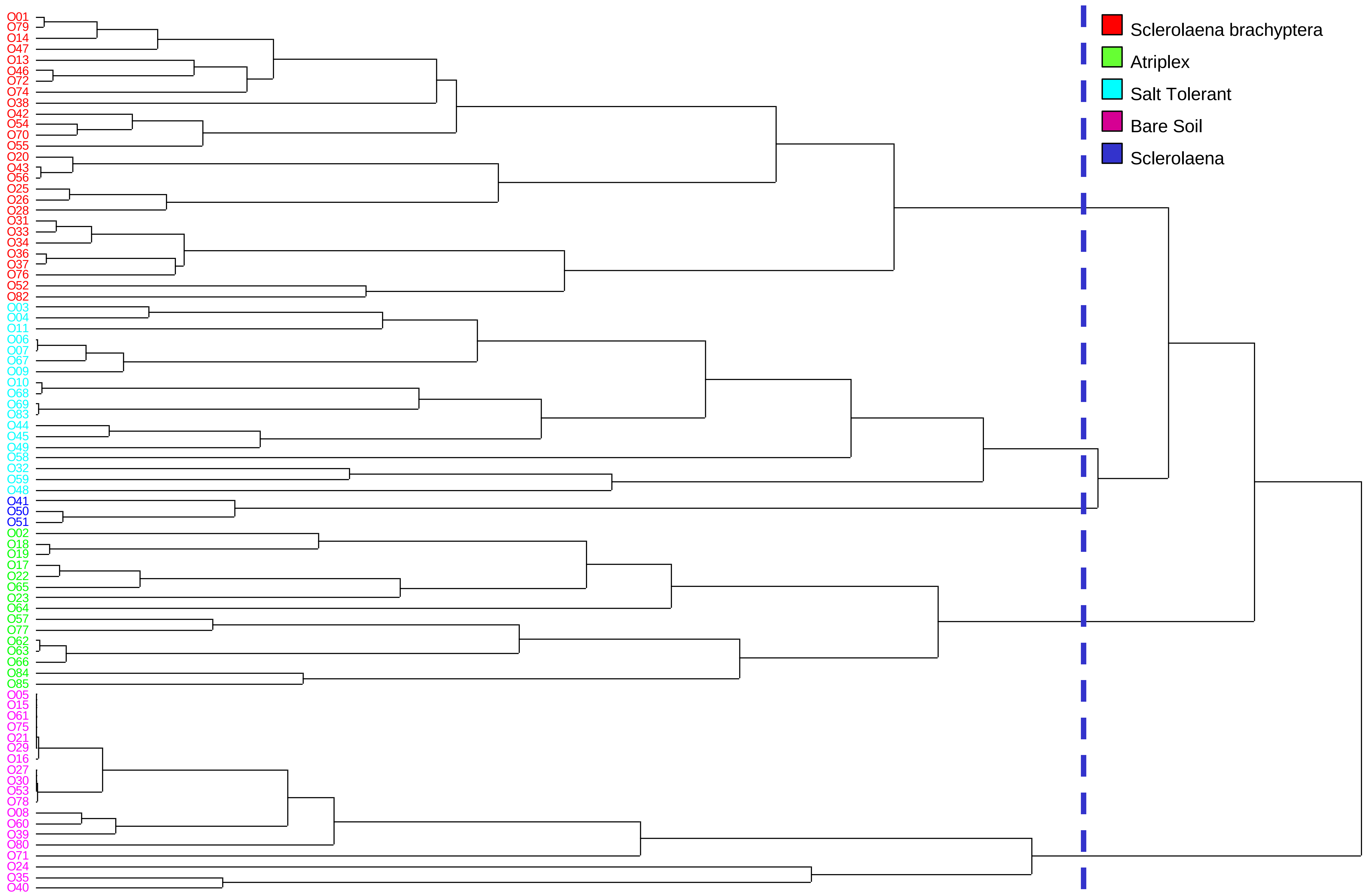

Figure 10: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2008 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 4: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=246) from the 2008 vegetation survey. Max. Group indicates group in which taxon had highest indicator value. P-value derived from Monte-Carlo test of significance (permutations=10,000). Significant (p<0.05) taxa are highlighted (*denotes exotic species).

Taxon	Max. Group	P-value
Atriplex spp.	*Atriplex*	0.0002
Bare soil	Bare Soil	0.0002
Brachyscome basaltica	*Atriplex*	0.0728
Carpobrotus rossii	Salt Tolerant	0.0002
Chenopodium nitrariaceum	Salt Tolerant	0.1598
Craspedia chrysantha	*Sclerolaena brachyptera*	0.2374
Enchylaena tomentosa	*Sclerolaena*	0.0332
Eragrostis australasica	Atriplex	0.223
Frankenia pauciflora	*Sclerolaena brachyptera*	0.5351
Halosarcia pergranulata	Salt Tolerant	0.6833
Maireana sp.	*Atriplex*	0.0934
Muehlenbeckia florulenta	*Atriplex*	0.1576
Pachycornia triandra	Salt Tolerant	0.0004
Rhagodia spinescens	*Sclerolaena brachyptera*	1
Salsola kali var. *kali*	Salt Tolerant	0.9212
Sclerolaena brachyptera	*Sclerolaena brachyptera*	0.0004
Sclerolaena divaricata	*Sclerolaena*	0.0002
Sclerolaena stelligera	*Sclerolaena brachyptera*	0.0002
Solanum oligacanthum	*Sclerolaena brachyptera*	1
Sporobolus mitchelli	*Atriplex*	0.0002
Unknown Dicot 1	Salt Tolerant	0.1514
Wahlenbergia fluminalis	Salt Tolerant	0.7383

3.4. 2009 Survey

Figure 11 shows the spatial distribution and vegetation communities based on groupings identified from cluster analysis (Figure 12) of the 80 survey sites across the Chowilla Floodplain in 2009.

A total of 17 taxa from six families were recorded across the 80 sites. The most frequently encountered species was *Sclerolaena brachyptera,* which accounted for 22.5% of all quadrat presences. Also abundant were *Sclerolaena stelligera, Atriplex* spp. and *Carpobrotus rossii* which cumulatively accounted for 49% of all quadrat presences. All species but *Carpobrotus rossii* (Aizoaceae) are members of the Chenopodiaceae. Of the 3,600 1 x 1 m cells surveyed, approximately 15% were found to be devoid of vegetation and classified as bare soil.

Cluster analysis separated sites into 5 groups at 30% similarity (Figure 12), which reflected the major differences between sites. Indicator Species Analysis (Table 5) produced a list of representative taxa for each group, which were used to name the five groups according to their characteristic taxa:

1. "Bare soil" characterised by empty cells (27.5% of sites).

2. "*Sclerolaena brachyptera*" sites characterised by high abundances of *Sclerolaena brachyptera* (51.5%).

3. "*Atriplex*" sites characterised by *Atriplex* spp., and *Sclerolaena divaricata* (6.25%).

4. "Salt Tolerant" sites characterised by the salt tolerant taxa *Carpobrotus rossii* and *Pachycornia triandra* (13.75%).

5. "*Maireana/Salsola kali*" site characterised by the shrubs *Maireana* sp. and *Salsola kali* var. *kali* (1%).

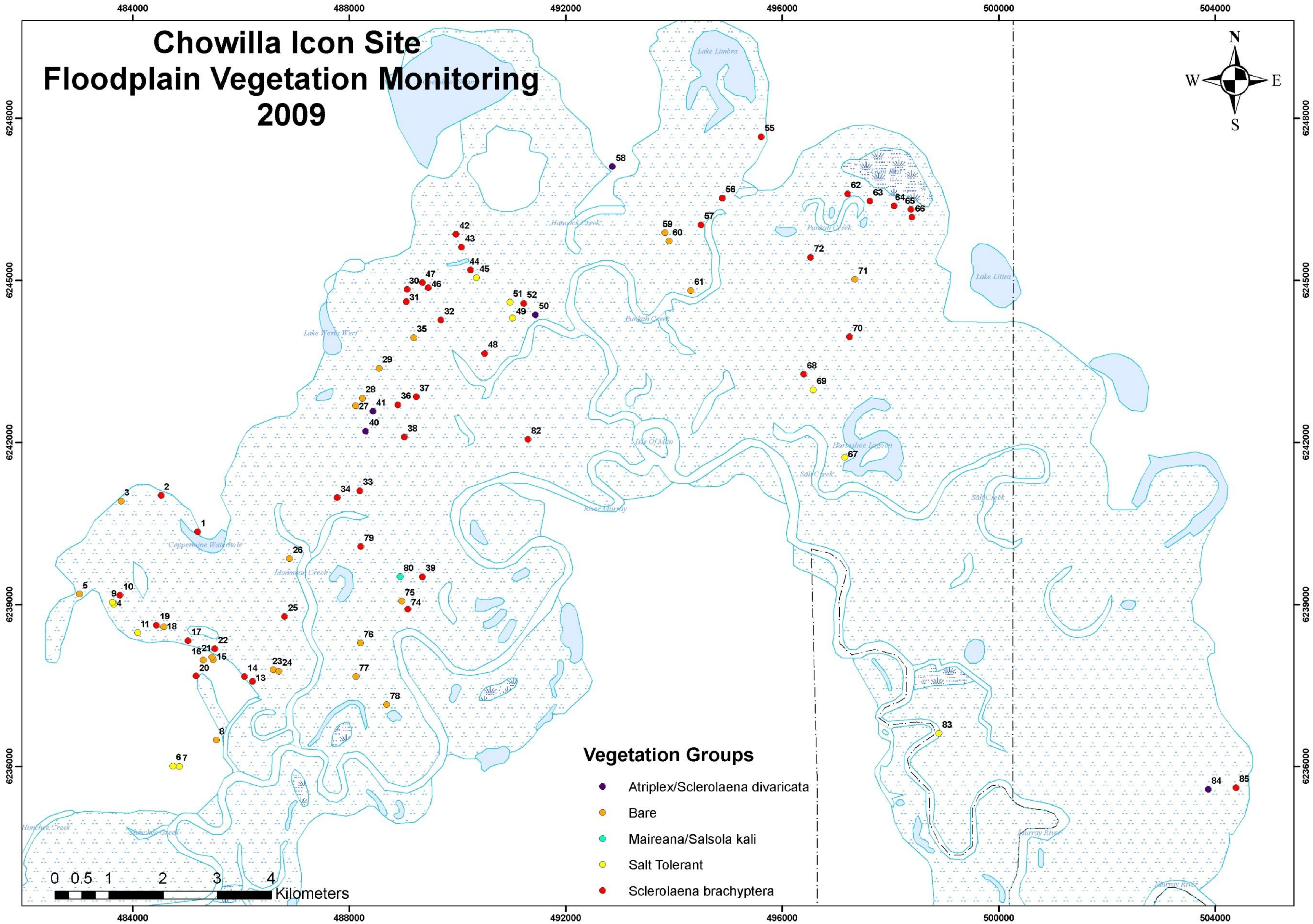

Figure 11: Spatial distribution and vegetation communities of the 80 survey sites across the Chowilla Floodplain for the 2009 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

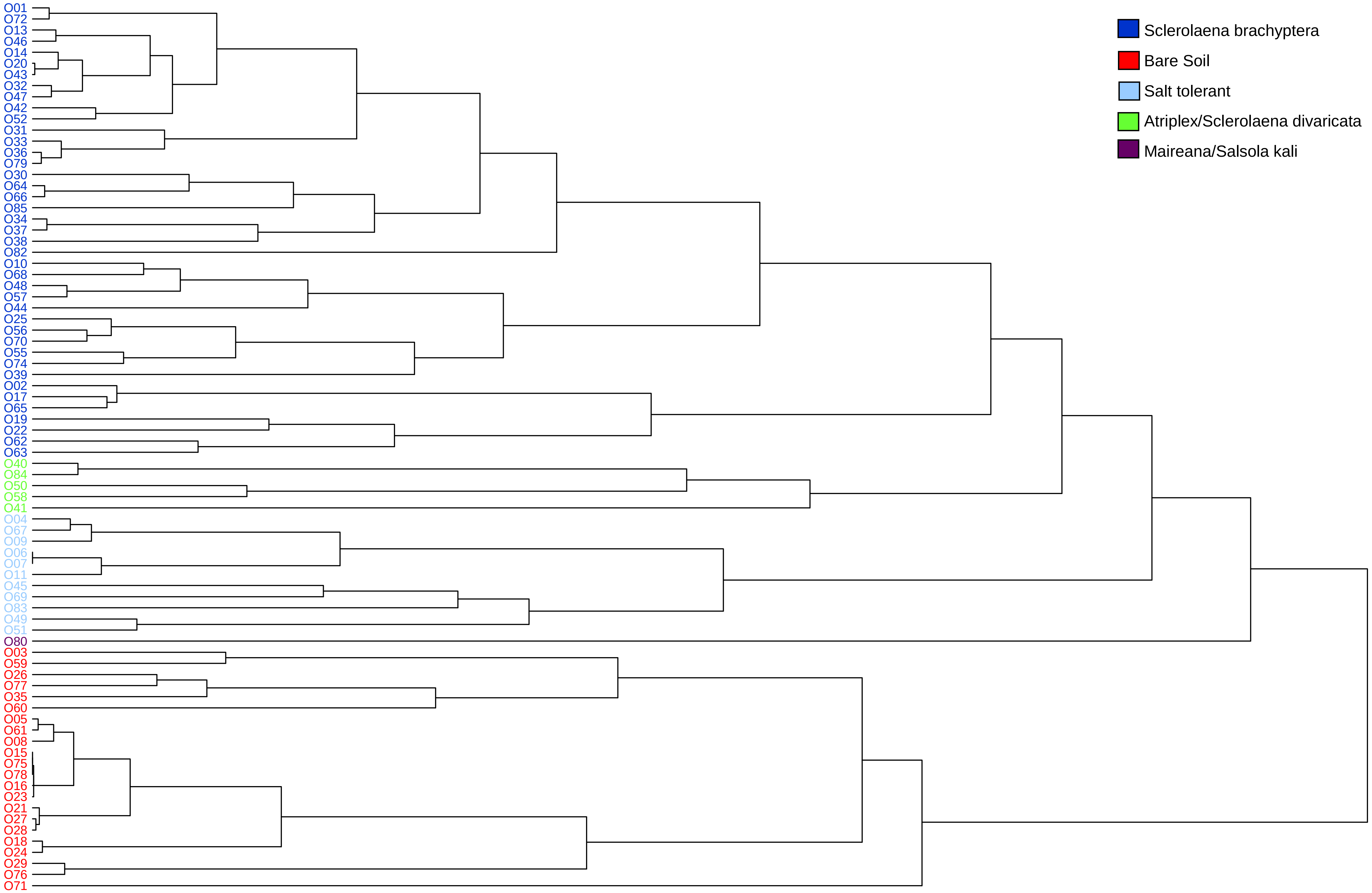

Figure 12: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2009 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 5: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=240) from the 2009 vegetation survey. Max. Group indicates group in which taxon had highest indicator value. P-value derived from Monte-Carlo test of significance (permutations=10,000). Significant (*p*<0.05) taxa are highlighted (*denotes exotic species).

Taxon	Max. Group	P-value
Atriplex spp.	*Atriplex/Sclerolaena divaricata*	0.0256
Bare soil	Bare Soil	0.0002
Carpobrotus rossii	Salt Tolerant	0.0002
Chenopodium nitrariaceum	Salt Tolerant	0.2206
Frankenia pauciflora	*Maireana/Salsola*	0.0782
Halosarcia pergranulata	Bare	0.2004
*Heliotropium europaeum**	Bare	0.4859
Maireana sp.	*Maireana/Salsola*	0.0024
Muehlenbeckia florulenta	*Sclerolaena brachyptera*	1.000
Pachycornia triandra	Salt Tolerant	0.0056
Rhagodia spinescens	*Atriplex/Sclerolaena divaricata*	0.0694
Salsola kali var. *kali*	*Maireana/Salsola*	0.0002
Sclerolaena brachyptera	*Sclerolaena brachyptera*	0.0002
Sclerolaena divaricata	*Atriplex/Sclerolaena divaricata*	0.0002
Sclerolaena stelligera	*Maireana/Salsola*	0.1102
Sporobolus mitchelli	*Sclerolaena brachyptera*	0.1606
Unknown 1	*Atriplex/Sclerolaena divaricata*	0.7025

3.5. 2010 Survey

Figure 13 shows the spatial distribution and vegetation communities based on groupings identified from cluster analysis (Figure 14) of the 74 survey sites across the Chowilla Floodplain in 2010.

Following re-watering of the Coppermine Complex and Gum Flat areas in spring 2009, the total number of species recorded more than doubled (compared to the 2009 survey); with a total of 42 species from 19 families across the 74 sites surveyed. The five most frequently encountered species did not differ from 2008 and 2009: *Sclerolaena brachyptera*, *Atriplex* spp., *Sclerolaena stelligera, Carpobrotus* spp. and bare soil, which accounted for 64% of all quadrat presences. Of the 2,115, 1 x 1 m cells surveyed, approximately 6% were found to be devoid of vegetation and classified as bare soil (less than half the number of bare cells recorded in 2009).

Cluster analysis produced five significantly different groups (at 30% similarity, Figure 14), although one group included a single site only. These groups reflected major differences between sites, and Indicator Species Analysis (Table 6) produced a list of representative taxa for each group:

1. "*Sclerolaena brachyptera*" sites were characterised by high abundances of *Sclerolaena brachyptera* and *Sclerolaena stelligera* (47.19% of sites).

2. "Gum Flat" sites were characterised by taxa: *Atriplex* spp., *Sporobolus mitchelli* and *Craspedia chrysantha* (22.60%).

3. "Coppermine Complex" sites were characterised by the flood responder taxa: *Cyperus difformis, Marsilea angustifolia, Eleocharis acuta* and *Ammannia multiflora* (18.60 %).

4. "Bare soil" sites were predominantly characterised by empty cells and occasional occurrences of *Muehlenbeckia horrida* and *Brachyscome dentata* (6.22%).

5. "*Sclerolaena divaricata*" site was characterised by *Sclerolaena divaricata* and *Phyllanthus lacunaris* (5.39%).

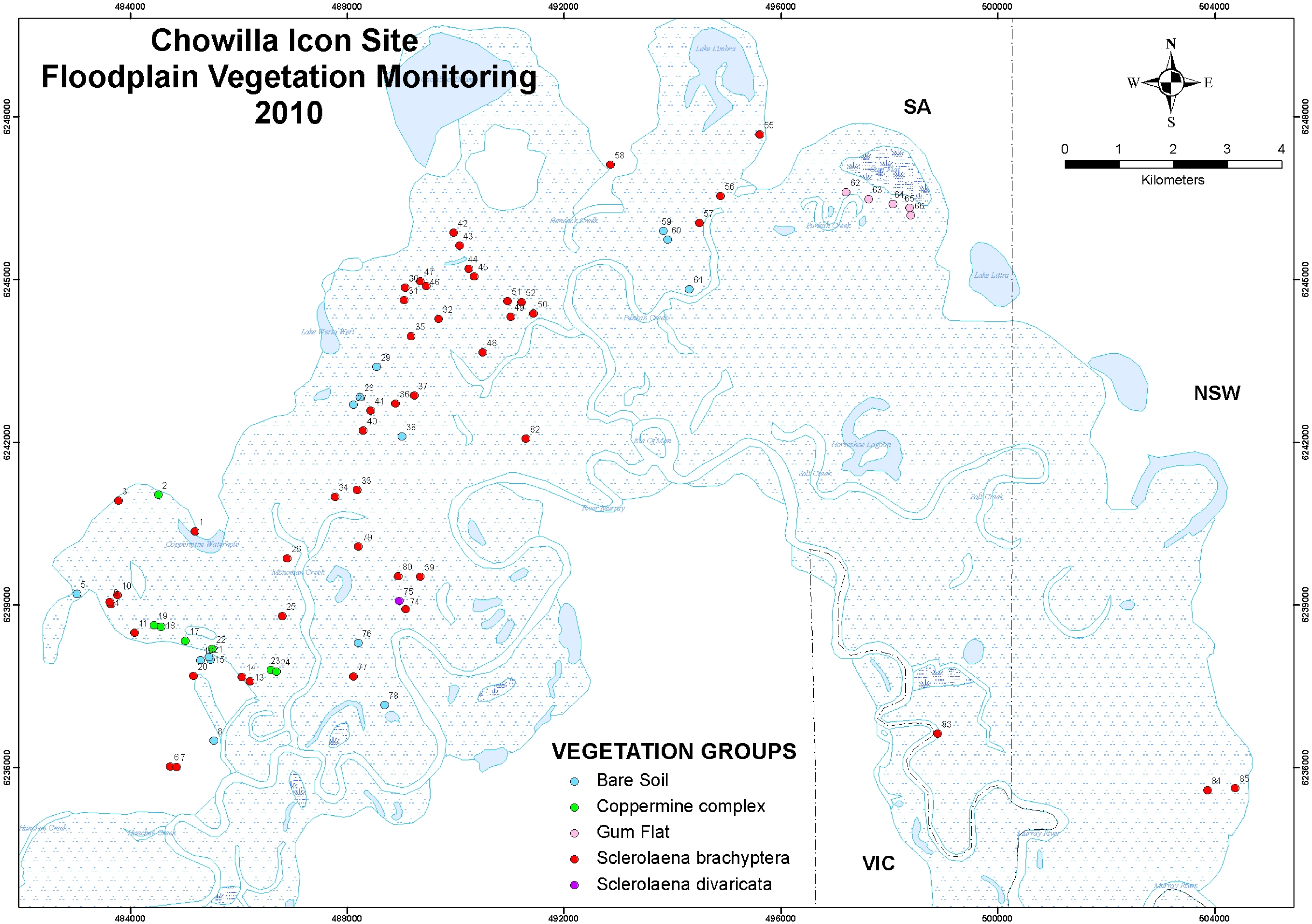

Figure 13: Spatial distribution and vegetation communities of the 74 survey sites across the Chowilla Floodplain for the 2010 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

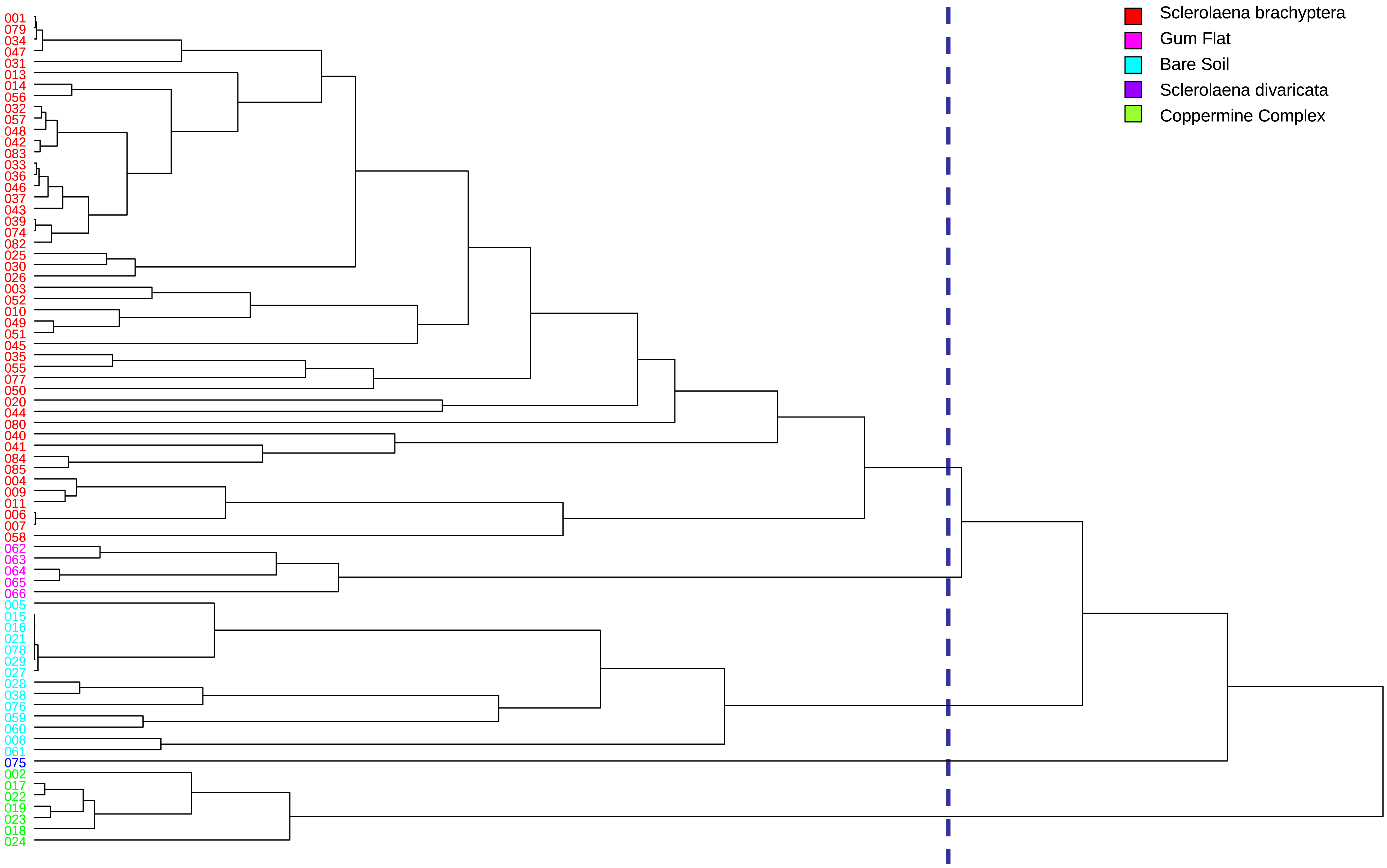

Figure 14: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2010 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 6: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (n=222) from the 2010 vegetation survey. Max. Group indicates group in which taxon had highest indicator value. P-value derived from Monte-Carlo test of significance (permutations=10,000). Significant (p<0.05) taxa are highlighted (*denotes exotic species).

Taxon	Max. Group	P-value
Alternanthera denticulata	Gum Flat	0.1075
Ammannia multiflora	Coppermine Complex	0.0001
Atriplex spp.	Gum Flat	0.0001
Bare Soil	Bare Soil	0.0001
Brachyscome basaltica	Gum Flat	0.0415
Brachyscome dentata	Bare Soil	0.9305
Calotis scapigera	Gum Flat	0.1268
Carpobrotus rossii	*Sclerolaena brachyptera*	0.0234
Centipeda minima	Coppermine Complex	0.0500
*Centaurium tenuiflorum**	*Sclerolaena brachyptera*	1.0000
Chenopodium nitrariaceum	*Sclerolaena brachyptera*	1.0000
*Conyza bonariensis**	Gum Flat	0.0785
Craspedia chrysantha	Gum Flat	0.0001
Cyperus difformis	Coppermine Complex	0.0001
Eleocharis acuta	Coppermine Complex	0.0001
Enchylaena tomentosa var. *tomentosa*	Gum Flat	0.1443
Eragrostis australasica	Coppermine Complex	0.0855
Frankenia pauciflora	*Sclerolaena brachyptera*	0.4562
Goodenia gracilis	Gum Flat	0.5078
*Heliotropium europaeum**	Coppermine Complex	0.0412
Isolepis hookeriana	Coppermine Complex	0.0289
Maireana microcarpa	*Sclerolaena brachyptera*	0.2596
Marsilea angustifolia	Coppermine Complex	0.0001
Mimulus repens	Coppermine Complex	0.0001
Muehlenbeckia florulenta	*Sclerolaena brachyptera*	1.0000
Muehlenbeckia horrida	Bare Soil	0.1751
Osteocarpum acropterum ssp. *acropterum*	Gum Flat	0.0319
Pachycornia triandra	*Sclerolaena brachyptera*	0.2031
*Phyla canescens**	*Sclerolaena brachyptera*	1.0000
Phyllanthus lacunaris	*Sclerolaena divaricata*	0.0006
*Polypogon monspeliensis**	Coppermine Complex	0.0490
Polygonum plebeium	Gum Flat	0.0309
Rhagodia spinescens	*Sclerolaena brachyptera*	1.0000
Salsola kali var. *kali*	*Sclerolaena brachyptera*	0.6349
Sclerolaena divaricata	*Sclerolaena divaricata*	0.0002
Sclerolaena stelligera	*Sclerolaena brachyptera*	0.0001
Sclerolaena brachyptera	*Sclerolaena brachyptera*	0.0001
Senecio runcinifolius	Gum Flat	0.0800
Sida ammophila	*Sclerolaena brachyptera*	1.0000
Solanum esuriale	Coppermine Complex	0.2340
Sporobolus mitchelli	Gum Flat	0.0007
Tetragonia tetragonioides	*Sclerolaena brachyptera*	1.0000
Typha domingensis	Coppermine Complex	0.0500

3.6. 2011 Survey

Figure 15 shows the spatial distribution and vegetation community based on groupings identified from cluster analysis (Figure 16) of the 67 survey sites across the Chowilla Floodplain in 2011.

Following flooding in 2010/11, the total number of species recorded increased by more than 50% (compared to the 2010 survey); with a total of 66 species, from 28 families, across the 67 sites surveyed. The five most frequently encountered species were *Atriplex* spp., *Sclerolaena stelligera, Ammannia multiflora*, *Carpobrotus rossii* and *Sporobolus mitchelli*, accounting for 42.5% of all quadrats surveyed. Of the 3,015, 1 x 1 m cells surveyed, approximately 1.5% were found to be devoid of vegetation, the lowest number recorded since surveys began in 2006.

Cluster analysis produced seven significantly different groups (at 30% similarity, Figure 16), although two groups included a single site. These groups reflected major differences between sites, and Indicator Species Analysis (Table 7) produced a list of representative taxa for each group:

1. "*Carpobrotus*" sites were characterised by salt tolerant and desiccation tolerant species: *Carpobrotus rossii* and *Pachycornia triandra* (32.7% of sites),

2. "*Ammannia*" sites were characterised by amphibious species: *Ammannia multiflora* and *Mimulus repens* (25.4%),

3. "*Tetragonia/Centipeda*" sites were characterised by floodplain species: *Tetragonia tetragonioides*, *Centipeda minima*, *Senecio runcinifolius*, *Plantago cunninghamii*, *Sporobolus mitchelli*, *Rorippa palustris** and *Psuedognaphalium luteo-album* (20.9%),

4. "*Marsilea/Eleocharis*" sites were characterised by amphibious, floodplain or salt tolerant species: *Marsilea angustifolia*, *Eleocharis acuta*, *Spergularia marina* and *Calotis scapigera* (10.5%),

5. "Bare soil" sites were predominantly characterised by empty cells (7.5 % of sites),

6. "*Craspedia/Salsola*" sites were characterised by terrestrial, salt tolerant or floodplain species: *Craspedia chrysantha*, *Salsola kali, Scleroblitum atriplicinum* and *Enchylaena tomentosa* (1.5%),

7. "*Sclerolaena brachyptera*" were characterised by *Sclerolaena brachyptera*, *Brachyscome basaltica* and *Taraxacum officinale* (1.5% of sites).

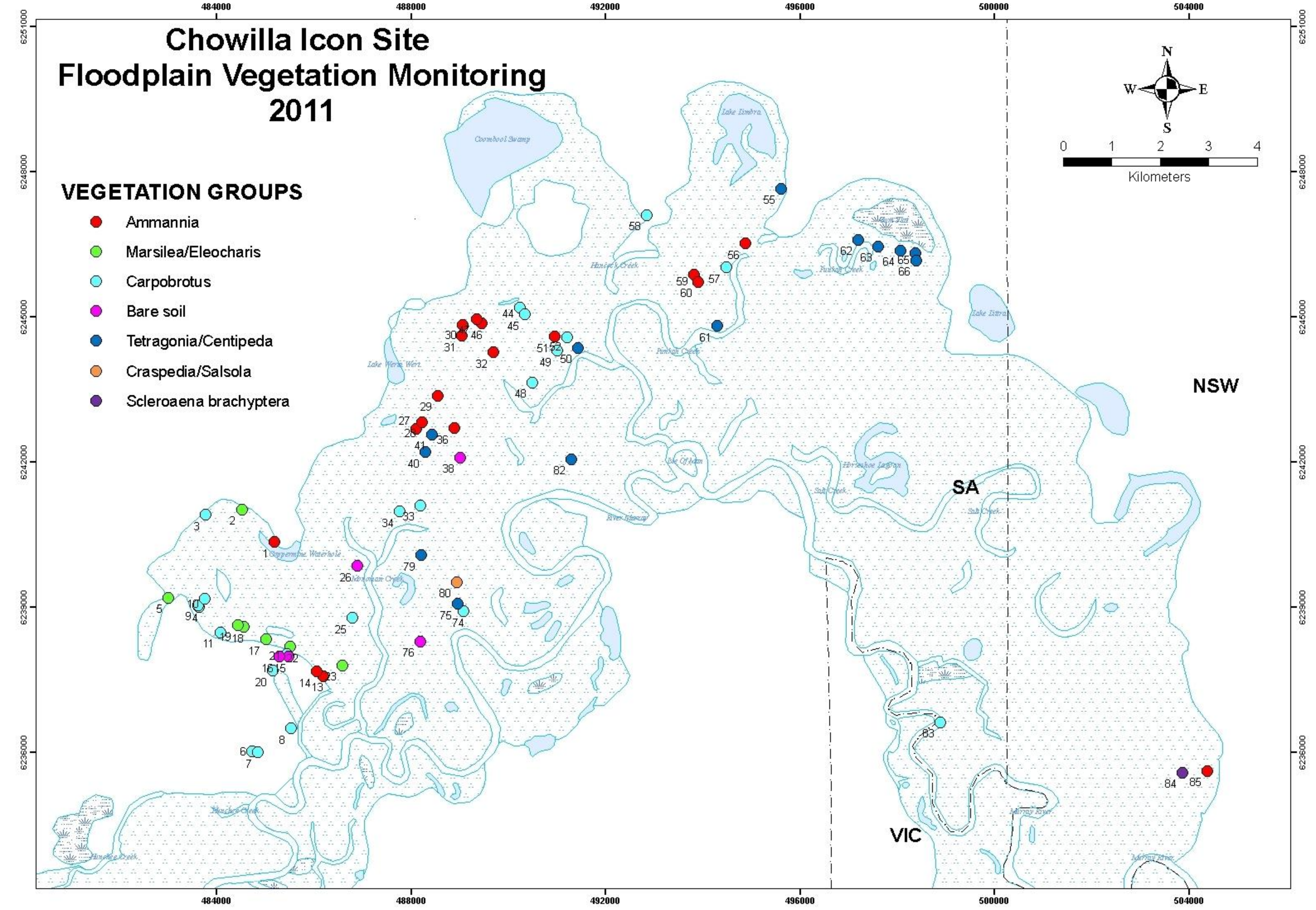

Figure 15: Spatial distribution and vegetation communities of the 67 survey sites across the Chowilla Floodplain for the 2011 survey. Colours refer to 2011 dendrogram groupings.

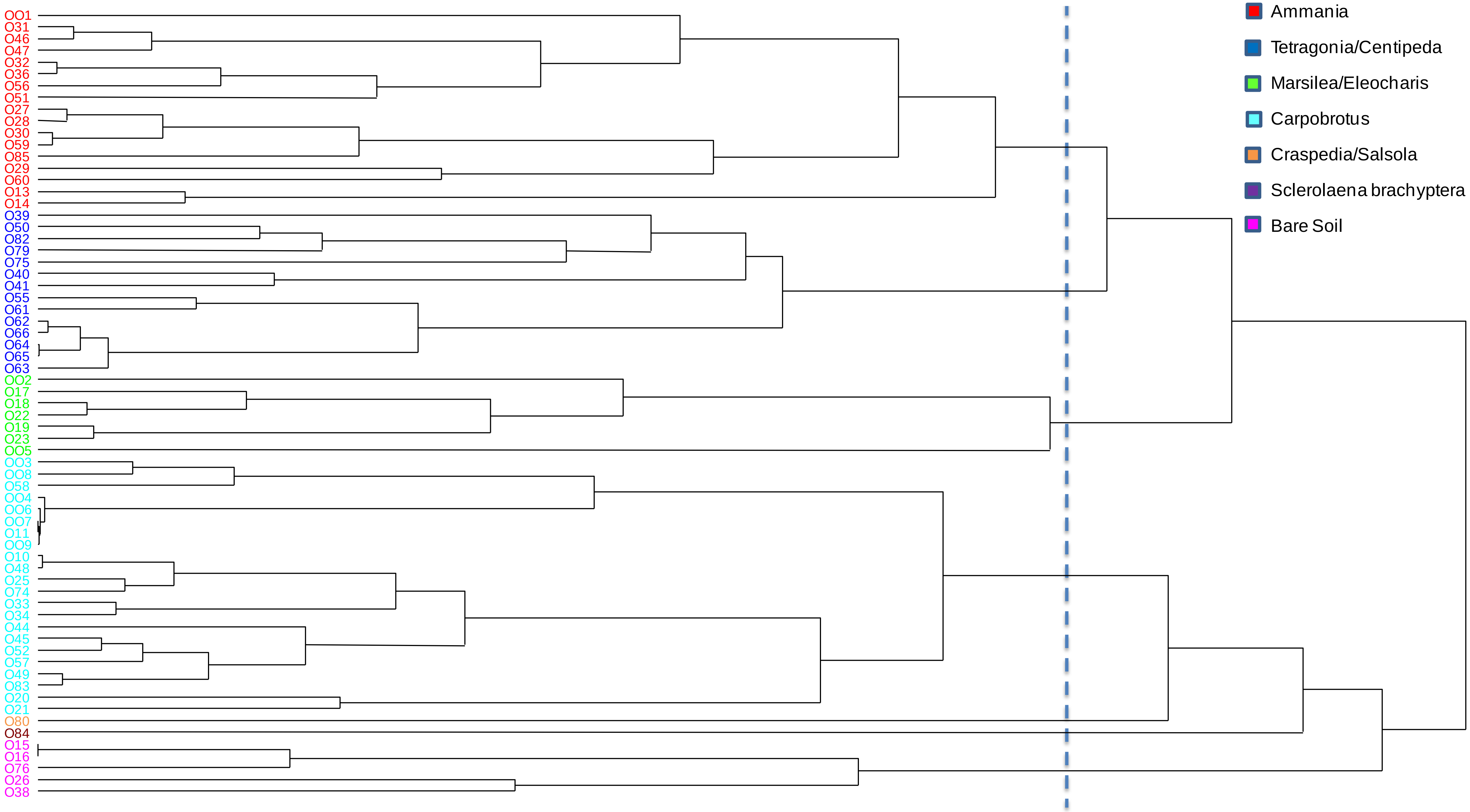

Figure 16: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2011 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 7: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=201) from the 2011 vegetation survey. Max. Group indicates group in which taxon had highest indicator value. P-value derived from Monte-Carlo test of significance (permutations=10,000). Significant (*p*<0.05) taxa are highlighted (*denotes exotic taxon; #denotes listed as rare in South Australia; ## denotes listed as endangered in South Australia).

Species	Max. Group	P-value
Alternanthera denticulata	*Marsilea/Eleocharis*	0.3472
Ammannia multiflora	*Ammannia*	0.0006
*Asphodelus fistulosus**	*Tetragonia/Centipeda*	0.4859
Atriplex spp.	*Tetragonia/Centipeda*	0.0552
Atriplex suberecta	*Tetragonia/Centipeda*	0.2932
Bare Soil	Bare soil	0.0001
Brachyscome basaltica	*Sclerolaena brachyptera*	0.0044
Calotis hispidula	*Ammannia*	0.2781
Calotis scapigera	*Marsilea/Eleocharis*	0.0305
Carpobrotus rossii	*Carpobrotus*	0.0001
Centipeda minima	*Tetragonia/Centipeda*	0.001
Chenopodium nitrariaceum	*Marsilea/Eleocharis*	0.4238
Chenopodium pumilio	*Tetragonia/Centipeda*	0.1347
*Conyza bonariensis**	*Tetragonia/Centipeda*	0.1347
Cotula australis	*Marsilea/Eleocharis*	0.2035
Craspedia chrysantha	*Craspedia/Salsola*	0.0004
Crassula helmsii	*Marsilea/Eleocharis*	0.2101
Crassula sieberana ##	*Tetragonia/Centipeda*	0.2426
Cyperus difformis	*Ammannia*	0.0929
Eleocharis acuta	*Marsilea/Eleocharis*	0.0005
Enchylaena tomentosa	*Craspedia/Salsola*	0.0007
Enneapogon nigricans	*Ammannia*	0.2212
Epaltes australis	*Marsilea/Eleocharis*	0.567
Eragrostis australasica	*Tetragonia/Centipeda*	0.726
*Erodium cicutarium**	*Tetragonia/Centipeda*	0.1716
Euphorbia drummondii	*Tetragonia/Centipeda*	0.1131
Frankenia pauciflora	*Carpobrotus*	0.3205
Glinus lotoides	*Marsilea/Eleocharis*	0.1166
Goodenia gracilis	*Ammannia*	0.4242
Helichrysum luteo-album	*Tetragonia/Centipeda*	0.0492
*Heliotropium amplexicaule **	*Marsilea/Eleocharis*	0.3022
*Heliotropium europaeum**	*Tetragonia/Centipeda*	0.4205
*Hypochoeris glabra **	*Carpobrotus*	1
Iseotopsis graminifolia	*Ammannia*	0.1507
Isolepis hookeriana	*Ammannia*	0.16
Limosella australis	*Tetragonia/Centipeda*	0.4205
Maireana spp.	*Craspedia/Salsola*	0.1016
Marsilea angustifolia	*Marsilea/Eleocharis*	0.0001
Medicago spp.*	*Ammannia*	0.5966
Mentha australis	*Tetragonia/Centipeda*	0.4174
Mimulus repens	*Ammannia*	0.0295
Mollugo cerviana	*Ammannia*	0.2247
Muehlenbeckia florulenta	*Craspedia/Salsola*	0.1584
Muehlenbeckia horrida#	*Craspedia/Salsola*	1
Myosurus minima	*Tetragonia/Centipeda*	0.1397
Neogunnia septifraga	*Bare soil*	0.3973
*Nothoscordum borbonicum**	*Tetragonia/Centipeda*	0.1935
Pachycornia triandra	*Carpobrotus*	0.0458
*Phyla canescens**	*Tetragonia/Centipeda*	0.4114
Picris angustifolia	*Carpobrotus*	1
Plantago cunninghamii	*Tetragonia/Centipeda*	0.0087

Species	Max. Group	P-value
*Rorippa palustris**	*Tetragonia/Centipeda*	0.0258
Rumex bidens	*Marsilea/Eleocharis*	0.3205
Salsola kali var. *kali*	*Craspedia/Salsola*	0.0004
Scleroblitum atriplicinum	*Craspedia/Salsola*	0.0471
Sclerolaena brachyptera	*Sclerolaena brachyptera*	0.0001
Sclerolaena divaricata	*Carpobrotus*	0.1477
Sclerolaena stelligera	*Marsilea/Eleocharis*	0.188
Senecio cunninghamii	*Ammannia*	0.5085
Senecio runcinifolius	*Tetragonia/Centipeda*	0.0039
Solanum lacunarium	*Ammannia*	0.6725
*Spergularia marina**	*Marsilea/Eleocharis*	0.0129
Sporobolus mitchelli	*Tetragonia/Centipeda*	0.0114
*Taraxacum officinale**	*Sclerolaena brachyptera*	0.029
Tetragonia tetragonioides	*Tetragonia/Centipeda*	0.0005
Trachymene cyanopetula	*Tetragonia/Centipeda*	0.1061
Wahlenbergia fluminalis	*Tetragonia/Centipeda*	0.2758

3.7. 2012 Survey

Figure 17 shows the spatial distribution and vegetation community based on groupings identified from cluster analysis (Figure 18) of the 73 survey sites across the Chowilla Floodplain in 2012.

In 2012, species richness had declined compared to 2011 from 66 to 51 species, from 22 families recorded across the 73 sites surveyed; nevertheless, this was the second highest species richness recorded since 2006. The five most frequently encountered taxa were *Atriplex* spp., *Sclerolaena stelligera, Sporobolus mitchelli, Carpobrotus rossii* and *Sclerolaena divaricata*, accounting for 61.3% of all quadrats surveyed. Of the 3,285, 1 x 1 m cells surveyed, approximately 4.5% were found to be devoid of vegetation, which is an approximate three-fold increase of the amount of bare cells recorded in the 2011 surveys but still significantly less than bare cells than recorded from 2006 to 2010.

Cluster analysis produced six significantly different groups (at 30% similarity, Figure 18) although one group included a single site. These groups reflected major differences between sites, and Indicator Species Analysis (Table 8) produced a list of representative taxa for each group:

7. "*Sclerolaena stelligera*" sites were predominantly characterised by salt tolerant, dryland species such as *Sclerolaena stelligera* and *Sclerolaena brachyptera* and (38.4% of sites),
8. "*Atriplex/Sporobolus*" sites were characterised by desiccation tolerant species such as *Atriplex* sp. and *Sporobolus mitchelli* (35.5%),
9. "*Carpobrotus/Pachycornia*" sites were relatively high elevation sites with salt tolerant species such as *Carpobrotus rossii* and *Pachycornia triandra* (11.0%),
10. "Bare soil" were predominantly characterised by empty cells (11.0%),
11. "Flood Responders" sites were characterised by floodplain, amphibious and terrestrial species such as *Alternanthera denticulata*, *Centipeda minima*, *Conyza bonariensis**, *Eleocharis acuta*, *Glinus lotoides*, *Heliotropium europaeum*, *Persicaria lapathifolium* and *Polygonum plebeium* (2.7 % of sites),
12. "*Calotis/Sclerolaena*" site was characterised by *Sclerolaena divaricata* and Calotis *hispidula* (1.4%).

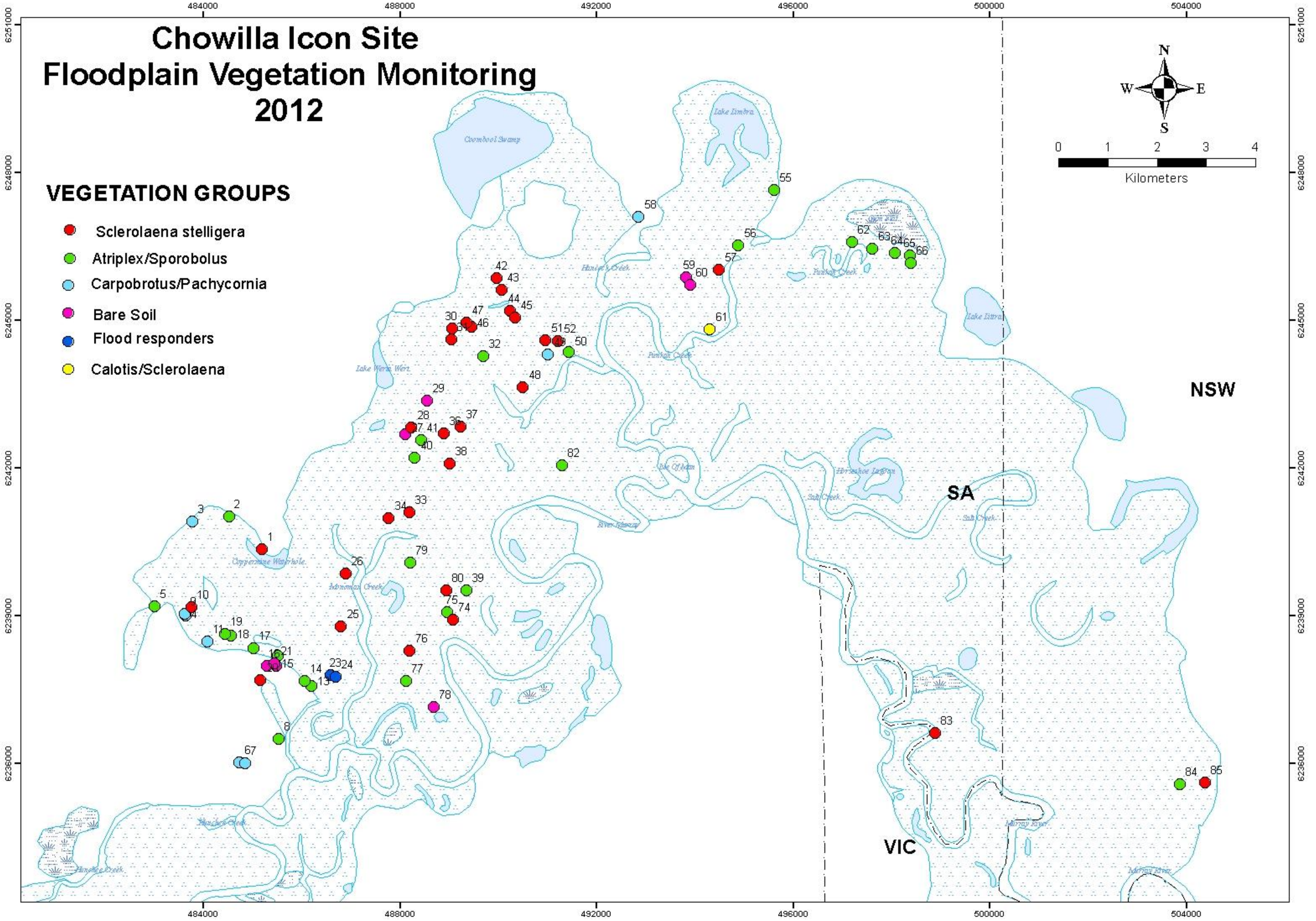

Figure 17: Spatial distribution and vegetation communities of the 73 survey sites across the Chowilla Floodplain for the 2012 survey. Colours refer to 2012 dendrogram groupings.

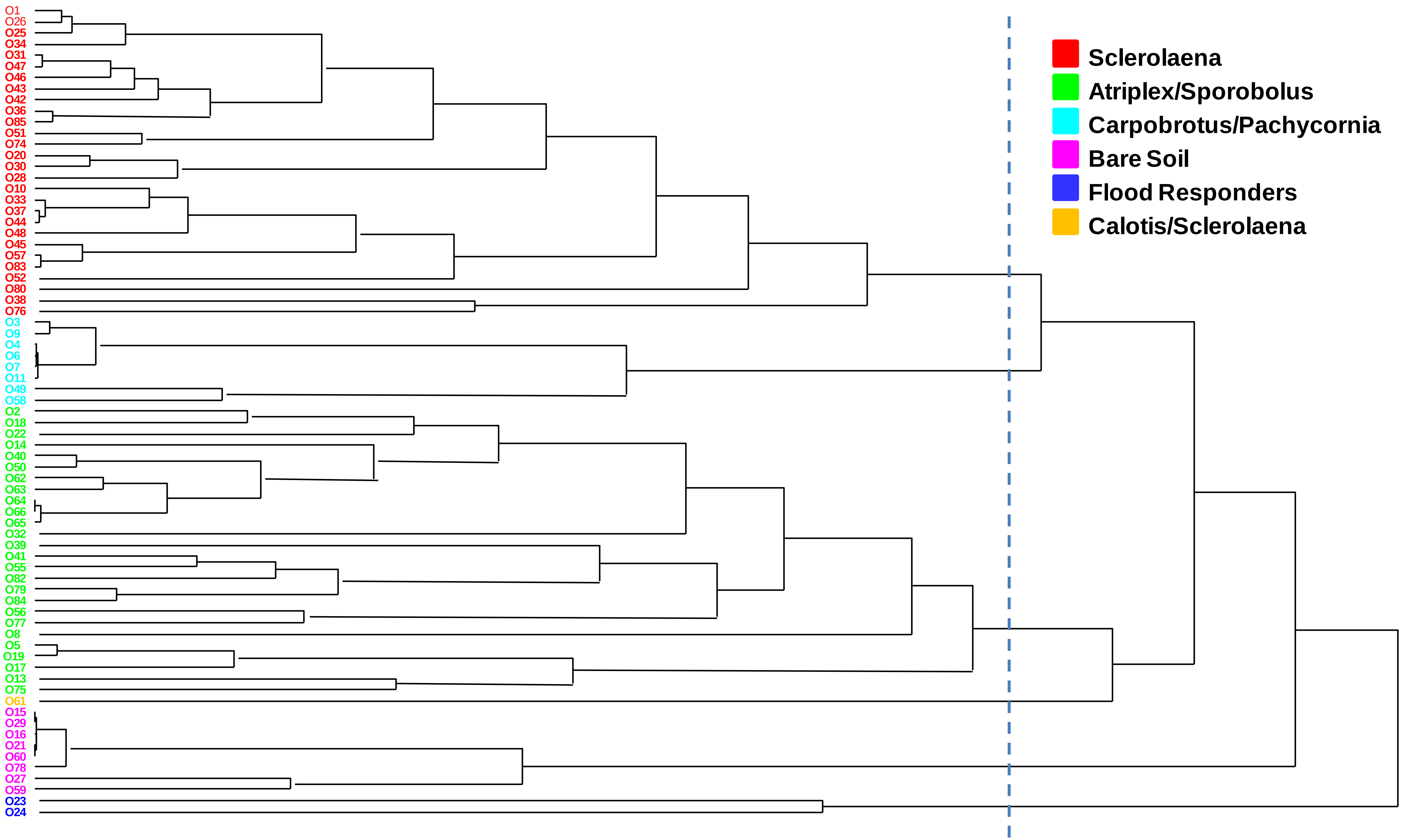

Figure 18: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2012 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 8: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=201) from the 2012 vegetation survey. Max. Group indicates group in which taxon had highest indicator value. P-value derived from Monte-Carlo test of significance (permutations=10,000). Significant (*p*<0.05) taxa are highlighted (*denotes exotic taxon; #denotes listed as rare in South Australia; ## denotes listed as endangered in South Australia).

Species	Max. Group	P-value
Alternanthera denticulata	Flood Responders	0.0045
Atriplex spp.	*Atriplex/Sporobolus*	0.0001
Atriplex suberecta	*Atriplex/Sporobolus*	0.5568
Bare soil	Bare Soil	0.0001
Brachyscome basaltica	*Carpobrotus/Pachycornia*	0.3832
Calotis scapigera	*Sclerolaena*	1
Calotis hispidula	*Calotis/Sclerolaena*	0.0001
Carpobrotus rossii	*Carpobrotus/Pachycornia*	0.0001
Centipeda minima	Flood Responders	0.0005
*Centaurium tenuiflorum**	*Atriplex/Sporobolus*	0.2081
Chenopodium nitrariaceum	*Carpobrotus/Pachycornia*	0.8787
*Citrullus lanatus**	*Atriplex/Sporobolus*	0.6197
*Conyza bonariensis**	Flood Responders	0.0373
Cyperus gymnocaulos	*Atriplex/Sporobolus*	0.608
Dittrichia graveloens	*Atriplex/Sporobolus*	0.6091
Eleocharis acuta	Flood Responders	0.0001
Enchylaena tomentosa	*Atriplex/Sporobolus*	0.6177
Epaltes australis	*Sclerolaena*	0.8969
Eragrostis australasica	*Atriplex/Sporobolus*	0.2664
Eremophila divaricata	*Atriplex/Sporobolus*	0.6172
Euphorbia drummondii	*Atriplex/Sporobolus*	1
Frankenia pauciflora	*Sclerolaena*	0.071
Glinus lotoides	Flood Responders	0.0004
Goodenia gracilis	*Sclerolaena*	0.4926
Halosarcia pergranulata ssp. *pergranulata*	*Atriplex/Sporobolus*	0.3301
*Heliotropium europaeum**	Flood Responders	0.0006
Maireana spp.	*Carpobrotus/Pachycornia*	0.5561
Marsilea spp.	Flood Responders	0.0709
Mimulus repens	*Atriplex/Sporobolus*	0.6091
Morgania floribunda	*Atriplex/Sporobolus*	0.6131
Muehlenbeckia florulenta	*Atriplex/Sporobolus*	0.0693
Muehlenbeckia horrida	*Sclerolaena*	0.2628
Pachycornia triandra	*Carpobrotus/Pachycornia*	0.0002
Persicaria lapathifolium	Flood Responders	0.0006
*Phyla canescens**	*Atriplex/Sporobolus*	0.2064
Phyllanthus lacunaris	*Atriplex/Sporobolus*	0.2235
Polygonum plebeium	Flood Responders	0.0405
*Rorippa palustris**	*Atriplex/Sporobolus*	0.6172
Rumex bidens	*Atriplex/Sporobolus*	0.6126
Salsola kali var. *kali*	*Sclerolaena*	0.4307
Sclerolaena brachyptera	*Sclerolaena*	0.0009
Sclerolaena divaricata	*Calotis/Sclerolaena*	0.0273
Sclerolaena stelligera	*Sclerolaena*	0.0001
Scleroblitum atriplicinum	*Atriplex/Sporobolus*	0.6172
Senecio runcinifolius	*Atriplex/Sporobolus*	0.6106
Solanum lacunarium	*Sclerolaena*	0.7221
*Spergularia marina**	*Atriplex/Sporobolus*	0.7733
Sporobolus mitchelli	*Atriplex/Sporobolus*	0.0093
Tetragonia tetragonioides	*Sclerolaena*	1
Teucrium racemosum	*Sclerolaena*	1
Wahlenbergia fluminalis	*Atriplex/Sporobolus*	0.6195

3.8. Change in Floristic Composition between 2006 and 2012

In spring 2006, two large areas of floodplain (Coppermine Complex and Gum Flat) were watered by pumping; resulting in sites 2, 19, 22, 23 (Coppermine Complex) and sites 62, 63, 64, and 65 (Gum Flat) being inundated. Surveys in 2007 indicated that the vegetation at these sites changed from a community dominated by desiccation tolerant terrestrial species in 2006, to one dominated by flood dependent herbs and grasses, then back to a drought tolerant terrestrial community in 2008. By 2009, all sites (with the exception of one bare site), were classified as salt tolerant communities. In spring 2009 these two areas were watered for a second time, resulting in slightly larger areas being inundated, including sites 2, 17, 18, 19, 22, 23 and 24 (Coppermine Complex) and sites 62, 63, 64, 65 and 66 (Gum Flat). Following the spring 2009 watering, communities were dominated by amphibious and floodplain species in 2010. As a result of flooding from August 2010 to May 2011, over 65% of sites surveyed in 2011 had been inundated. During the time of the 2012 survey in February to March 2012 the sites remained dry (i.e. neither watered nor flooded) though further flooding occurred following the survey with a return of high flows in autumn 2012. Table 9 summarises inundation history of the aforementioned sites.

Table 9: List of sites (surveyed in 2012) and inundation history (*Unflooded* = sites that remained dry throughout survey period (2006-2012); *Flooded* = sites flooded in 2010/11; *1 Water + Flooding* = sites watered in spring 2009 and flooded in 2010/11; *2 water + Flooding* = sites watered in spring 2006, re-watered in spring 2009 and flooded in 2010/11. CC = Coppermine Complex; GF = Gum Flat).

	Unflooded	***Flooded***	***1 x Watering + Flooding***	***2 x Watering + Flooding***
Site #	4, 5, 6, 7, 8, 9, 11, 15, 16, 21, 25, 26, 38, 45, 52, 57, 58, 74, 76, 80, 82, 83, 84	1, 3, 10, 13, 14, 20, 27, 28, 29, 30, 31, 32, 33, 34, 36, 39, 40, 41, 44, 46, 47, 48, 49, 50, 51, 55, 56, 59, 60, 61, 75, 79, 85	CC: 17, 18 GF: 66	CC: 2, 19, 22, 23 GF: 62, 63, 64, 65
Total	**23**	**33**	**3**	**8**

Between 2006 and 2009, species richness generally declined across the Chowilla Floodplain (Figure 19) despite a rise in species richness in 2007. This peak of 48 taxa followed the first watering of Coppermine Complex and Gum Flat in spring 2006, but in subsequent years species richness steadily declined, such that by 2009, a total of only 17 taxa were recorded (Figure 19). Re-watering of the same areas in spring 2009 resulted in higher species richness in the 2010 survey similar to the numbers recorded in the 2007 survey (42 and 48 taxa, respectively) (Figure 19). In 2011, following overbank flooding, species richness increased by more than 50%

compared to 2010 (66 and 42 taxa respectively) but by 2012 species richness had declined slightly (51 taxa) (Figure 19).

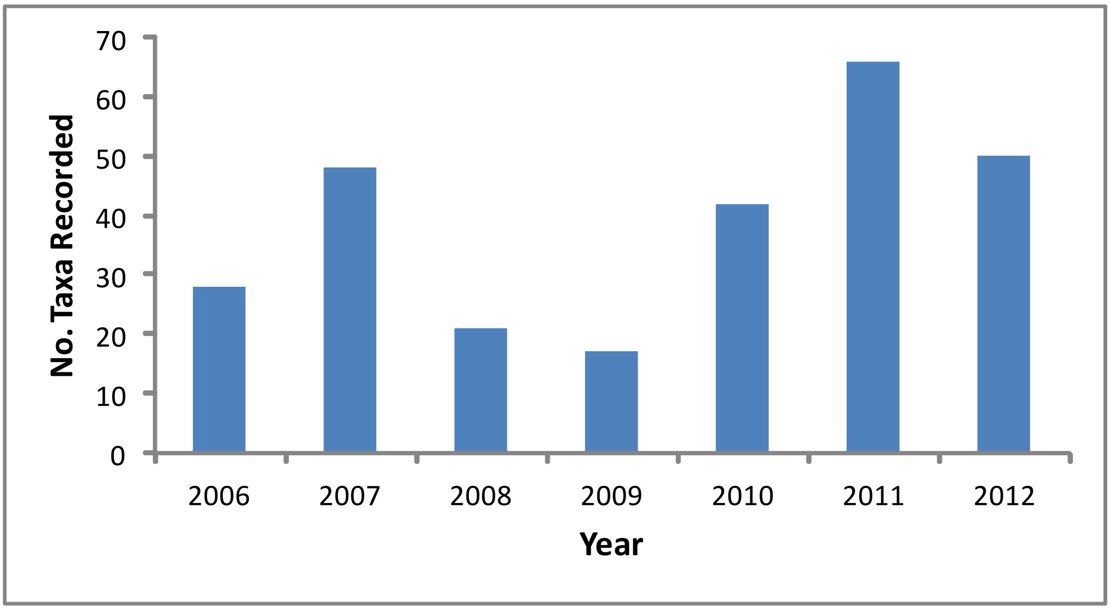

Figure 19: Changes through time in species richness (number of taxa) of the Chowilla Floodplain from 2006 to 2012.

In 2006, the floodplain understorey was mostly comprised of taxa from salt tolerant and terrestrial functional groups (Figure 20); however, following the first watering of the Coppermine Complex and Gum Flat (spring 2006) there was an increase in amphibious, floodplain and salt tolerant taxa and a concomitant decrease in terrestrial taxa and bare soil (Figure 20). In 2008 and 2009, the number of observations of bare soil, terrestrial and salt tolerant taxa increased, while floodplain and amphibious taxa were not observed (Figure 20). Re-watering of the Coppermine Complex and Gum Flat (spring 2009) resulted in an increase in floodplain and amphibious taxa in 2010 (Figure 20). Overbank flooding in 2010/11 resulted in a further decline in bare soil, terrestrial and salt tolerant taxa, a moderate increase in amphibious taxa and a large increase of floodplain taxa (Figure 20). In 2012 the number of observations of terrestrial and salt tolerant taxa and bare soil had increased while the observations of amphibious and floodplain taxa had decreased compared to the previous year (Figure 20).

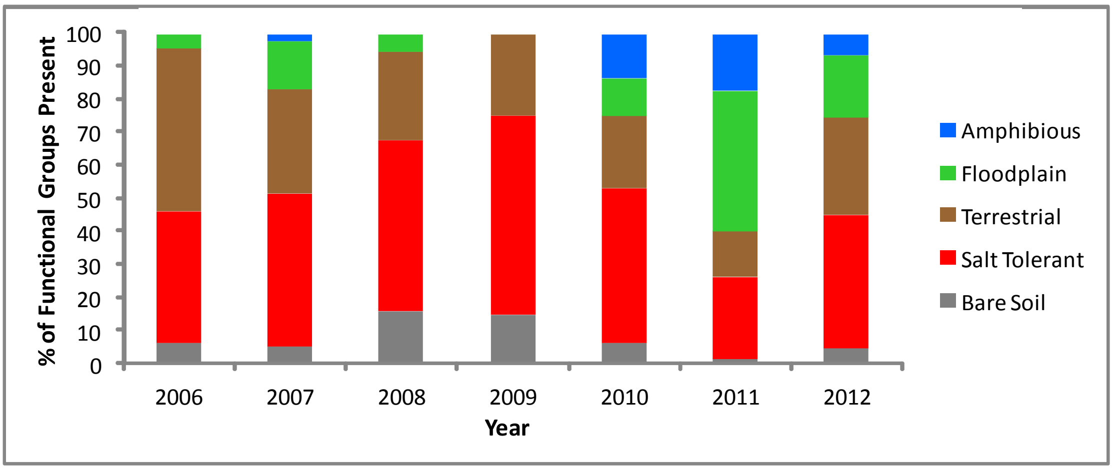

Figure 20: Changes in the percentage of observation of vegetation functional groups of the Chowilla Floodplain from 2006 to 2012.

The change in floristic composition over the Chowilla Floodplain between 2006 and 2012 were strongly related to site inundation history. Two factor PERMANOVA results (Table 10) showed the floristic composition was significantly different between years and inundation history: *unflooded* (sites remained dry since 2006); *flooded* (sites flooded in 2010/11); *watered* (sites were watered in spring 2006 and rewatered in spring 2009, then flooded in 2010/11). There was a significant interaction between year and inundation history (Table 10), which indicated that change through time was not consistent between sites.

Table 10: PERMANOVA *pseudo-F*-statistic results comparing years (2006 to 2012) and watering (or flow conditions: Unflooded; Flooded and 2 waterings + flooded).

Factor	*df*	*Pseudo-F*	*P*
Year	6, 412	8.51	<0.001
Inundation History	2, 412	30.86	<0.001
Year x Inundation History	12, 412	2.57	<0.001

NMS ordination (Figure 21) shows that the plant communities in unflooded sites (years 2006–2011) and flooded sites (years 2006–2010) were similar (group A). This group was floristically similar to sites that were surveyed between 12 and 24 months after they were watered or flooded (group B). Watered sites in year 2010 (i.e. Coppermine Complex and Gum Flat sites that were watered twice) and watered sites in year 2011 (i.e. Coppermine Complex and Gum Flat sites that were watered twice and then flooded) also shared similarities (group C) as did watered sites in year 2007 (i.e. Coppermine Complex and Gum Flat sites that were watered once in spring 2006; surveyed in 2007) and watered sites that were surveyed one year after flooding in 2010/11 (group D). Sites that were only flooded in 2011 (i.e. no watering) grouped together based on shared similarities (group E) (Figure 21).

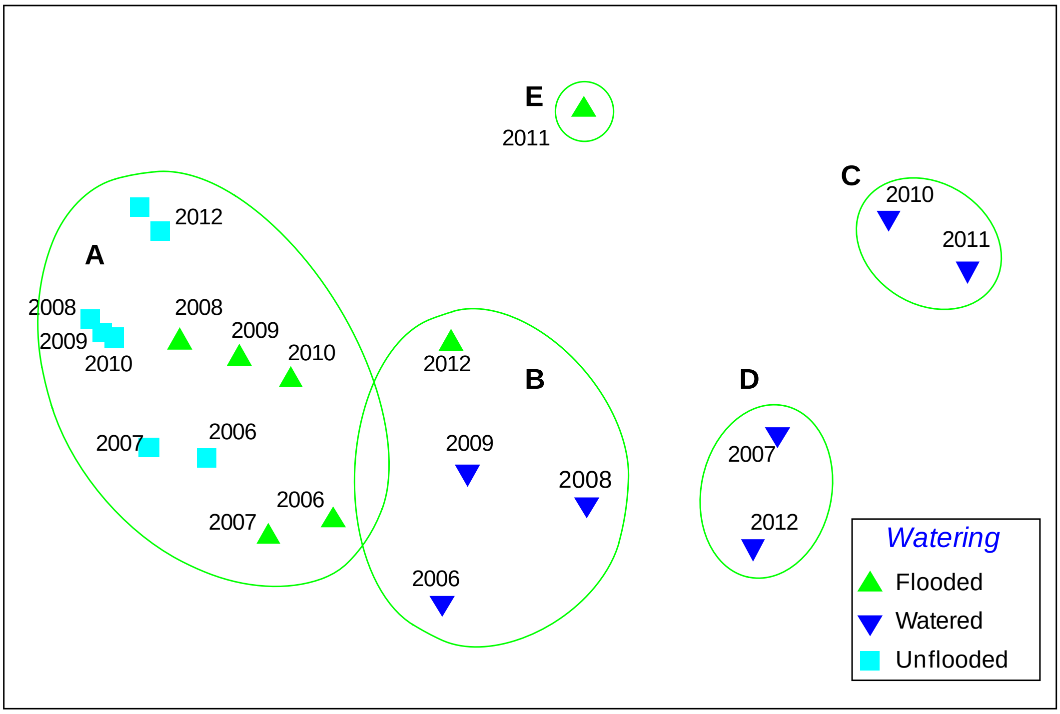

Figure 21: NMS ordination comparing sites and inundation history across the survey period at a similarity of 55%. Light blue squares: unflooded sites that remained dry. Green triangles: flooded sites that were flooded in 2010/11. Blue triangles: a) sites that were watered in spring 2006 (i.e. surveyed 2007), and again in spring 2009 (surveyed 2010), then flooded in 2010/11 (surveyed 2011) and surveyed post-flood (surveyed 2012). Stress = 7%.

In the unflooded areas of the floodplain (group A sites), changes in floristic composition were driven by changes in abundance of bare soil, and in abundance of salt tolerant taxa such as, *Carpobrotus rossii, Pachycornia triandra* and *Sclerolaena brachyptera* (Table 11). Sites that were surveyed prior to watering (spring 2006); and in the intervening years before re-watering (spring 2009) (i.e. Coppermine Complex and Gum Flat sites) and sites that were flooded in 2010/2011 and then surveyed the following year (summer 2012) (group B) were characterised by the abundance of *Calotis hispidula* and *Phyla canescens* (Table 11). Sites that were watered twice (i.e. Coppermine Complex and Gum Flat sites) and sites watered in year 2011 (i.e. Coppermine Complex and Gum Flat sites that were watered twice and then flooded) (Group C) were characterised by abundances of a diverse range of amphibious, floodplain and terrestrial taxa, namely: *Ammannia multiflora, Centipeda minima, Chenopodium pumilio, Cotula australis, Craspedia chrysantha, Crassula helmsii, Cyperus difformis, Eleocharis acuta, Enchylaena tomentosa, Erodium cicutarium, Euphorbia drummondii, Heliotropium amplexicaule, Marsilea angustifolia, Mentha australis, Mimulus repens, Osteocarpum acropterum, Plantago cunninghamii, Polygonum plebeium, Polypogon monspeliensis, Spergularia marina and Typha domingensis* (Table 11). Sites that were surveyed in the year 2007 (i.e. Coppermine Complex and Gum Flat sites, following watering in spring 2006) and again in 2012, one year after flooding in 2010/11 (group

D) were characterised by amphibious, floodplain and terrestrial taxa: *Alternanthera denticulata*, *Atriplex* spp., *Citrullus lanatus*, *Conyza bonariensis*, *Cyperus gymnocaulos, Dittrichia graveolens, Epaltes australis, Glinus lotoides, Heliotropium europaeum, Isolepis hookeriana, Mollugo cerviana, Phyllanthus lacunaris, Plantago turrifera, Polygonum aviculare, Sclerolaena divaricata, Sporobolus mitchelli* (Table 11). Sites that were only flooded in 2010/2011 and surveyed in 2011 (Group E) were characterised by the abundances of a diverse range of amphibious, floodplain and terrestrial taxa, namely: *Asphodelus fistulosus*, *Atriplex suberecta, Brachyscome basaltica*, *Calotis scapigera, Crassula sieberiana*, *Enneapogon nigricans, Eragrostis australasica, Frankenia pauciflora, Goodenia gracilis, Iseotopsis graminifolia, Limosella australis, Medicago* spp., *Muehlenbeckia florulenta, Myosurus minima, Neogunnia septifraga, Nothoscordum borbonicum*, Psuedognaphalium luteo-album, Rorippa palustris, Rumex bidens, Scleroblitum atriplicinum, Sclerolaena stelligera, Senecio cunninghamii, Senecio runcinifolius, Solanum lacunarium, Tetragonia tetragonioides, Trachymene cyanopetula* and *Wahlenbergia fluminalis* (Table 11).

Table 11: Indicator Species Analysis (Dufrene and Legendre 1997) results and functional group list (Nicol *et al.* 2010) based on unpooled data (*n*=253) from the 2006 – 2012 vegetation surveys of sites that were watered in spring 2006, re-watered in spring 2009 and then flooded in 2010/11. Inundation History indicates the group in which taxon had the highest indicator value. A = sites that were never watered or flooded (unflooded 2006-2012); B = pre-watered sites (Watered 2006) + sites 2-3 years following water (Watered 2008, 2009) and sites one year post-flooding (Flooded 2012); C = sites that received 2 waterings (Watered 2010) and then flooded (Watered 2011); D = sites one year after watering (Watered 2007) and one year following flooding (Watered 2012) and E = sites that were flooded only (Flooded 2011). P-value derived from Monte-Carlo test of significance (permutations=10,000). Significant (p<0.05) taxa are highlighted (*denotes exotic taxon; # denotes taxon listed as rare in South Australia; ## denotes taxon listed as endangered in South Australia; § denotes species not recorded in Chowilla Floodplain system since 1989, see Nicol 2009).

Species	Inundation History	P-value
Alternanthera denticulata	D	0.0001
Ammannia multiflora	C	0.0001
*Asphodelus fistulosus**	E	0.0003
Atriplex spp.	D	0.0001
Atriplex suberecta	E	0.0012
Bare Soil	A	0.0001
Brachyscome basaltica	E	0.1262
Brachyscome dentata	A	1
Calotis cuneifolia	B	0.2865
Calotis hispidula	B	0.0007
Calotis scapigera	E	0.0001
Carpobrotus rossii	A	0.0001
*Centaurium tenuiflorum**	B	0.0805
Centipeda minima	C	0.0001
Chenopodium nitrariaceum	B	0.1464
Chenopodium pumilio	C	0.0007
*Citrullus lanatus**	D	0.1341
*Conyza bonariensis**	D	0.0001
Cotula australis	C	0.002
Craspedia chrysantha	C	0.0001
Crassula helmsii	C	0.0763
Crassula sieberana##	E	0.0093
Cyperus difformis	C	0.0001
Cyperus gymnocaulos	D	0.0001
*Dittrichia graveloens**	D	0.0742
Eleocharis acuta	C	0.0001
Enchylaena tomentosa	C	0.5474
Enneapogon nigricans	E	0.0136

Species	Inundation History	P-value
Epaltes australis	D	0.0914
Eragrostis australasica	E	0.2018
Eremophila divaricata	A	1
*Erodium cicutarium**	C	0.0433
Euphorbia drummondii	C	0.0024
Frankenia pauciflora	E	0.3639
Glinus lotoides	D	0.2374
Goodenia gracilis	E	0.0022
Haloragis aspera	A	1
Halosarcia pergranulata ssp. *pergranulata*	B	0.0945
Helichrysum luteo-album	E	0.0001
*Heliotropium amplexicaule**	C	0.0519
*Heliotropium europaeum**	A	1
*Heliotropium europaeum**	D	0.0019
Iseotopsis graminifolia	E	0.0001
Isolepis hookeriana	D	0.0003
Ixiolaena brevicompta	A	1
Lachnagrostis filiformis	A	1
Limosella australis	E	0.1604
Maireana spp.	A	0.0516
*Malva parviflora**	A	1
Marsilea angustifolia	C	0.0001
Medicago spp.*	E	0.0005
Mentha australis	C	0.0761
Mimulus repens	C	0.0001
Mollugo cerviana	D	0.0026
Morgania floribunda	A	1
Muehlenbeckia florulenta	E	0.0077
Muehlenbeckia horrida#	A	0.6186
Myosurus minima	E	0.0004
Neogunnia septifraga	E	0.0017
*Nothoscordum borbonicum**	E	0.0001
Osteocarpum acropterum	C	0.0032
Pachycornia triandra	A	0.002
*Phyla canescens**	B	0.0088
Phyllanthus lacunaris	D	0.021
Picris angustifolia	A	1
Plantago cunninghamii	C	0.0001
Plantago turrifera	D	0.0543
*Polygonum aviculare**	D	0.1163
Polygonum plebeium	C	0.0039
*Polypogon monspeliensis**	C	0.0001
Rhagodia spinescens	A	1
*Rorippa palustris**	E	0.0001
Rumex bidens	E	0.0068
Salsola kali	A	0.3479
Scleroblitum atriplicinum	E	0.2908
Sclerolaena brachyptera	A	0.0001
Sclerolaena divaricata	D	0.01
Sclerolaena stelligera	E	0.0001
Senecio cunninghamii	E	0.0086
Senecio runcinifolius	E	0.0001
Sida ammophila	A	1
Solanum lacunarium	E	0.156
Solanum nigrum	A	1
*Spergularia marina**	C	0.0001
Sporobolus mitchelli	D	0.0001
Tetragonia tetragonioides	E	0.0001
Teucrium racemosum	D	0.3771
Trachymene cyanopetula	E	0.0002
Typha domingensis	C	0.0003
Wahlenbergia fluminalis	E	0.0007
Xanthium occidentale	D	0.0765

4. Discussion

The floodplain vegetation condition monitoring program for the Chowilla Living Murray Icon Site has provided comprehensive spatial coverage of open habitats with a broad range of flood frequencies across the floodplain (Figure 3). The extensive sampling provided good baseline information, and follow up surveys provided further information regarding medium-term vegetation dynamics of the system and the impacts of watering and natural flooding. In order to monitor medium to long-term vegetation changes these sites should continue to be consistently re-surveyed on an annual basis.

The clearest pattern observed in the 2006 survey was the statistically significant, positive association of the "Salt Tolerant" vegetation type with rarely flooded sites. This association was strong in one direction only, i.e. "Salt Tolerant" vegetation was most likely to be encountered on rarely flooded sites, but rarely flooded sites also hosted other vegetation types. The reason for this association is unclear; the relationships between flood frequency and soil and groundwater salinity are complex and may be overridden by local-scale soil, groundwater and topographic conditions. The association is particularly interesting given that the regularly flooded lagoon, Lake Limbra, is currently dominated by the halophyte *Halosarcia pergranulata* ssp. *pergranulata* (Zampatti *et al.* 2011; Nicol 2012). It may be that the plant assemblages in these two differing environments are convergent due to high salinity, regardless of the mechanism by which the salinity is generated.

Also interesting is the fact that the two sites identified as having a "Flood Responder" vegetation type in 2006 were located in areas that fell within the "Sometimes" flood frequency class, having flood return frequencies of 1 in 10 and 1 in 11 years. Given that the vegetation at these sites was characterised by species that are typical of recently inundated areas it is possible either that the spatial resolution of the flood model may be too coarse to identify small localised areas of higher flood frequencies (i.e. narrow flood runners) or that the vegetation at these sites established in response to water from a source other than flooding (e.g. runoff from tracks).

Data from the 2007 survey showed that when areas were watered, the floristic composition changed from a terrestrial dryland plant community to a community dominated by flood dependent species. This indicated that these species form a long-lived seed bank or propagules disperse into these areas by hydrochory, which enables them to colonise areas rapidly in response to inundation. In addition to the flood dependent species that recruited at these sites large numbers of *Atriplex* spp. seedlings were present (Table 3). This is in contrast to the remainder of the floodplain where this taxon was present in significantly lower numbers in 2007 compared with 2006.

Watering areas of floodplain increased the species richness of the Chowilla system; in 2006, 28 species from 13 families were recorded, whilst in 2007 (after watering), 48 species from 20 families were recorded. The increase in species richness was primarily due to the colonisation of native flood dependent herbs and grasses in the areas that were watered. However, the number of species decreased to 21 (from eight families) in 2008 and 17 (from six families) in 2009 with *Sporobolus mitchelli* (a drought tolerant, perennial floodplain species, Nicol 2004) being the only flood dependent species present.

In 2010, species richness increased (42 taxa from 19 families) in response to rewatering of Gum Flat and Coppermine Complex; however, the plant communities present in Coppermine Complex and Gum Flat were significantly different (Figure 14). Gum Flat was dominated by native flood dependent and terrestrial species whereas Coppermine Complex was dominated by amphibious species (Table 6). The differences in plant communities between the two sites were probably the result of differences in timing and duration of watering; Gum Flat was watered earlier than Coppermine Complex and inundated for a shorter period. Furthermore, surface water was present in parts of Coppermine Complex when surveyed in February 2010 whereas Gum Flat was completely dry (and had been for several months) and the majority of desiccation sensitive species present at Coppermine Complex were absent at Gum Flat.

In 2011, species richness for the Chowilla Floodplain was the highest recorded over the study period (66 taxa from 28 families). This response was almost undoubtedly due to overbank flooding, which inundated more than 65% (>10,000 ha) of the floodplain from August 2010 to May 2011. During this period, flow to South Australia peaked at 93,000 ML day^{-1}, which was the highest flow into the state since 1993 (MDBA 2011). As expected, there were distinct differences between those areas of the floodplain that were flooded versus those areas that remained unflooded (Figure 21). Unflooded sites continued to be dominated by terrestrial and salt tolerant taxa, whereas areas that were inundated were dominated by flood responders. The significant increase in the abundance of flood responders between 2010 and 2011 indicates that the plant community is resilient and able to recolonise after an extended absence of inundation. However, whether recolonisation resulted from the resident seed bank or from propagules brought in by floodwaters (hydrochory) is unknown. Strandlines (organic matter deposited by receding floodwaters) were observed in numerous areas throughout the floodplain. Species richness was generally higher at sites where strandlines were present within quadrats (J. Nicol pers. obs.). Furthermore, *Muehlenbeckia florulenta* seedlings were only observed in quadrats that contained strandlines (J. Nicol pers. obs.). Nevertheless, many floodplain species (especially annual herbs and grasses) form long-lived (>10 years) seed banks (Leck and Brock 2000) and resident seed banks may be important sources of regeneration.

There were also distinct differences between the areas that were watered in spring 2006, and again in spring 2009, versus areas that were only flooded. The watered areas were dominated by a mix of floodplain and amphibious taxa, whereas the flooded areas were predominantly floodplain taxa. These results provide evidence that emergency watering of areas of floodplain during extended drought may be important in ensuring persistence of amphibious species outside of the littoral zone.

Results from this study, and monitoring of environmental watering sites during the recent drought (Nicol *et al.* 2010), show that watering may be important for the persistence of amphibious taxa; however, it is not a substitute for flooding. Watering involves the construction of banks, the use of pumps and is limited to water retaining areas of the floodplain. In contrast, flooding has no infrastructure requirements, is hydraulically complex and inundates much larger areas including water-shedding areas, increasing connectivity between permanent and ephemeral habitats. Flooding is also important for regeneration of the two most abundant taxa in 2011 and 2012 *Atriplex* spp. and *Sclerolaena stelligera* (terrestrial taxa), evidenced by large numbers of seedlings observed in areas that were flooded.

Surprisingly, all of the exotic species identified by Nicol (2007) of high or extreme invasion risk due to the operation of the Chowilla Creek regulator were not significant indicators of flooding or watering (Table 11). Furthermore, *Heliotropium amplexicaule, Heliotropium europaeum, Hypochoeris glabra, Medicago* spp. and *Phyla canescens* were the only taxa present in 2011 (Table 7) of the 29 that were identified as being a high or extreme invasion risk (Nicol 2007). Furthermore, these species were also present in very low numbers. In 2012, *Heliotropium europaeum* the only species present on the Chowilla Floodplain that was considered a high or extreme invasion risk by Nicol (2007). The declared noxious weed *Xanthium* spp., which recruits in large numbers on the River Murray Floodplain after inundation, was not observed in 2011 or 2012, despite being abundant in Werta Wert Wetland and Twin Creeks after watering (Nicol *et al.* 2010), and on the banks of the River Murray and Monoman Creek after increased discharge into South Australia in 2005 (Zampatti *et al.* 2011). In addition, the floodplain weeds *Abutilon theophrasti* and *Heliotropium curassivicum,* which were abundant in areas watered during the drought (Nicol *et al.* 2010), were not recorded in the 2011 or 2012 surveys.

One year following flooding (February 2012), species richness had decreased and the abundance of bare soil, salt tolerant and terrestrial species had increased; however, the area and abundance of flood dependent and amphibious species was greater compared to the 2006 to 2010 surveys. Results from environmental watering monitoring (Nicol *et al.* 2010) and this study show that the response of flooding is short-lived (typically 12 to 24 months) due to the annual life history of most flood dependent species (Cunningham *et al.* 1981; Nicol 2004). However, this life history strategy ensures that plants reach maturity quickly and can replenish the seed bank to ensure colonisation after the next flood. The abundance of flood dependent and amphibious species would be expected to decline further with a corresponding increase in terrestrial and salt tolerant species and bare soil in the absence of flooding or watering. In contrast, if there is another overbank flood, an increase in flood dependent and amphibious and corresponding decrease in terrestrial and salt tolerant and bare soil is expected.

4.1. TLM Targets

Prior to 2010, icon site Target 5 (improve the area and diversity of grass and herblands), Target 6 (improve the area and diversity of flood dependent understorey vegetation), and Target 8 (maintain or improve the area and diversity of grazing sensitive plant species) were not met without management intervention (watering) (Nicol *et al.* 2010). Whilst watering resulted in the aforementioned targets being met, the spatial extent was limited and there were often significant increases in the abundance of pest plants hence Target 9 (limit the extent of invasive (increaser) species, including weeds) was not being met.

The overbank flow in 2010/11 resulted in over 60% of the floodplain being inundated (MDBA 2011), and provided significant recruitment of flood dependent and amphibious species (including grazing sensitive species) with minimal weed recruitment. Therefore, all of the relevant TLM targets for the Chowilla Icon Site were met in 2011. Whilst overbank flow provided the greatest spatial extent of target species recruitment, watering has been an important management tool to maintain amphibious species on floodplain habitats during extended periods of low flow.

One year following flooding, the area and diversity of grass and herblands and flood dependent species has declined; however, both area and diversity of the aforementioned communities are greater than were previously recorded from 2006 to 2010 (even in years following watering). Therefore, Targets 5 and 6 have probably been met in 2012 when compared to all surveyed years, except 2011. Furthermore, grazing sensitive species were abundant in comparison to all surveyed years except 2011 indicating that Target 8 has also been met. Finally, there was no significant increase in the abundance of invasive species; hence, Target 9 was met in 2012.

5. References

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6. Appendices

Appendix 1: Site GPS coordinates (UTM format, map datum WGS 84).

Site Identifier	Easting	Northing	Site Identifier	Easting	Northing
001	485198	6240345	**043**	490075	6245613
002	484523	6241019	**044**	490242	6245188
003	483784	6240912	**045**	490345	6245049
004	483645	6239006	**046**	489458	6244864
005	483016	6239192	**047**	489351	6244956
006	484742	6236011	**048**	490503	6243645
007	484859	6236000	**049**	491017	6244303
008	485543	6236491	**050**	491442	6244363
009	483624	6239042	**051**	490966	6244592
010	483764	6239169	**052**	491223	6244572
011	484087	6238477	**053**	494051	6247841
013	486211	6237577	**054**	494249	6247739
014	486064	6237665	**055**	495612	6247657
015	485487	6237975	**056**	494893	6246522
016	485298	6237971	**057**	494499	6246028
017	485021	6238331	**058**	492860	6247105
018	484572	6238585	**059**	493830	6245882
019	484438	6238618	**060**	493910	6245725
020	485169	6237680	**061**	494310	6244810
021	485459	6238026	**062**	497206	6246599
022	485513	6238180	**063**	497618	6246464
023	486597	6237792	**064**	498069	6246375
024	486698	6237764	**065**	498376	6246311
025	486805	6238779	**066**	498394	6246168
026	486896	6239849	**067**	497154	6241724
027	488116	6242678	**068**	496397	6243263
028	488241	6242818	**069**	496572	6242971
029	488551	6243371	**070**	497243	6243954
030	489071	6244832	**071**	497342	6245017
031	489052	6244608	**072**	496523	6245423
032	489693	6244265	**074**	489083	6238916
033	488193	6241105	**075**	488969	6239062
034	487778	6240977	**076**	488205	6238287
035	489188	6243939	**077**	488122	6237666
036	488897	6242699	**078**	488692	6237147
037	489238	6242844	**079**	488209	6240070
038	489017	6242097	**080**	488942	6239515
039	489350	6239512	**082**	491300	6242057
040	488303	6242207	**083**	498893	6236615
041	488438	6242575	**084**	503870	6235576
042	489973	6245851	**085**	504385	6235609