Review of Water Thresholds - Gnangara

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Contents

Introduction

This report details an analysis that reviews the ecological impacts of revised proposed water level thresholds for wetlands in the Gnangara mound.

Full analysis can be found at (https://github.com/ChrisKav/DWER-Thresholds-2019)

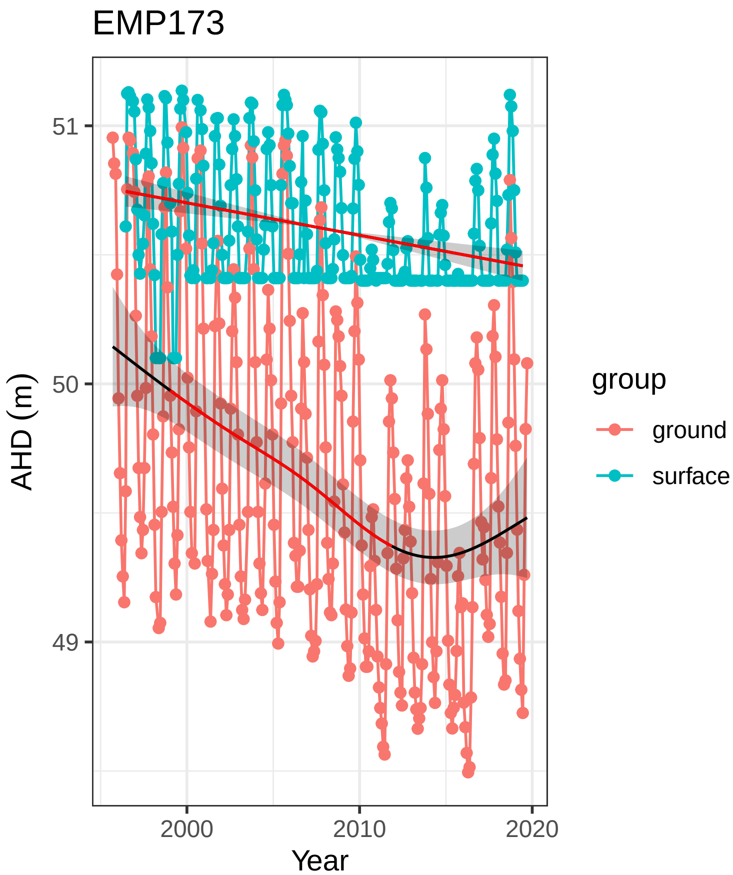

Figure 1: Ground and surface water levels recorded at bores and staff gauges in the vicinity of EMP 173

Melaleuca Park 173

Melaleuca Park 173 (EPP 173) is located within the Bassendean North Vegetation Complex and represents a regionally significant wetland (HILL 1996) that is fed from a series of springs along the western margin of the basin. The waters supported a rich macro invertebrate community and an endemic population of the black-striped minnow (*Galaxiella nigrostriata*). There have been dramatic decreases in surface and groundwater levels, to the point where the lake is almost dry during the summer months. Declining water levels are thought to be attributed to the local extinction of the black-striped minnow and degradation of fringing vegetation.

Water levels

There has been a prolonged decline in surface water levels since 1990 that show similar trends with fluctuations in ground water levels (Figure 1). Since 2011, there has been a slight but non-significant increase in groundwater levels. Mean maximum and minimum water levels have decreased by 0.8 m and 0.5 m, respectively, since 1994 (Table 1). The latest 5 year period (20014-2019) suggests that ground waters are reaching annual minimums earlier than previously.

Table 1: Five year summaries of ground water level data at EMP 173. Data is based from bore 61613213 due to many readings on surface water staff 6162628 being bellow the minimum reading.

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	50.9	49.2	1.73	September	May	242
08/1999 - 07/2004	50.8	49.1	1.66	September	May	220
08/2004 - 07/2009	50.6	49.0	1.59	September	May	168
08/2009 - 07/2014	50.0	48.7	1.27	October	June	224
08/2014 - 07/2019	50.1	48.7	1.38	September	April	225

Vegetation dynamics

Vegetation monitoring has been occurring at Melaleuca Park from 1997 to 2018. There has been marked changes in vegetation composition along the transect during this monitoring period (Figure 2). In 2014, *Baumea articulata* was absent from the transect, however, due to a wet season which saw Plot A and B submerged in 2018, *B. articulata* was recorded in low abundance. Similar changes have been observed for *Astartea scoparia*, which prior to 2018 was recorded wither dead or in poor condition. Since 2018, many of the *A. scoparia* plants were observed with new shoots. Other important vegetation components in Plot A include *Lepidosperma longitudinale* and *Leptocarpus scariosus*, both of which are also present in Plot B, whilst the former is present throughout the transect.

The long-term decline in water levels has had an adverse effect on the health of the *Melaleuca preissiana* population. Generally, this important canopy forming species has been declining in health, despite slight increases in plant health for 2018. The slight increase in *M. preissiana* health can be attributed to the recent stabilisation of ground water in levels.

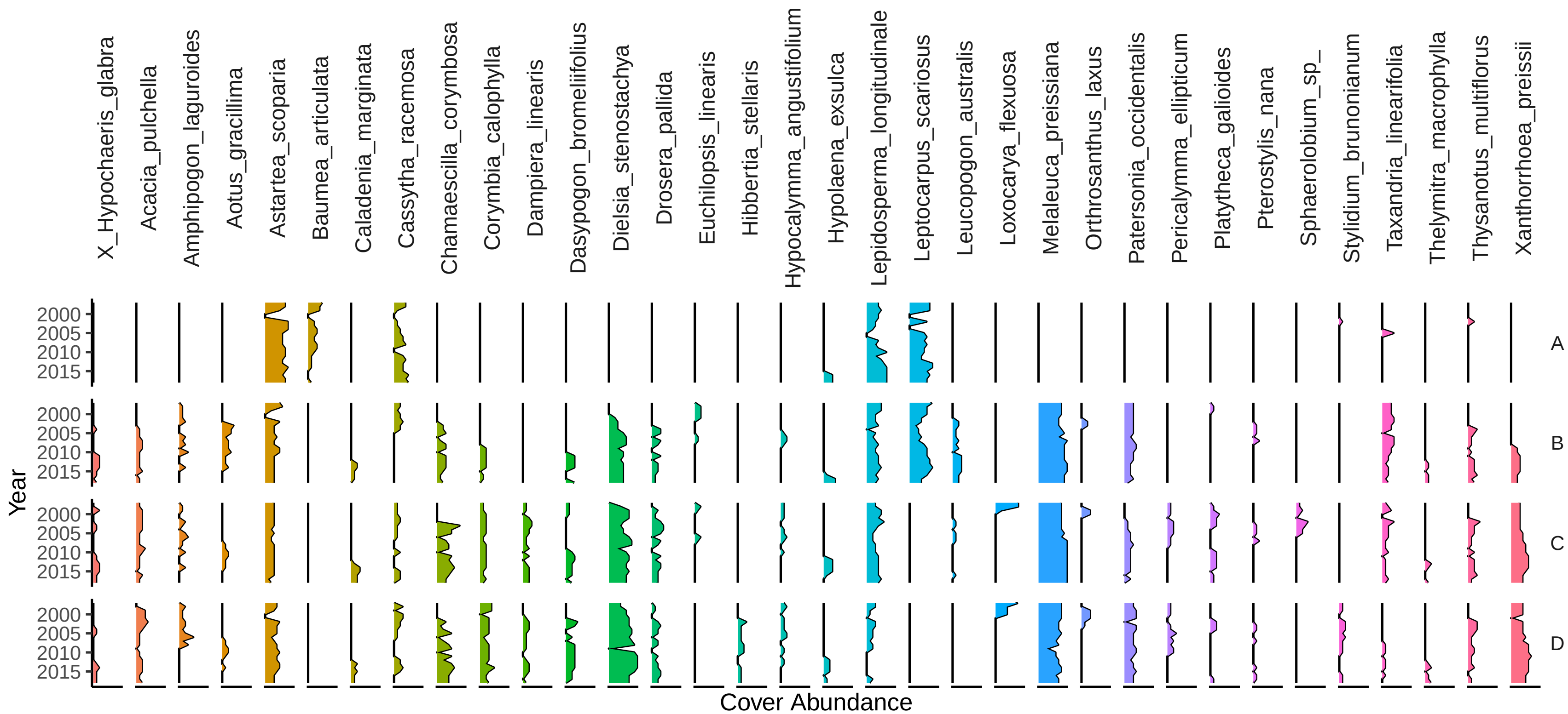

Figure 2: Cover abundances for each species across the four plots (A, B, C, D) at the Melaleuca Park 173 transect. Invasive species are denoted by 'X'. Only the most common species are included.

Ordination reveals distinct shifts in community composition since 1997 (Figure 3). Although Plot A is distinct, in terms of vegetation cover abundances, to Plots B, C and D, all plots display an upwards trajectory along the second axis (LV2). For Plot A, this the shift in composition is likely due to the loss of *B. articulata* from the plot. Modeling compositional changes in vegetation with changes in groundwater levels suggests a number of species which are likely to increase in cover abundance with declining ground water levels (Figure 4). These species, such as *Xanthorrhoea preissii*, are likely to become abundant in Plot A under a scenario of continuing declining ground water levels.

Aquatic Invertebrates

Revised water level threshold effects

Table 2: Ecological consequences of revised thresholds in terms of compliance of stated site values and site management objectives.

	Likely effect of 2030 revised thresholds	Future Compliance
Site values		
* Unique hydrology		
* High vertebrate and macro invertebrate species richness		
* Contains most northern population of black stripe minnow (*Galaxiella nigrostriata*)		
Site management objectives		
* Maintain wildlife and landscape values of the wetlands		
* Maintain the existing areas of wetland and stream vegetation they support		
* To protect invertebrate communities dependent on the wetland and stream		No
* To protect the fish species, *Galaxiella nigrostriata*		No

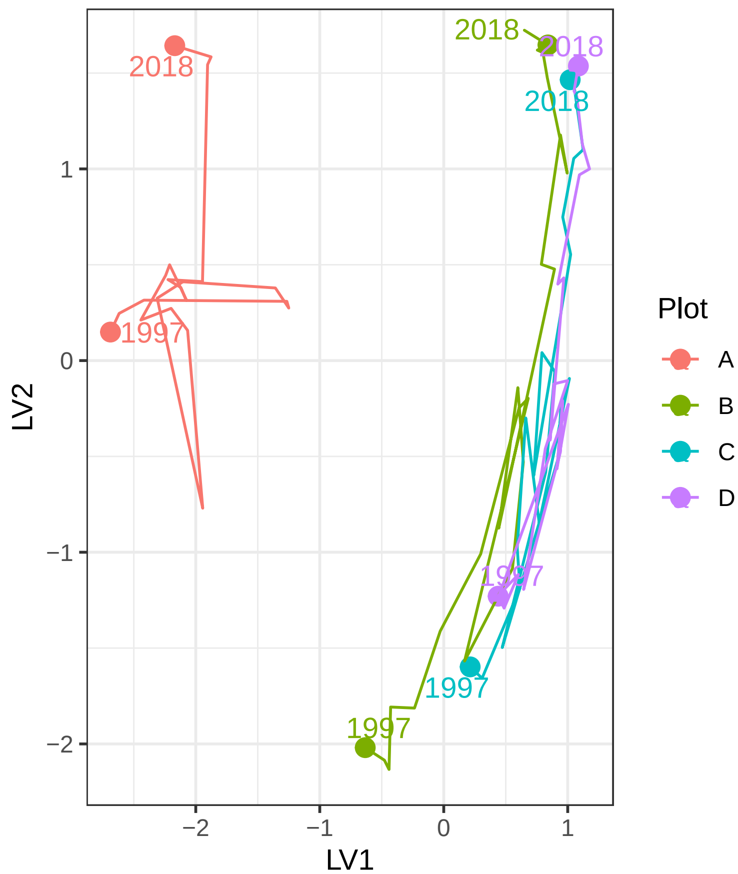

Figure 3: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

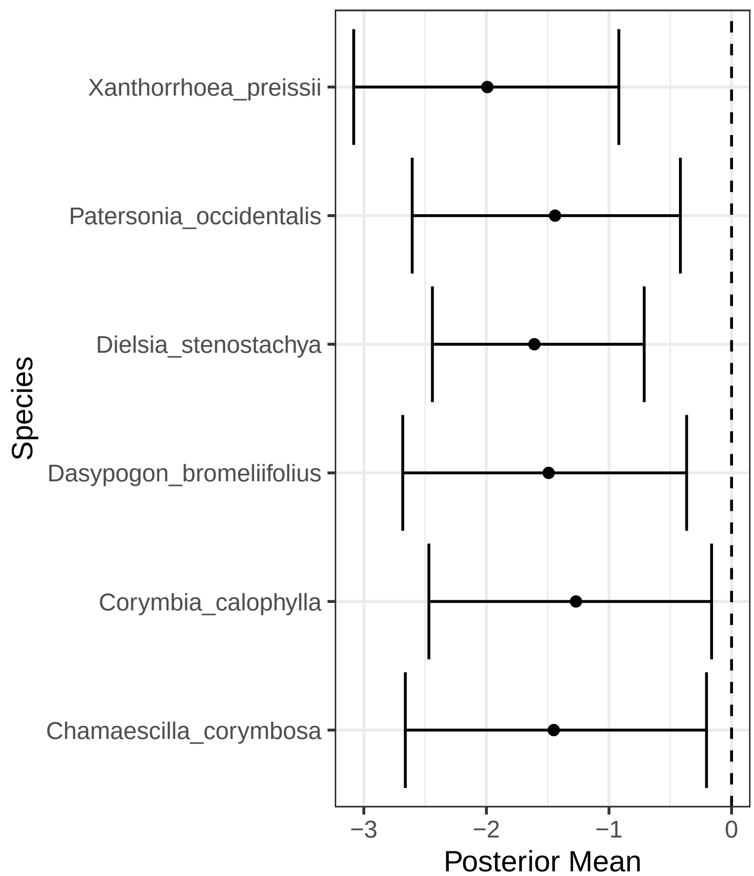

Figure 4: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 3: Five year summaries of surface water level data at EMP 78

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	66.2	66.0	0.17	July	June	-27
08/1999 - 07/2004	66.2	65.8	0.40	October	May	235
08/2004 - 07/2009	66.0	65.6	0.36	November	April	228
08/2009 - 07/2014	65.4	65.1	0.31	October	July	213
08/2014 - 07/2019	65.2	64.9	0.29	November	May	170

EMP 78

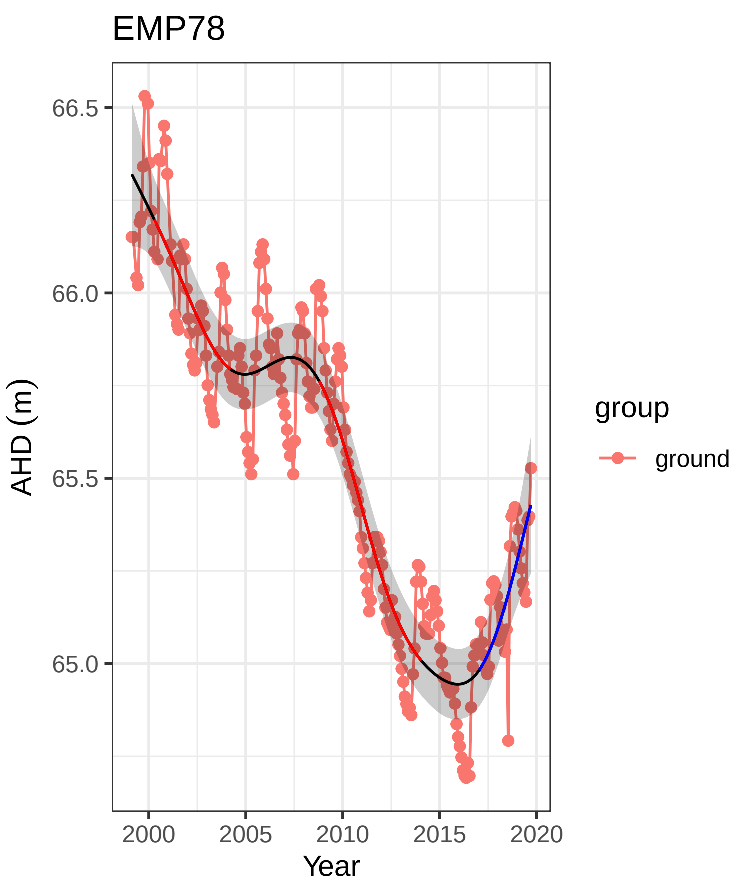

Figure 5: Ground and surface water levels recorded at bores and staff gauges in the vicinity of EMP 78

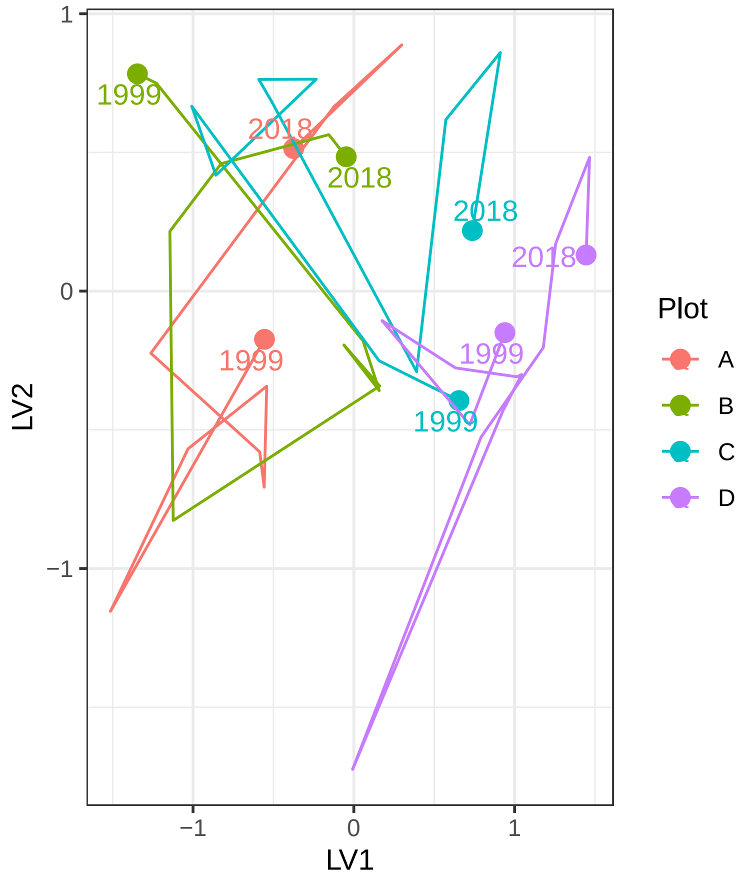

Figure 6: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

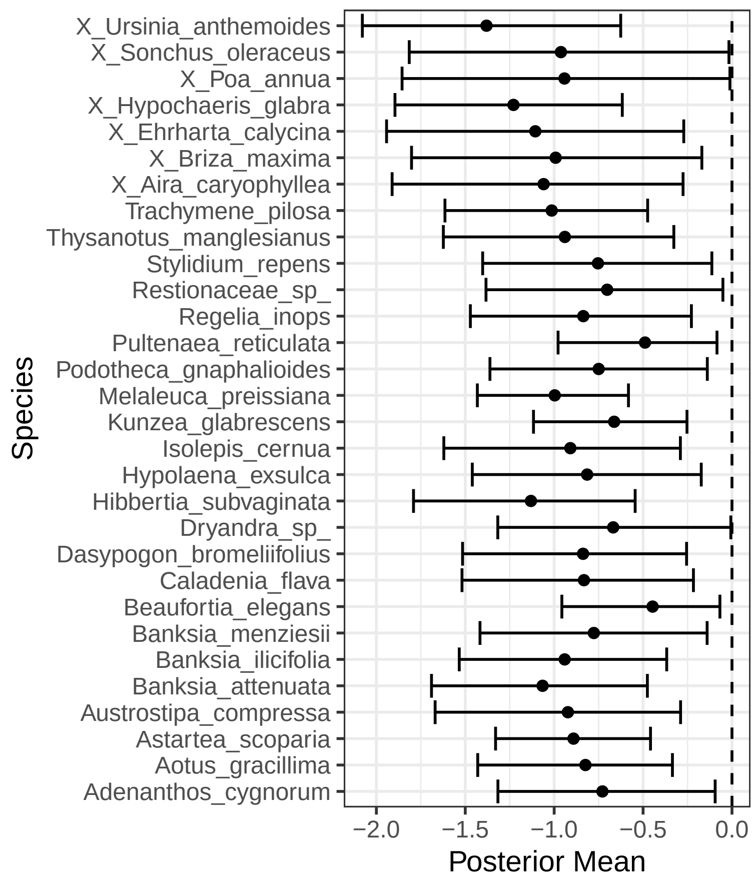

Figure 7: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 4: Five year summaries of surface water level data at Gingin

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	39.6	39.2	0.45	October	July	219
08/1999 - 07/2004	39.2	38.6	0.52	December	May	198
08/2004 - 07/2009	38.5	38.1	0.43	October	June	213
08/2009 - 07/2014	37.9	37.5	0.40	October	May	221
08/2014 - 07/2019	37.8	37.4	0.43	November	May	141

Gingin

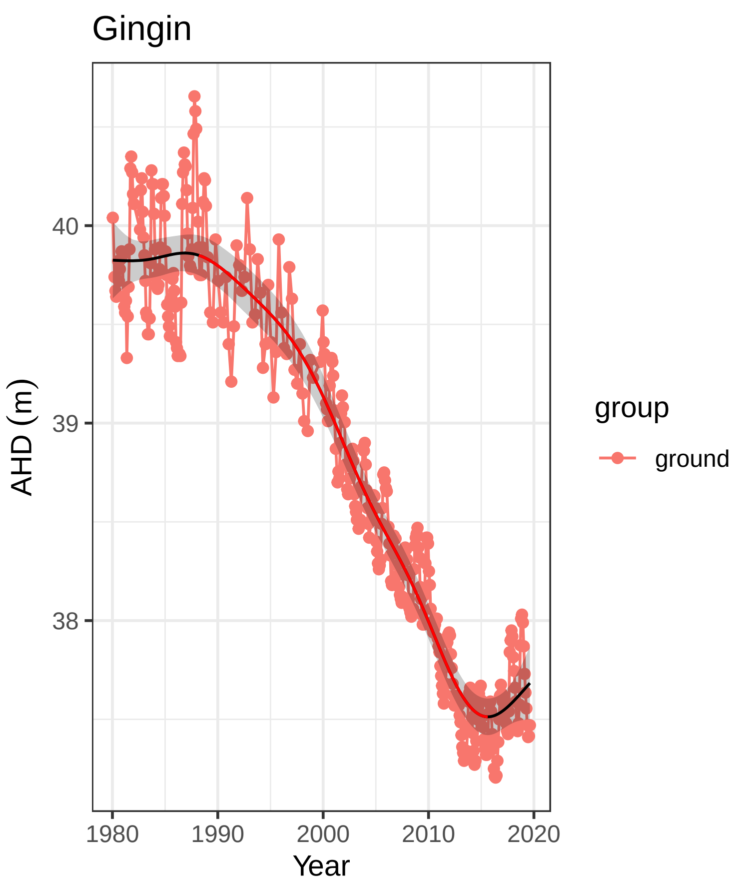

Figure 8: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Gingin

Table 5: Five year summaries of surface water level data at Goollelal

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	27.5	26.8	0.78	October	May	207
08/1999 - 07/2004	27.5	26.7	0.80	September	March	206
08/2004 - 07/2009	27.4	26.6	0.75	September	April	137
08/2009 - 07/2014	27.2	26.5	0.73	October	April	190
08/2014 - 07/2019	27.4	26.7	0.68	November	April	139

Lake Goollelal

Lake Goollelal, located within the Yellagonga Regional Park, is recognised as an important waterbird habitat and drought refuge (FROEND 2006) as well as habitat for the Swan River Goby (*Pseudogobius olorum*) and the Western Pygmy Perch (*Edelia vittata*) (WAWA 1995). The permanent deep waters found in the lake not only provides significant habitat for fauna and fringing vegetation, but also has significant value as a place of public enjoyment.

Water levels

Surface water levels recorded at Lake Goollelal reveal peak levels generally occur between September and November and lowest water levels between March and May (Table 5). There has been a consistent range of about 0.7 m in annual water level during this period. There has been a general trend of decreasing water levels since 1995 although recent increases since 2016 show surface waters at a similar depth to 1990 levels. Surface water levels show similar trends to groundwater levels at a nearby bore () as the lake is largely fed by groundwater. Although the preferred minimum threshold of 26.2 mAHD has not been breached, it is likely the threshold is set too low as the acidification of waters entering the lake is a concern (Quintero Vasquez 2018).

Vegetation dynamics

The composition of vegetation at Lake Goollelal has been assessed 14 times between 1997 and 2014 at four plots [I NEED TO READ THE 2014 VEG REPORT]. Plot A represents fringing *Melaleuca rhaphiophylla*/*Eucalyptus rudis* complex and a stable community of the native sedges, *Baumea articulata* and *Lepidosperma gladiatum*. The *Melaleuca rhaphiophylla*/*Eucalyptus rudis* complex continues throughout the transect, which has also remained relatively stable in terms of cover abundance since 2002.

Ordination reveals that Plot A has a distinct assemblage to the other plots but has displayed similar vegetation compositional changes. Shifts in compositional change has followed similar trajectories for each of the plots. All plots show an initial shift in community cover abundance from the 1997 survey and a return to 1997-like composition in the recent survey years.

Table 6: Ecological consequences of revised thresholds in terms of compliance of stated site values and site management objectives.

	Likely effect of 2030 revised thresholds	Future Compliance
Site values		
Waterbird habitat and drought refuge		
Supports good populations of native fish species, Swan River goby (*Pseudogobius olorum*) and the western pygmy perch (*Edelia vittata*)		

	Likely effect of 2030 revised thresholds	Future Compliance
Site management objectives		
Conservation and public enjoyment of natural and modified landscapes		
Protect and if possible enhance, fringing wetland vegetation including woodland and sedge vegetation		
Maintain permanent, deep water for waterbird habitat and as a drought refuge		
Maintain permanent water for fish and other dependent species		
Maintain the landscape amenity values of the wetland		

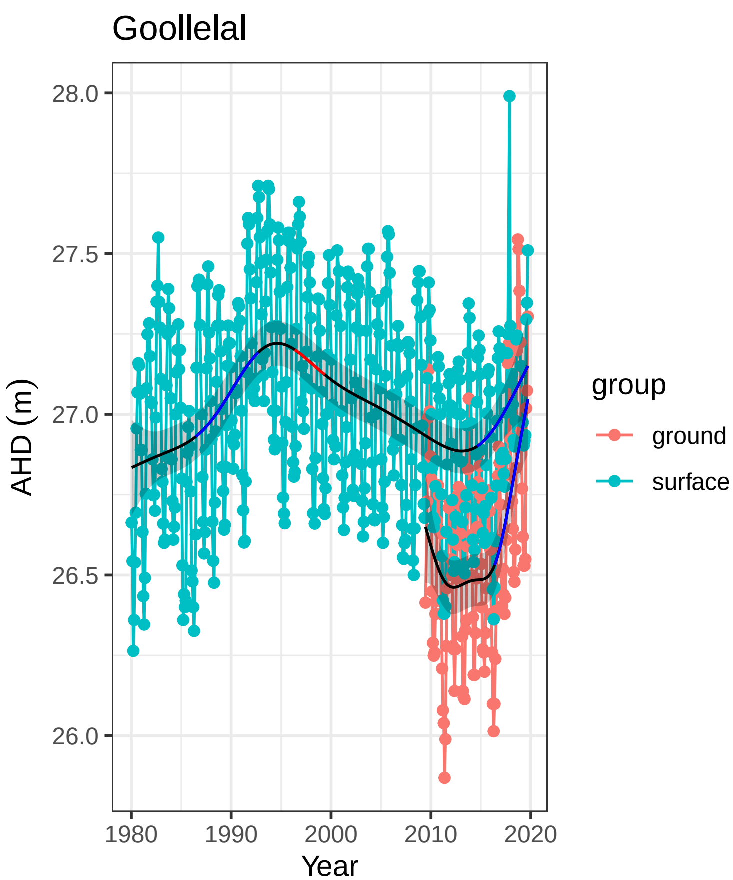

Figure 9: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Goollelal

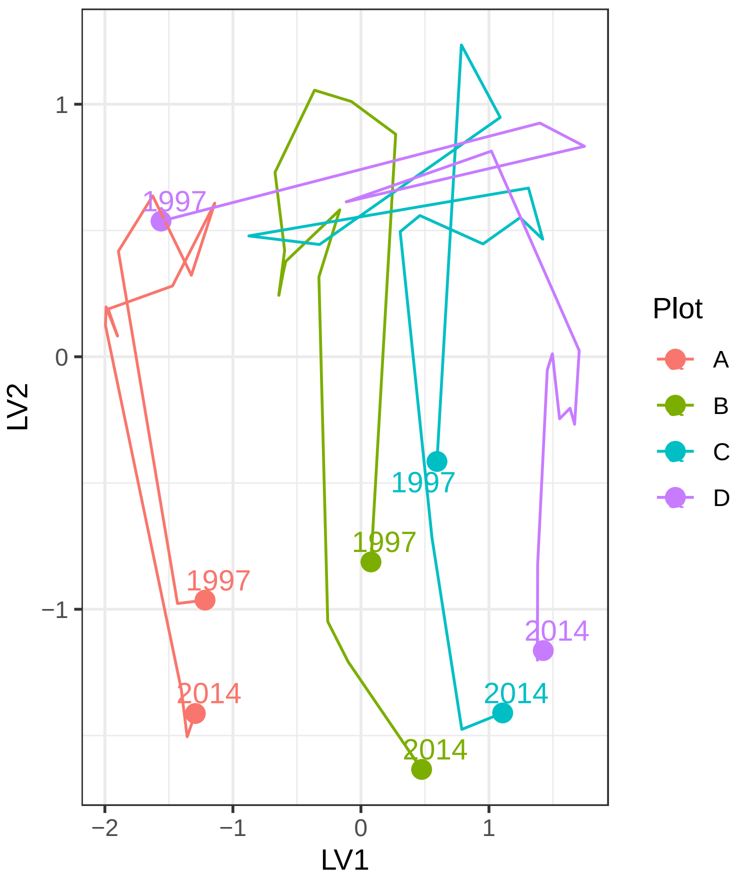

Figure 10: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

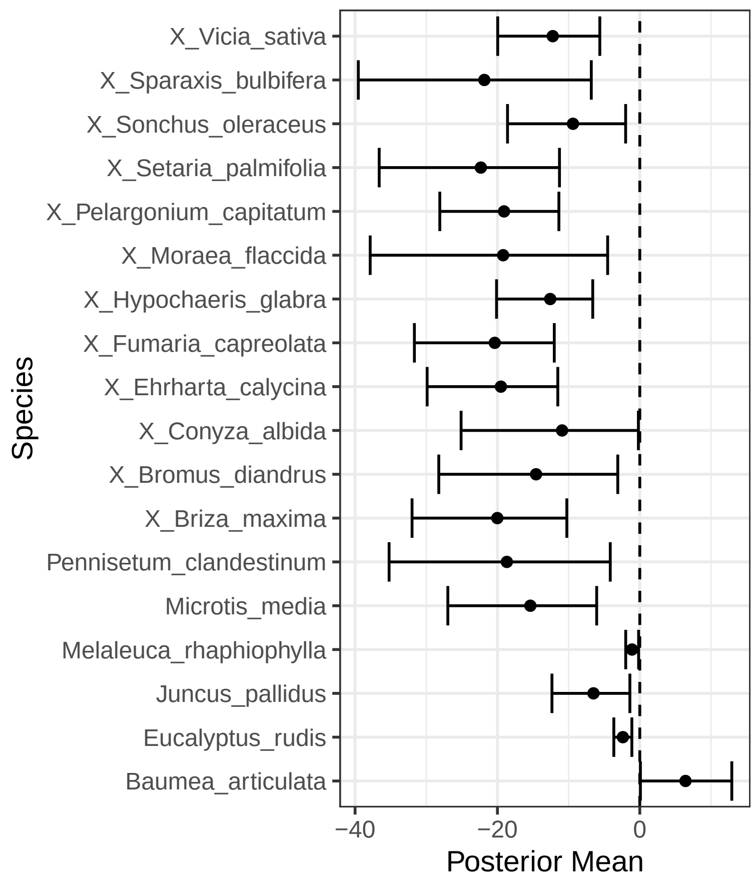

Figure 11: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 7: Five year summaries of surface water level data at Gwelup

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	7.5	5.7	1.85	September	April	239
08/1999 - 07/2004	6.7	5.1	1.52	October	April	172
08/2004 - 07/2009	6.3	5.0	1.32	September	December	14
08/2009 - 07/2014	6.1	5.0	1.17	October	January	138
08/2014 - 07/2019	7.3	5.6	1.66	October	April	222

Gwelup

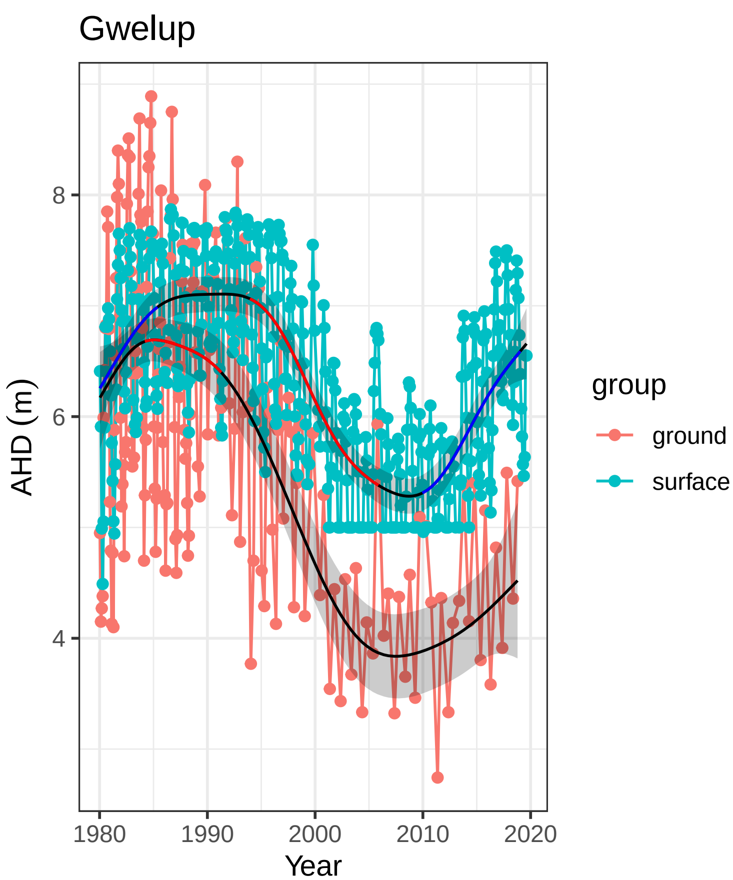

Figure 12: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Gwelup

Figure 13: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

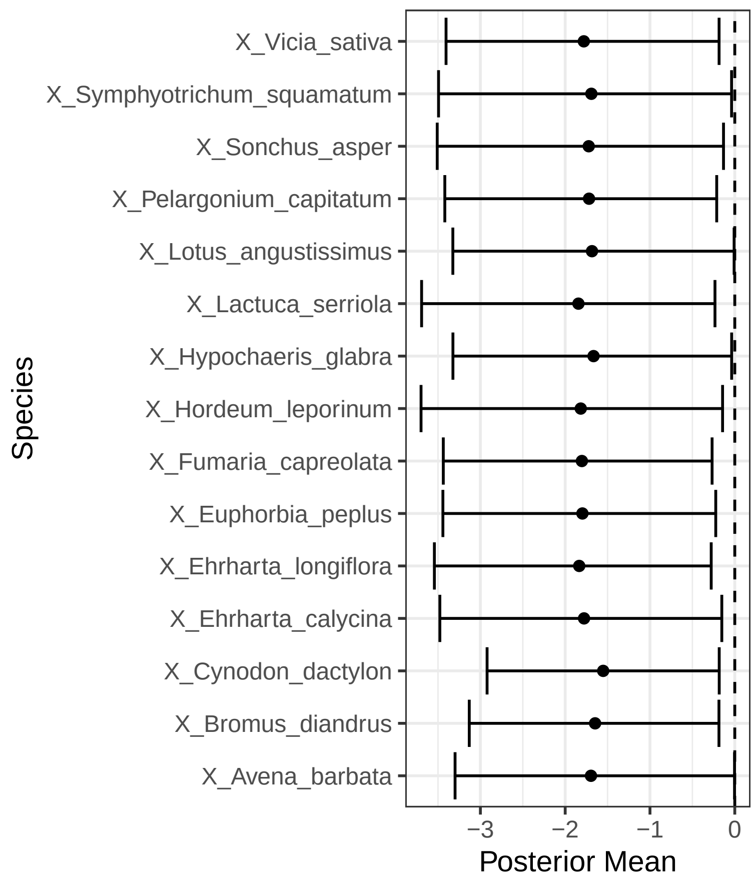

Figure 14: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 8: Five year summaries of surface water level data at Jandabup

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	44.9	44.1	0.81	October	February	156
08/1999 - 07/2004	44.9	44.2	0.64	September	March	151
08/2004 - 07/2009	44.8	44.2	0.59	July	March	108
08/2009 - 07/2014	44.7	44.2	0.52	October	January	164
08/2014 - 07/2019	44.7	44.2	0.51	September	March	182

Jandabup

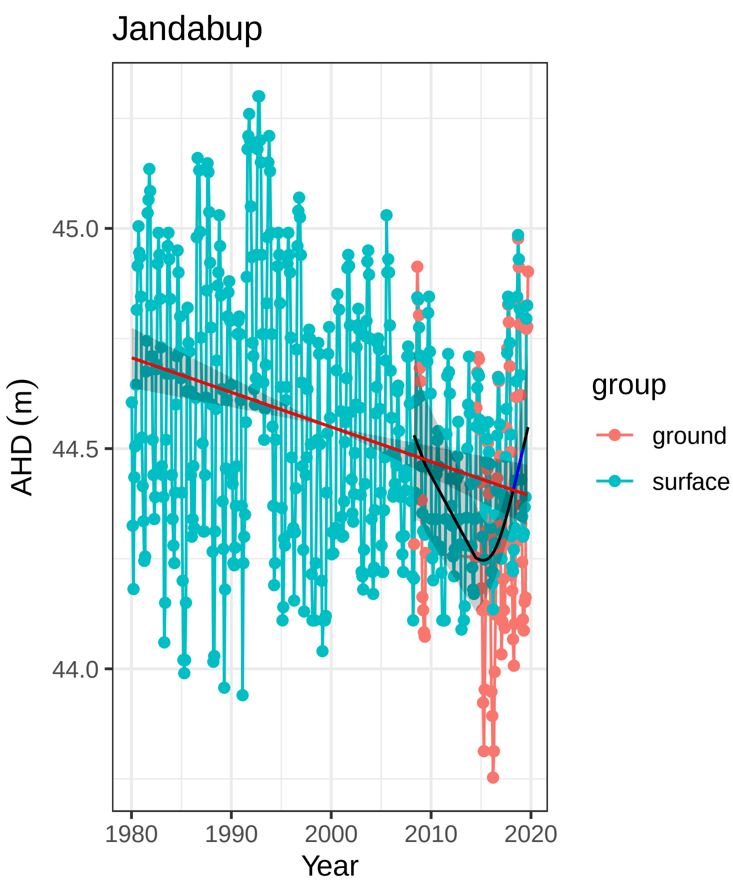

Figure 15: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Jandabup

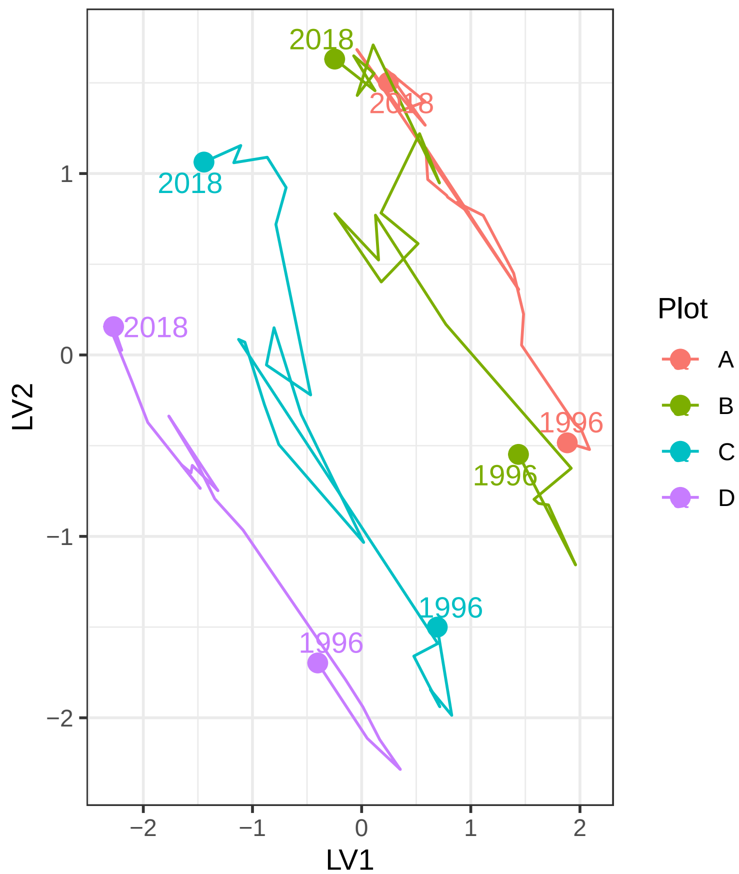

Figure 16: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

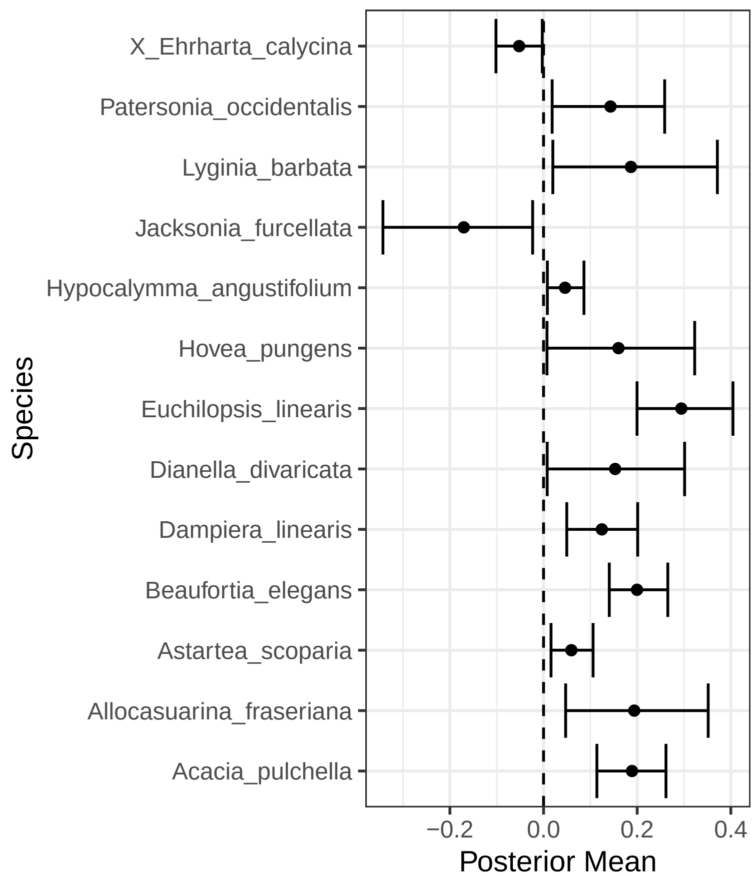

Figure 17: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 9: Five year summaries of surface water level data at Joondalup

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	17.2	16.2	0.96	September	April	213
08/1999 - 07/2004	17.0	16.1	0.92	October	April	179
08/2004 - 07/2009	16.9	16.1	0.79	October	April	181
08/2009 - 07/2014	16.9	16.1	0.82	October	March	173
08/2014 - 07/2019	17.2	16.5	0.68	October	April	206

Joondalup

At 611.5 ha, Lake Joondalup is the largest GMEMP monitored wetland and is managed by the Department of Biodiversity, Conservation and Attractions. The lake is an important habitat and drought refuge for water birds, and in conjunction with Lake Goollelal, is managed to support the full range of avian habitats (WAWA 1995). Other management objectives include the conservation of diverse wetland vegetation communities, including sedge beds, fringing woodlands and aquatic macrophytes, and the maintenance or enhancement of aquatic fauna in the lake. Lake Joondalup supports an important population of Pygmy Perch (*Edelia vittata*) and Swan River Goby (*Pseudogobius olorum*) and the fringing woodlands and bushland support a variety of significant mammal species.

Water levels

Lake Joondalup has remained permanently inundated at the staff gauge [HOW DO I FIND THIS OUT] since 1986 (REFERENCE Chapter 5 Horwitz et al). However, vast regions of the basin dry most summers. Historically, groundwater levels at monitoring bore 61610661 declined significantly from 19.3 to 18.1 mAHD from 1970 to 2002 (Figure 1). Currently, groundwater levels at this bore, as well as bore 61611423 (likely to better reflect lake surface water variation), have been increasing since 2015 to levels similar to the early 1990?s. Recent monitoring of surface water levels at the staff gauge 6162572 remained relatively stable from 2002 but have been increasing from 16.4 mAHD to approximately 17.2 mAHD in 2019. Five-year summaries of hydrological regimes at Lake Joondalup also reveal the higher mean minimum and maximum surface water levels in the latest period compared to earlier periods, as well as an increase in the number of days to reach seasonal minimum water levels (Table 1).

Vegetation Dynamics

The recent increases in surface water levels has increased the pH from 6.8 in 2016 to 8.4 in 2018 and increased alkalinity to 206 mg/L. Recent nutrient levels have been decreasing. [I NEED THIS DATA TO ANALYSE TRENDS] Vegetation surveys have been conducted along two transect at Lake Joondalup (Figure 2 and 3). Both the northern and southern transects were established in 1996 and were last surveyed in 2015. *Melaleuca raphiophylla* dominates the overstorey of plots in the northern transect while exotic species are abundant in the understory vegetation. There has been an increasing trend in cover abundance of the exotics *Bromus diandrus*, *Ehrharta longiflora*, *Euphorbia terracina*, *Fumaria muralis* and *Peargonium capitatum* in recent years. Fires in 2003 reduced the canopy condition and abundance of *M. raphiophylla* in the southern transect, and despite the slightly higher cover abundance of native species, native and exotic species richness is equal along the transect. The site also contains healthy stands of *Baumea articulate* in the submerged regions of the transect.

All plots in both transects have displayed similar trends in community compositional change during the survey period. In the southern transect, latent model ordination reveals separation of the plots along the first axis, with a general increasing temporal trend along the second axis, except for a period around 2003 ? 2006 where there was a hiatus (Figure 4). This hiatus in change would be associated with the 2003 bushfire and represents the recovery period. The trajectory for plot A is different, however, as the trend away from

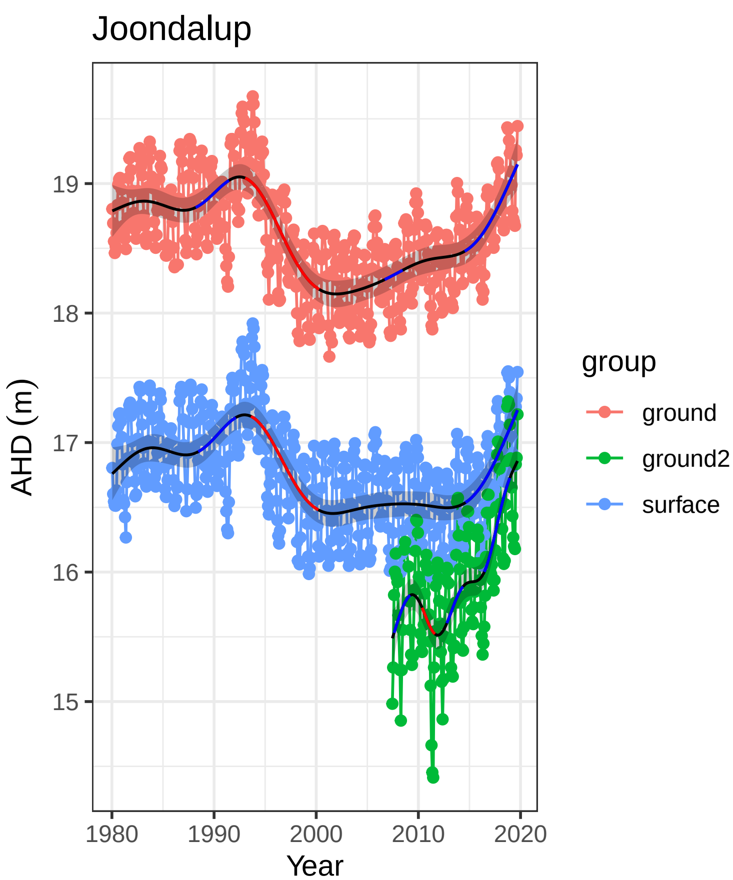

Figure 18: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Joondalup

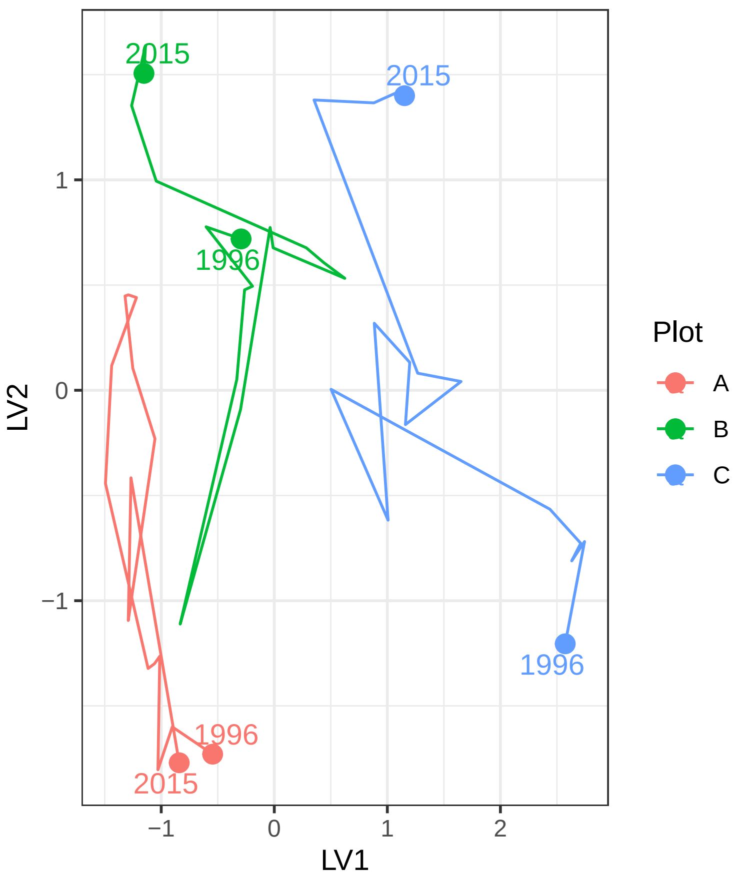

Figure 19: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for at the northern Joondalup transect

the original 1996 survey has reversed and the contemporary community is now becoming more like the 1996 communities. When the ordination model was re-run accounting for fluctuations in groundwater levels as a co-variate, the pattern of change in community trajectories remained unchanged, suggesting that these shifts have not been greatly influenced by groundwater levels. A similar temporal shift was observed in the northern transect, where the contemporary plot A has returned to a composition similar to the 1996 survey (Figure 5). Changes associated with groundwater fluctuations are also weak, with ordination accounting for groundwater levels displaying similar patterns to the full residual model. The proportion of native species has generally remained below 50% for both transects since 2009 (Figure 6 & 7).

Aquatic Invertebrates

Aquatic invertebrates have been sampled from Lake Joondalup every year since 1996. During this period, 16-30 families of aquatic invertebrates have been recorded per sampling event, except for the latest round in 2018 where family richness was only nine. This exceptionally low family richness was likely due to the lack of insects and associated parasitic mites among the sampled communities. The phreatoicid isopod *Amphisopus palustris* was also absent in 2018 despite being collected every spring in Lake Joondalup (expect 2004). Furthermore, this reduced richness occurred during a period of relatively high surface water levels, suggesting other anthropogenic factors may be responsible for the decline of insect fauna within the lake. Otherwise, the lake hosts abundant populations of Ceinidae (amphipods), *Palaemonetes australis* (crustacean), *Calanoid copepods* and Cyprididae (ostracods). [ANALYSE INVERTS HERE]

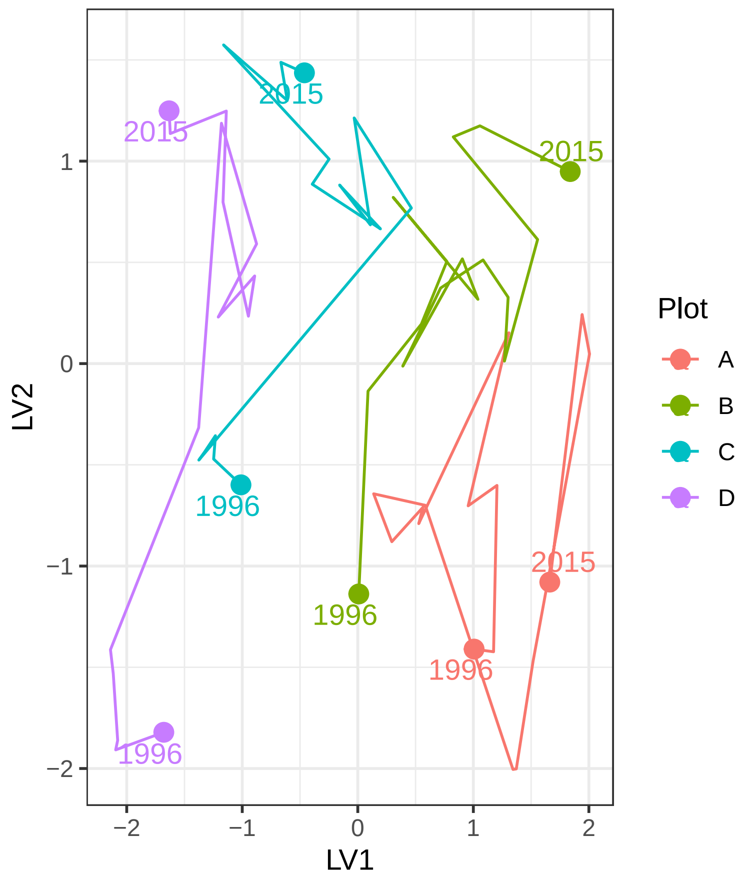

Figure 20: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for at the southern Joondalup transect

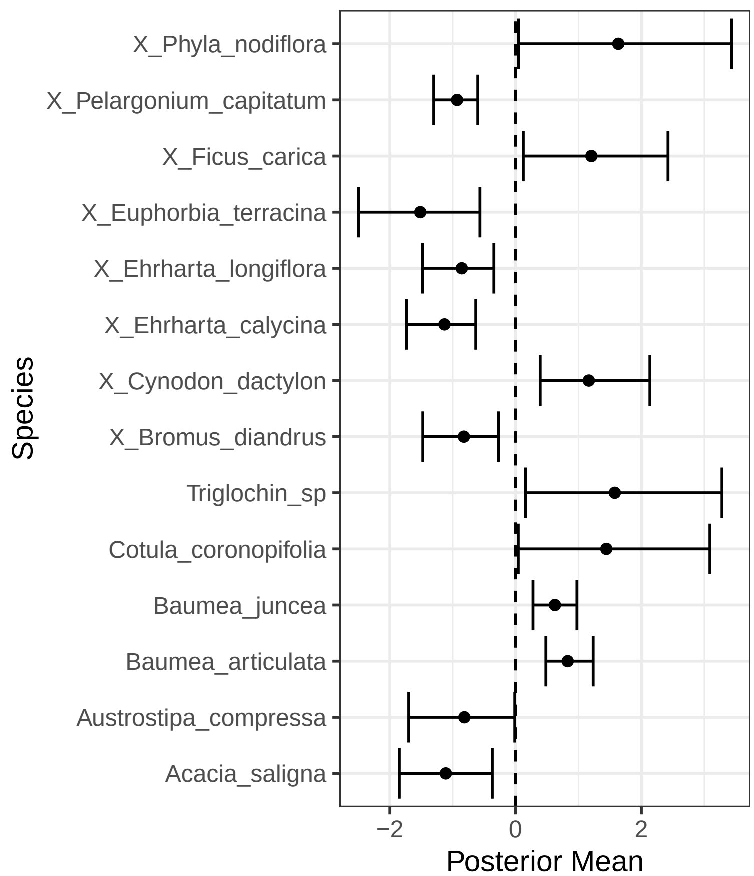

Figure 21: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

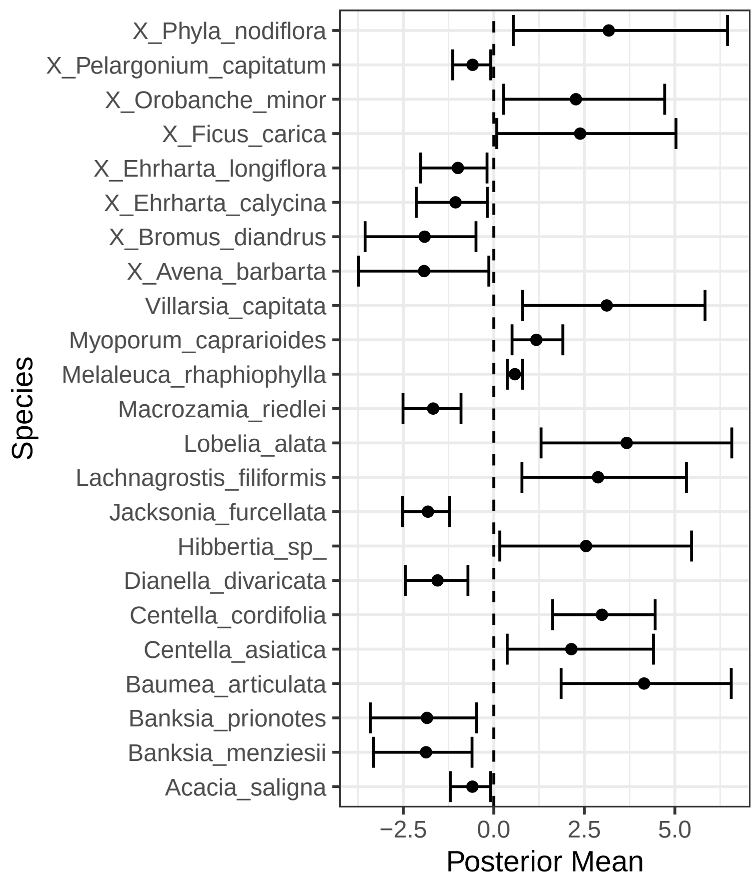

Figure 22: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Revised water level threshold effects

[Insert plot of future changes in groundwater]

The water levels in the vicinity of Lake Joondalup are expected to increase up to 2.1m by 2030 from 2013 levels based on the revised groundwater allocations. This increase in water level will continue the increasing trend being observed in the lake?s surface water levels since 2015. Maintaining surface water levels above 16.2mAHD at staff 6162572 will ensure permanent water habitat for fauna and flora and the visual amenity of the area. The diverse macrophytes inhabiting plot A and B of both transects are likely to persist and continue to provide a rich habitat for aquatic vertebrates. Although important native macrophytes and wetland species are likely to continue at relatively high cover abundances under the future scenario, there is a high proportion of exotic taxonomic richness at these sites that the model presented here does not associate with groundwater levels. The contribution of exotic species is likely associated with climatic factors and landscape changes and under the 2030 proposed groundwater thresholds, they will likely to continue contributing a large proportion of the taxonomic richness to the Lake Joondalup vegetation community. Further vegetation monitoring is required at these transects to determine vegetation compositional changes since 2015 to understand if the trajectory in compositional change is continuing.

Table 10: Ecological consequences of revised thresholds in terms of compliance of stated site values and site management objectives.

	Likely effect of 2030 revised thresholds	Future Compliance
Site values		
Water bird habitat and drought refuge	The proposed increases in groundwater levels around the lake will ensure the site remains an important water bird habitat. The proposed increases will also ensure the lake is permanently inundated, which will ensure the lake is a drought refuge for water birds.	Yes
Diverse range of macrophytes	The current diversity of macrophytes, including *B. articulata*, *B. juncea* and *L. longitudinale*, will continue. There is the possibility of these species extending into current terrestrial regions of the lake.	Yes
Site management objectives		
Conservation and public enjoyment of natural and modified landscapes		Yes
Conserve existing wetland vegetation, including sedge beds, fringing woodland and aquatic macrophytes	The predicted increases in groundwater levels will ensure the current wetland at a state similar to 2015. It is possible that sustained increases in groundwater levels will extend the range of these species around the lake by ‘migrating’ up slope.	Yes
Maintain and if possible, enhance the aquatic fauna of the lake		

	Likely effect of 2030 revised thresholds	Future Compliance
In conjunction with Lake Goollelal, to support the full range of habitats for avian fauna	The maintenance of permanent surface water and wetland vegetation will continue to provide a diverse habitat for different avian species. [NEED TO COMMENT ON AQ INVERTS AS FOOD]	Yes
Ensure the landscape and amenity values of the lake are maintained, except under very low rainfall climatic conditions		Yes

Table 11: Five year summaries of surface water level data at Lexia186

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	3.2	1.8	1.34	September	May	213
08/1999 - 07/2004	2.8	1.8	0.98	October	March	168
08/2004 - 07/2009	2.4	2.0	0.39	September	November	12
08/2009 - 07/2014	2.0	1.0	0.98	October	July	88
08/2014 - 07/2019	2.0	1.0	0.97	September	January	124

Lexia 186

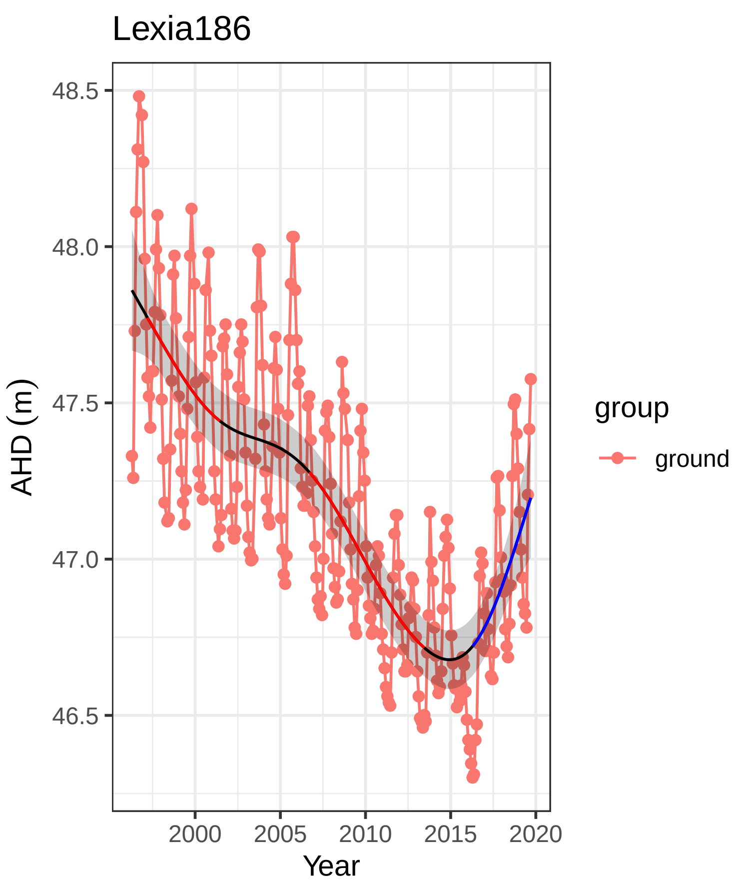

Figure 23: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Lexia 186

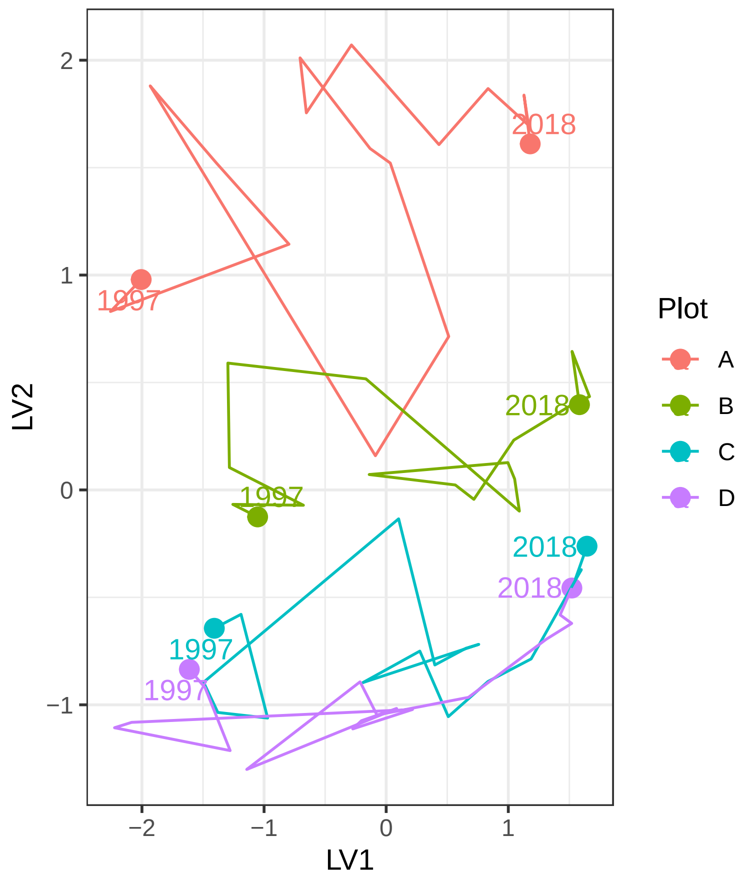

Figure 24: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

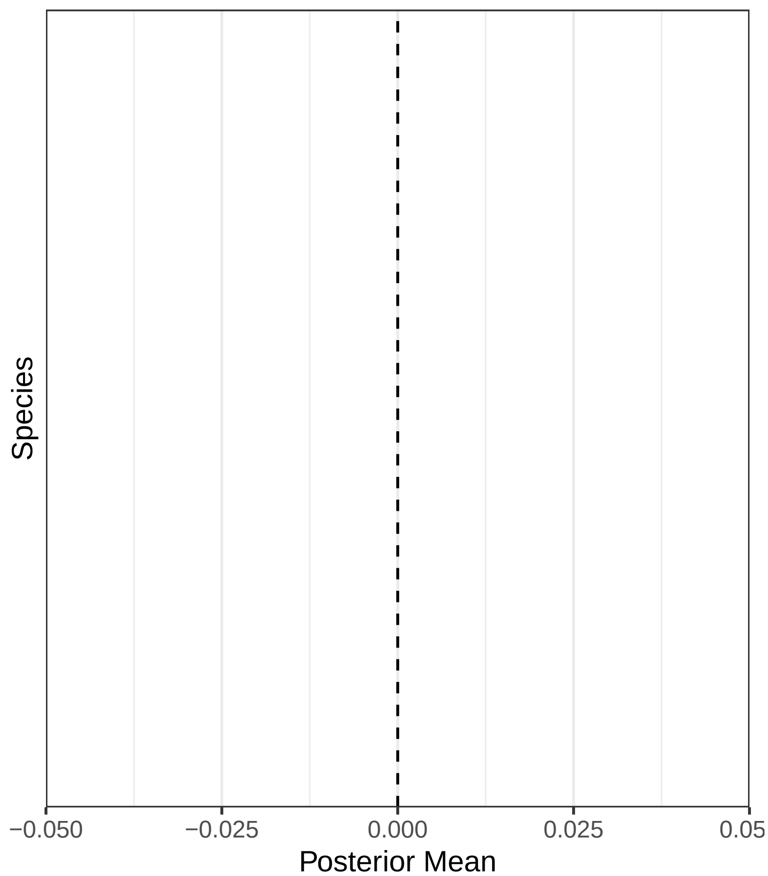

Figure 25: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 12: Five year summaries of surface water level data at Loch McNess

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	7.1	7.0	0.11	September	March	123
08/1999 - 07/2004	7.1	6.9	0.12	July	March	91
08/2004 - 07/2009	7.0	6.8	0.21	June	February	131
08/2009 - 07/2014	6.5	6.2	0.31	October	May	229
08/2014 - 07/2019	6.2	6.1	0.11	December	July	25

Loch McNess

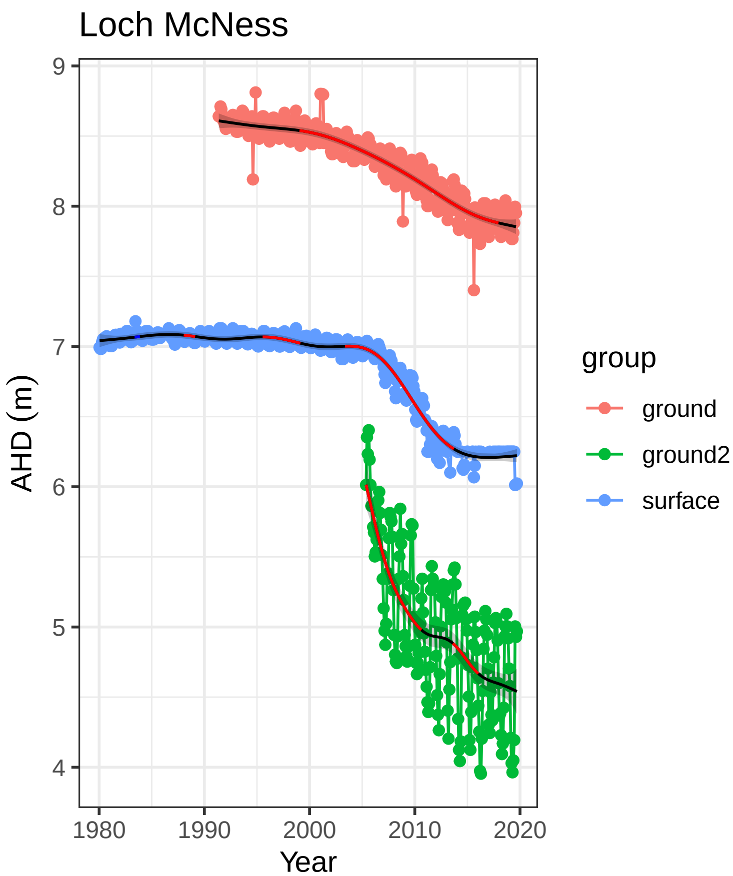

Figure 26: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Loch McNess

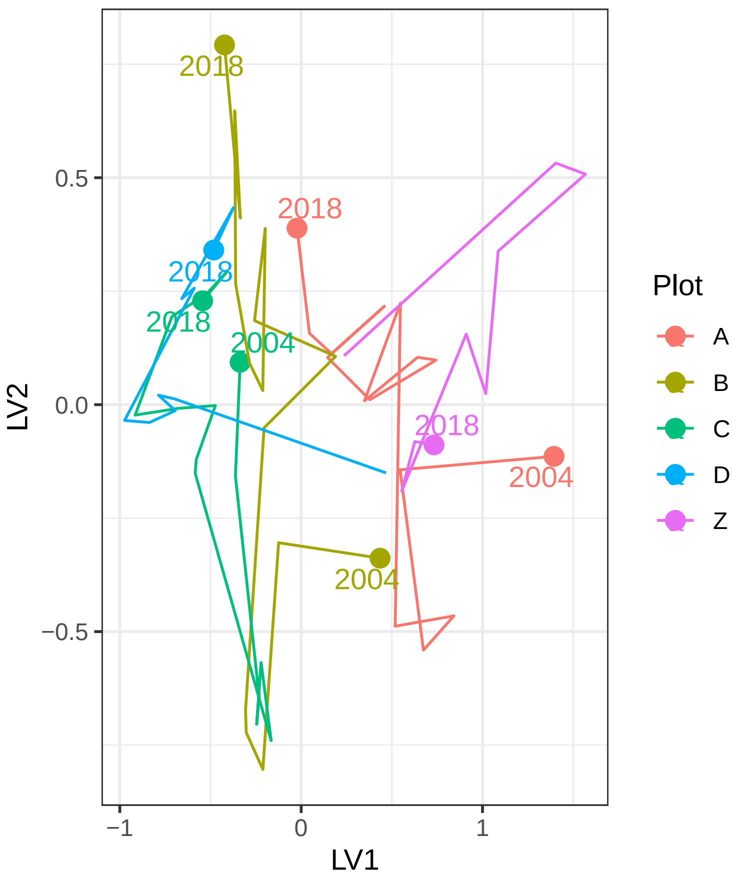

Figure 27: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

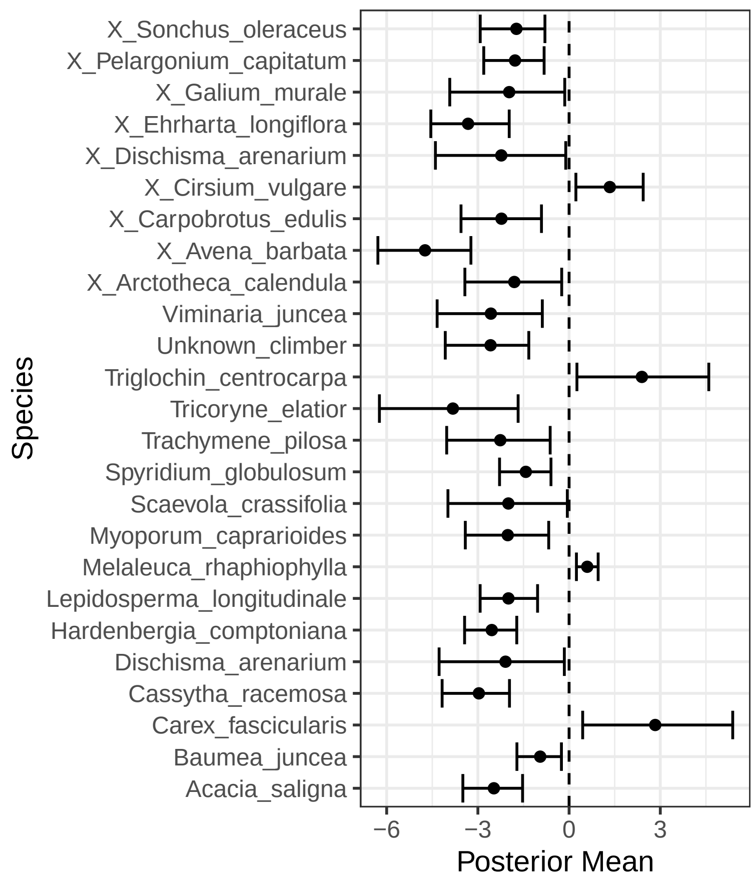

Figure 28: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 13: Five year summaries of surface water level data at Mariginiup

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	42.0	41.2	0.81	September	February	176
08/1999 - 07/2004	41.8	41.3	0.51	October	July	136
08/2004 - 07/2009	41.5	41.3	0.21	September	July	112
08/2009 - 07/2014	41.3	41.1	0.19	October	January	21
08/2014 - 07/2019	41.4	41.0	0.40	September	January	134

Mariginiup

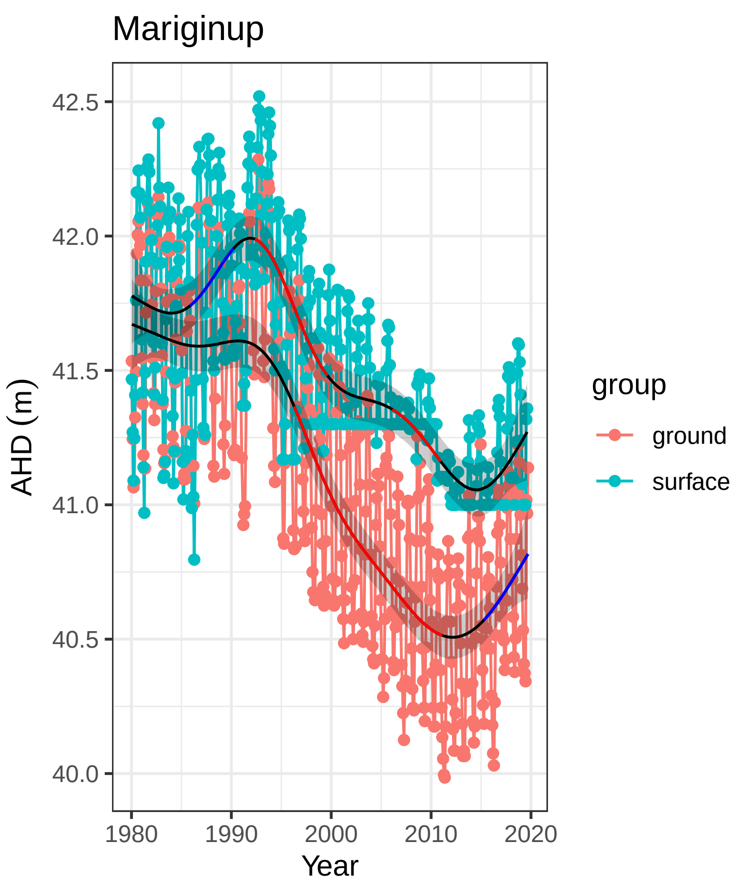

Figure 29: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Mariginiup

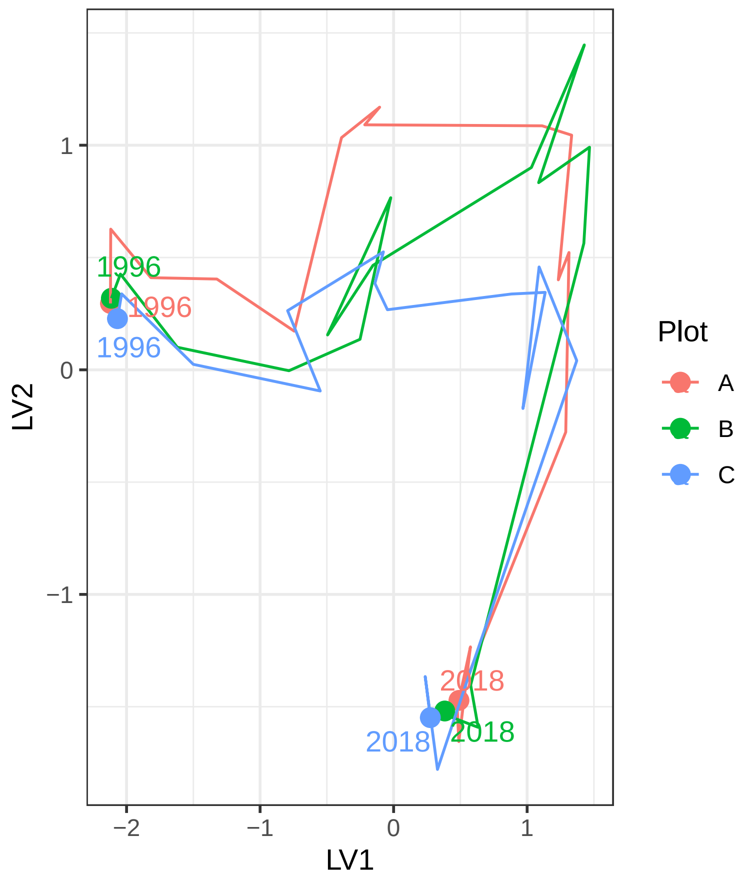

Figure 30: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

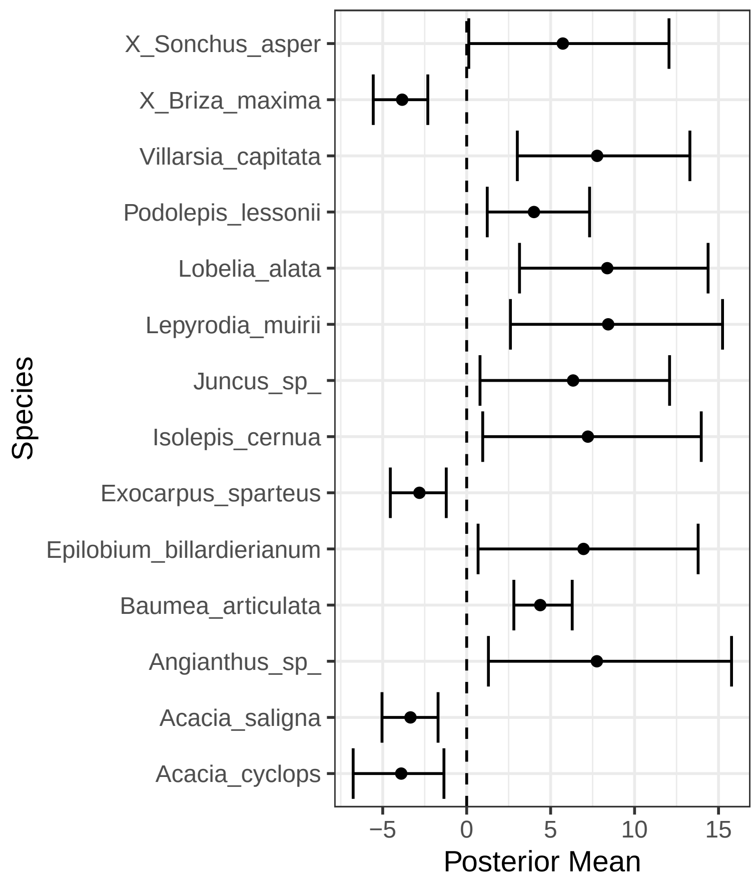

Figure 31: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 14: Five year summaries of surface water level data at MM59B

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	18.9	18.0	0.88	September	May	221
08/1999 - 07/2004	18.6	17.8	0.82	October	April	188
08/2004 - 07/2009	18.6	17.9	0.68	October	March	144
08/2009 - 07/2014	18.8	18.1	0.69	October	May	206
08/2014 - 07/2019	19.0	18.4	0.60	September	April	224

MM59B

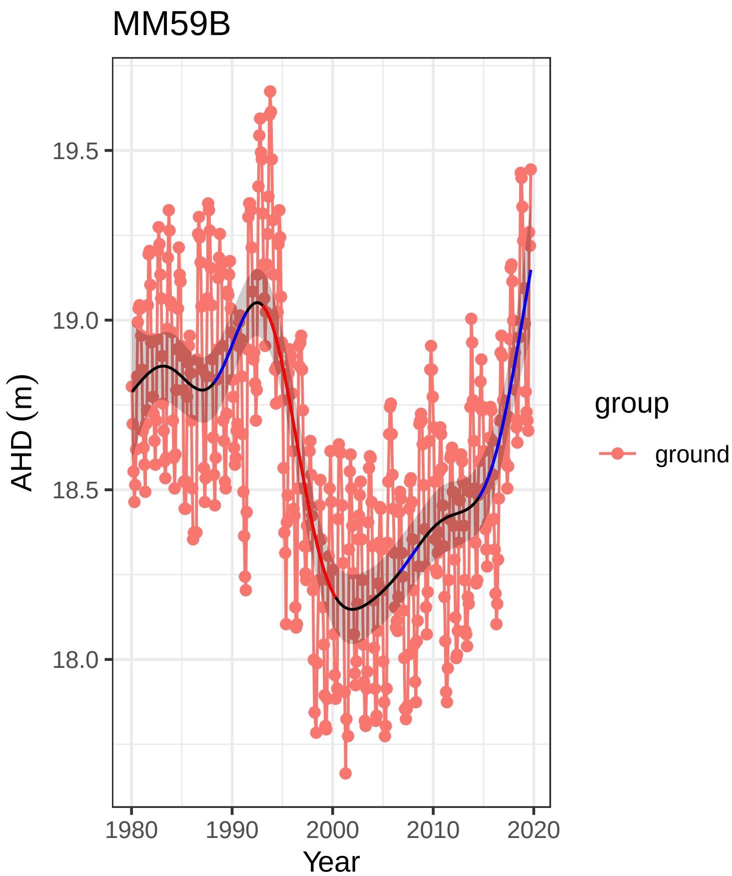

Figure 32: Ground and surface water levels recorded at bores and staff gauges in the vicinity of MM59B

Table 15: Five year summaries of surface water level data at Nowergup

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	17.0	16.2	0.84	October	May	115
08/1999 - 07/2004	16.7	16.0	0.72	October	May	20
08/2004 - 07/2009	16.8	16.2	0.56	October	September	-1
08/2009 - 07/2014	16.2	16.0	0.17	September	December	79
08/2014 - 07/2019	16.0	15.6	0.39	September	November	56

Nowergup

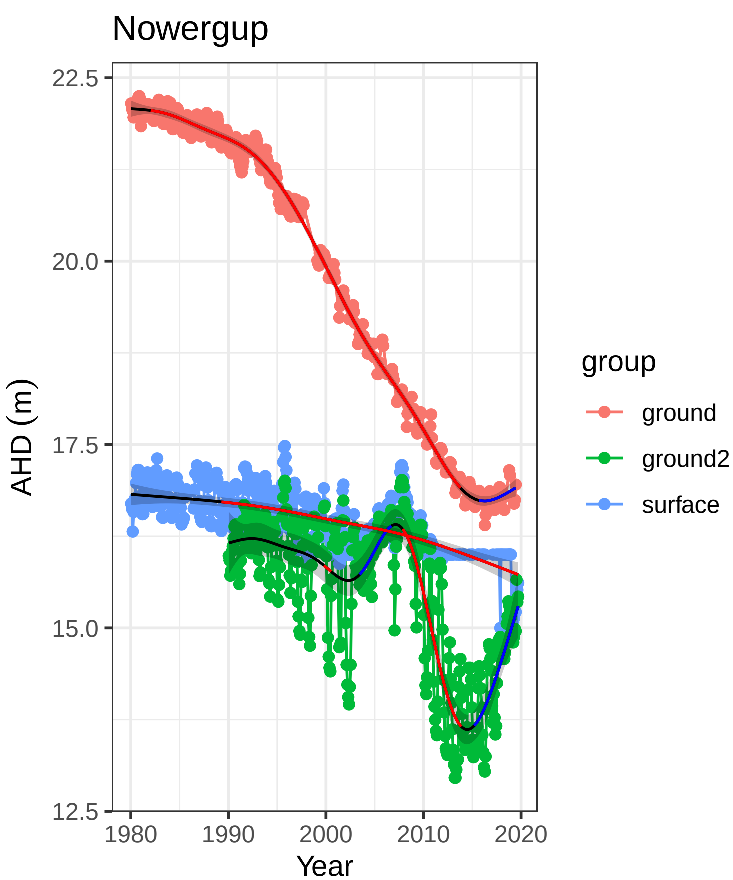

Figure 33: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Nowergup

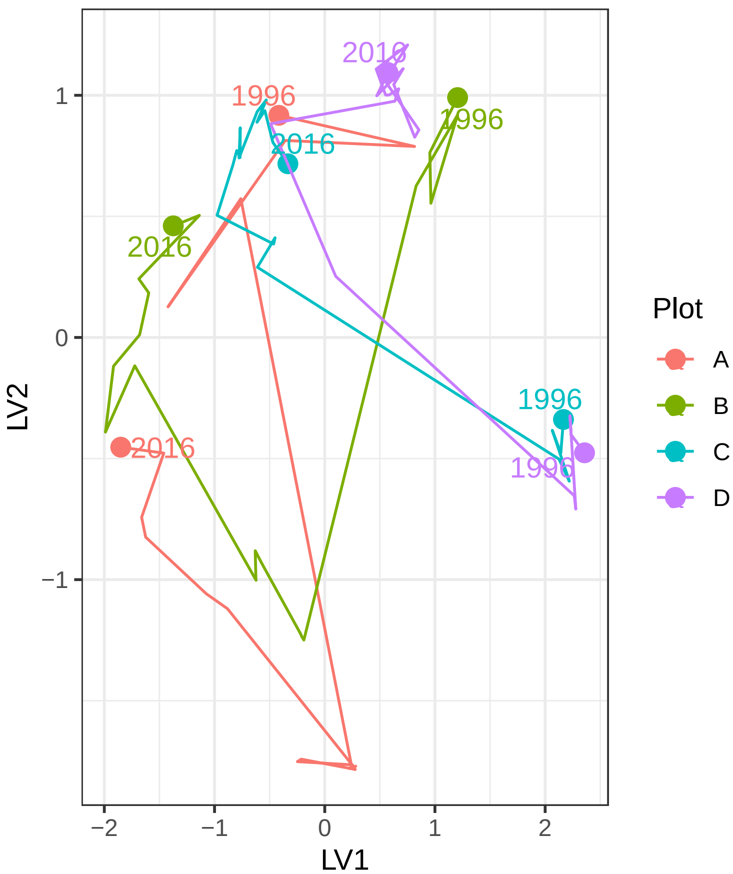

Figure 34: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

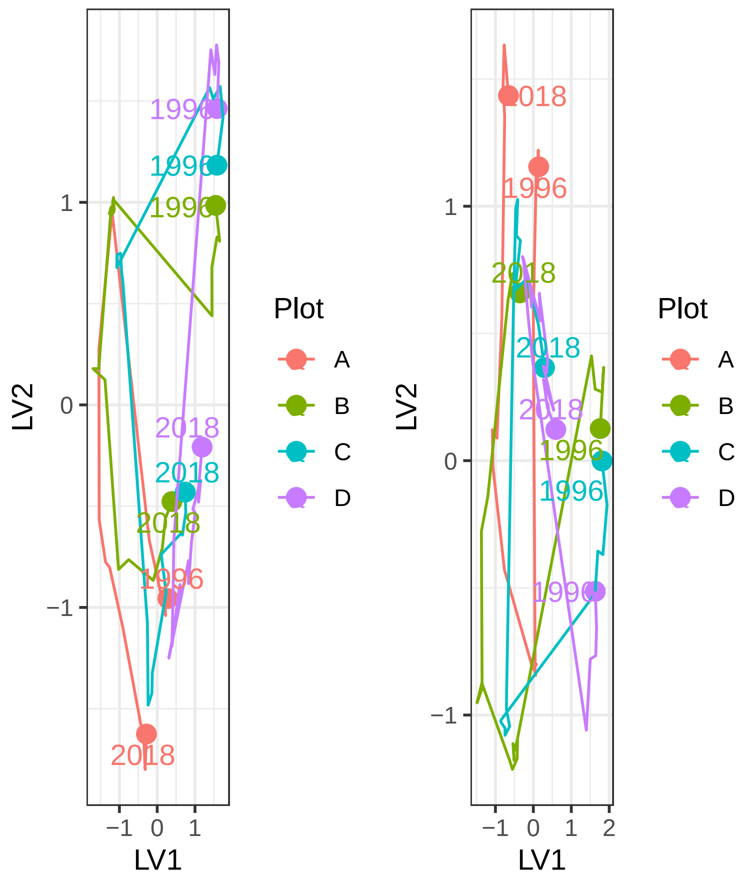

Figure 35: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

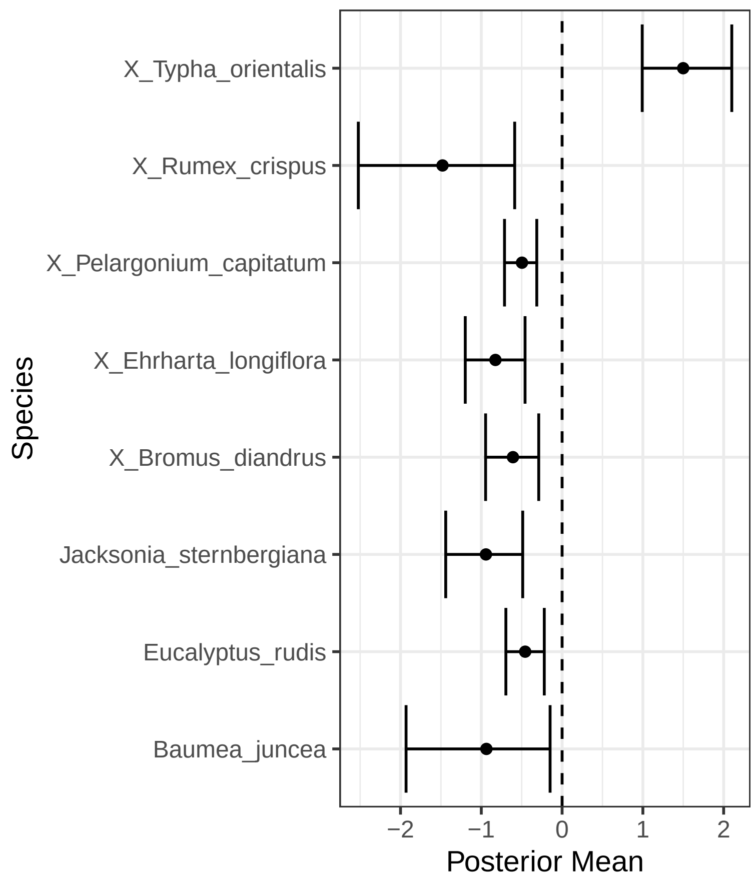

Figure 36: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

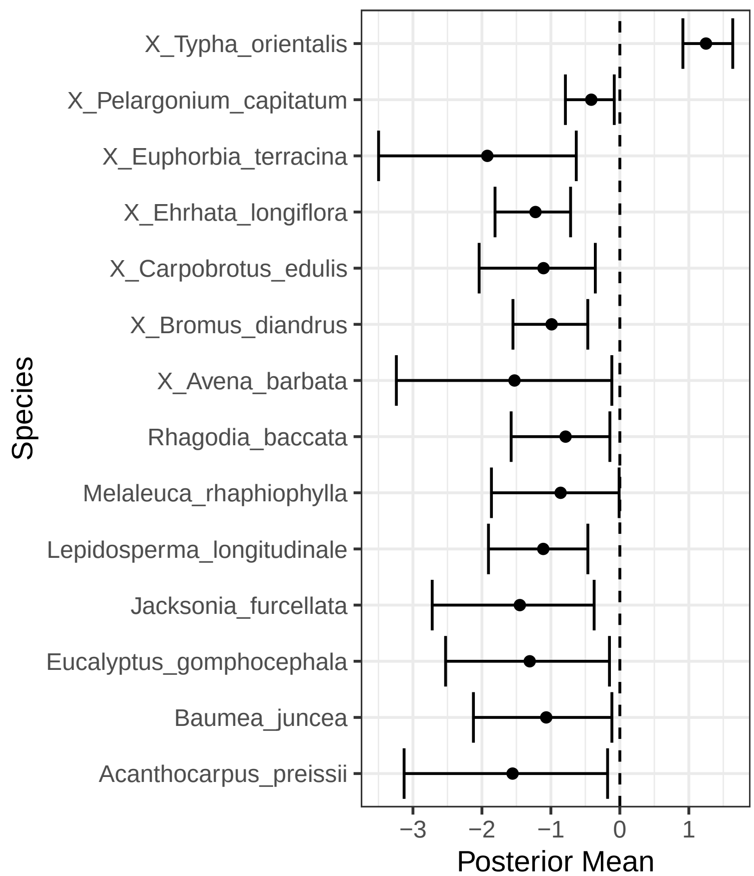

Figure 37: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 16: Five year summaries of surface water level data at Pipidinny

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	3.2	1.8	1.34	September	May	213
08/1999 - 07/2004	2.8	1.8	0.98	October	March	168
08/2004 - 07/2009	2.4	2.0	0.39	September	November	12
08/2009 - 07/2014	2.0	1.0	0.98	October	July	88
08/2014 - 07/2019	2.0	1.0	0.97	September	January	124

Pipidinny

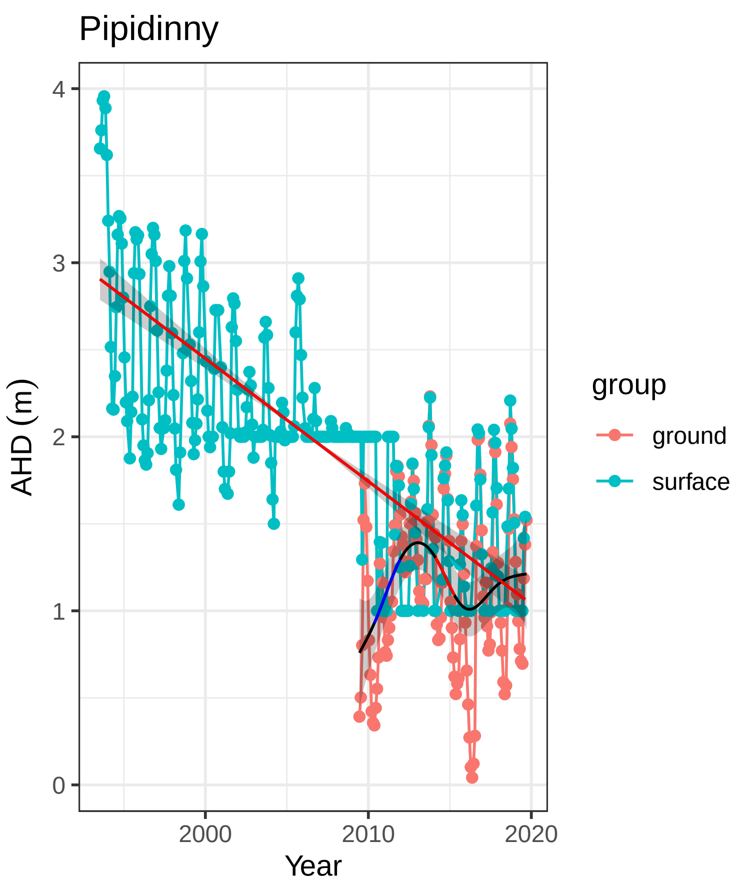

Figure 38: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Pipidinny

Table 17: Five year summaries of surface water level data at PM9

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	58.4	57.7	0.73	November	June	252
08/1999 - 07/2004	57.5	56.8	0.68	September	July	201
08/2004 - 07/2009	56.5	56.0	0.49	October	July	257
08/2009 - 07/2014	55.2	54.7	0.44	November	September	207
08/2014 - 07/2019	54.4	52.8	1.55	December	May	242

PM9

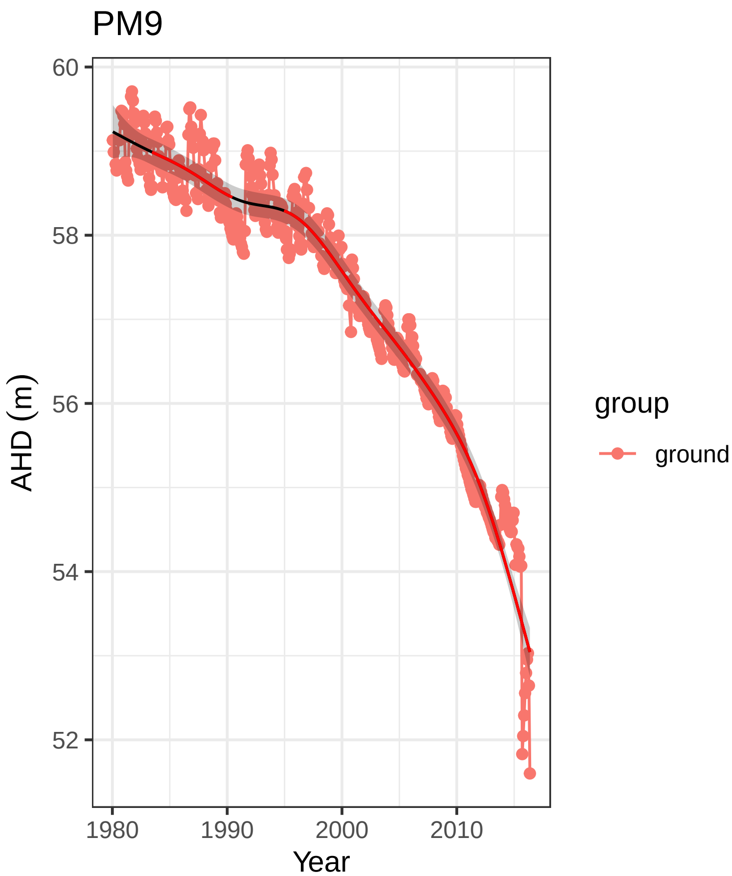

Figure 39: Ground and surface water levels recorded at bores and staff gauges in the vicinity of PM9

Table 18: Five year summaries of surface water level data at Quin Brook

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	59.0	58.8	0.26	January	July	125
08/1999 - 07/2004	58.2	58.1	0.16	January	April	93
08/2004 - 07/2009	57.1	56.9	0.25	October	April	203
08/2009 - 07/2014	55.6	55.4	0.14	November	April	196
08/2014 - 07/2019	54.1	54.0	0.11	October	October	47

Quin Brook

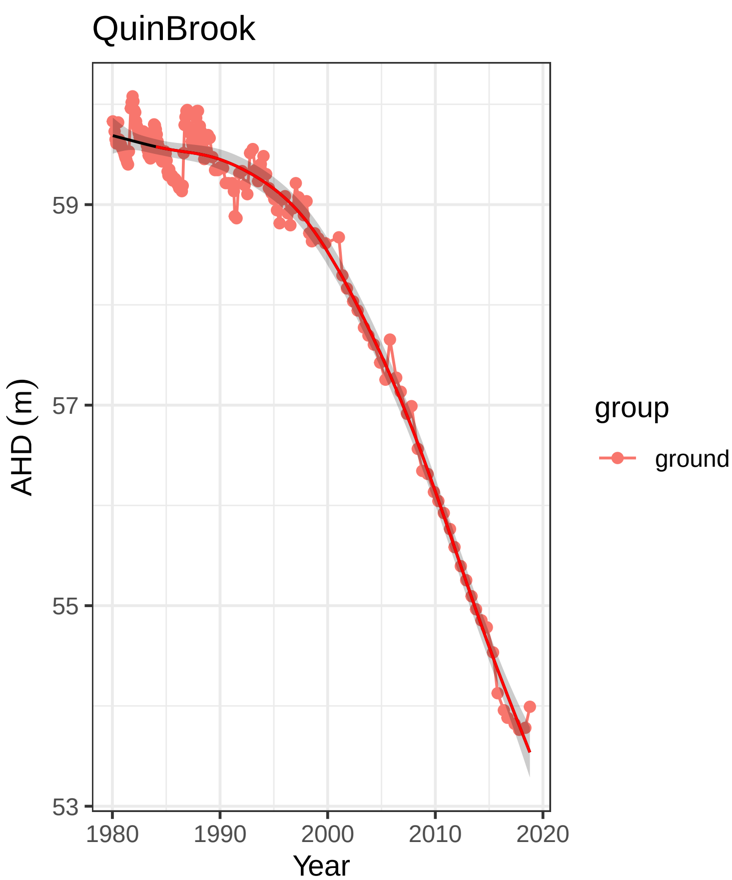

Figure 40: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Quin Brook

Table 19: Five year summaries of surface water level data at Wilgarup

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	5.2	4.3	0.91	October	March	184
08/1999 - 07/2004	4.7	4.0	0.73	October	April	193
08/2004 - 07/2009	4.3	3.7	0.62	September	May	150
08/2009 - 07/2014	3.8	3.2	0.59	October	April	190
08/2014 - 07/2019	3.6	3.1	0.55	October	May	212

Wilgarup

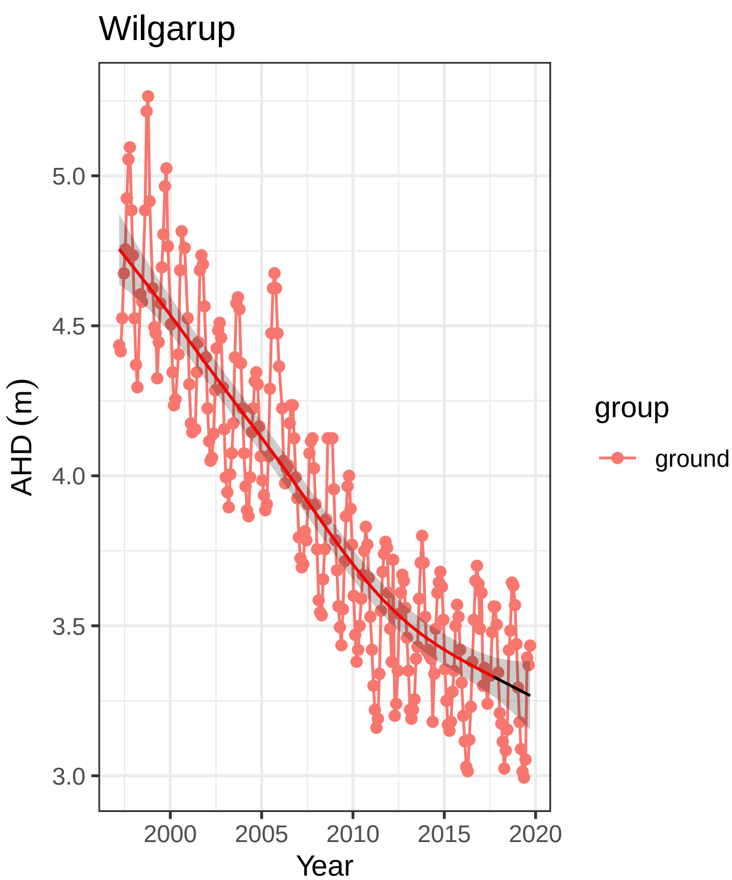

Figure 41: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Wilgarup

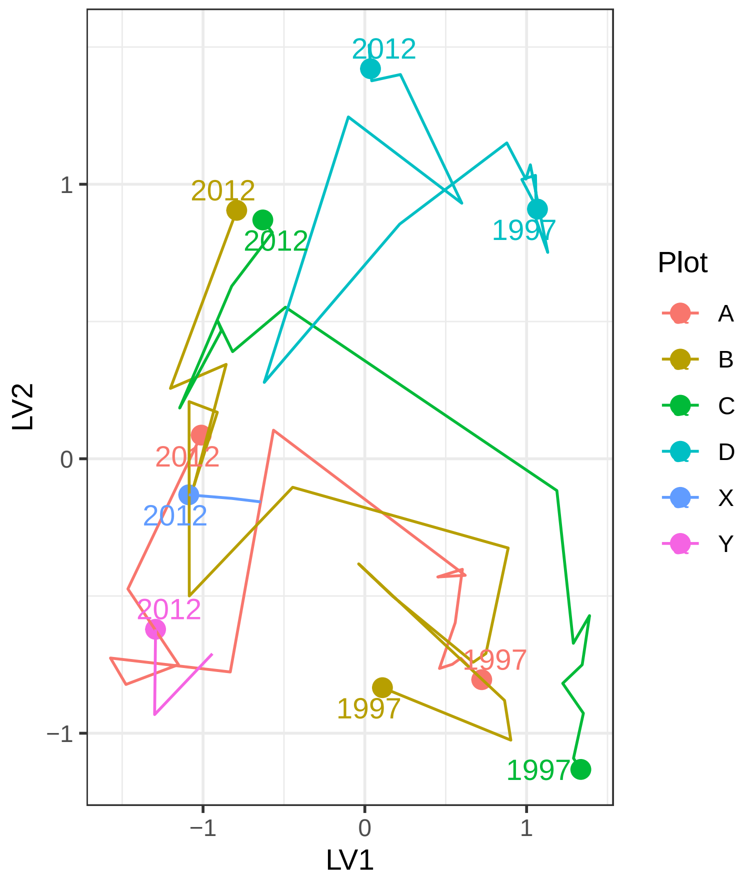

Figure 42: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

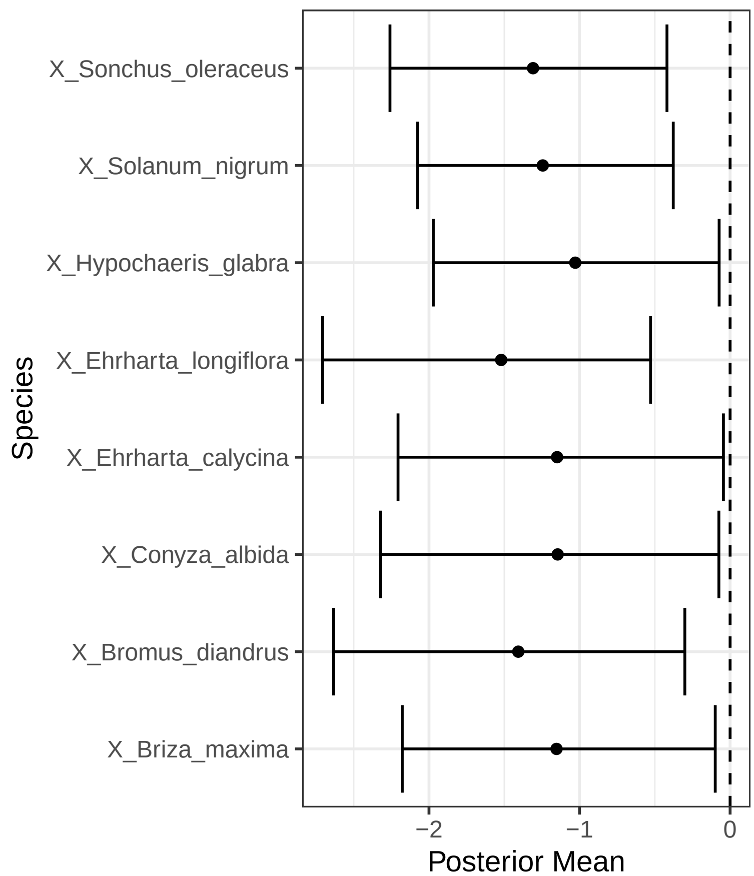

Figure 43: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 20: Five year summaries of surface water level data at WM1

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	57.1	56.2	0.95	November	April	217
08/1999 - 07/2004	56.5	55.6	0.86	October	June	246
08/2004 - 07/2009	55.9	55.1	0.81	October	July	200
08/2009 - 07/2014	54.9	54.3	0.54	October	August	204
08/2014 - 07/2019	55.1	54.5	0.57	October	August	110

WM1

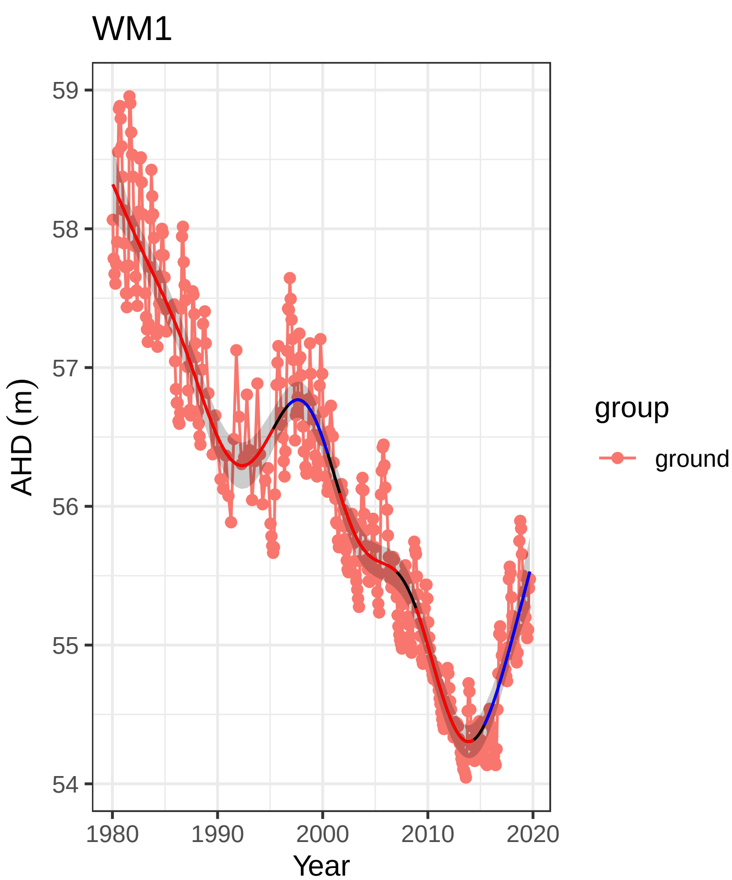

Figure 44: Ground and surface water levels recorded at bores and staff gauges in the vicinity of WM1

Table 21: Five year summaries of surface water level data at WM2

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	68.5	67.6	0.94	November	April	216
08/1999 - 07/2004	68.1	67.4	0.68	October	June	246
08/2004 - 07/2009	67.7	67.1	0.62	October	July	205
08/2009 - 07/2014	66.8	66.4	0.46	October	August	210
08/2014 - 07/2019	67.0	66.5	0.52	October	May	79

WM2

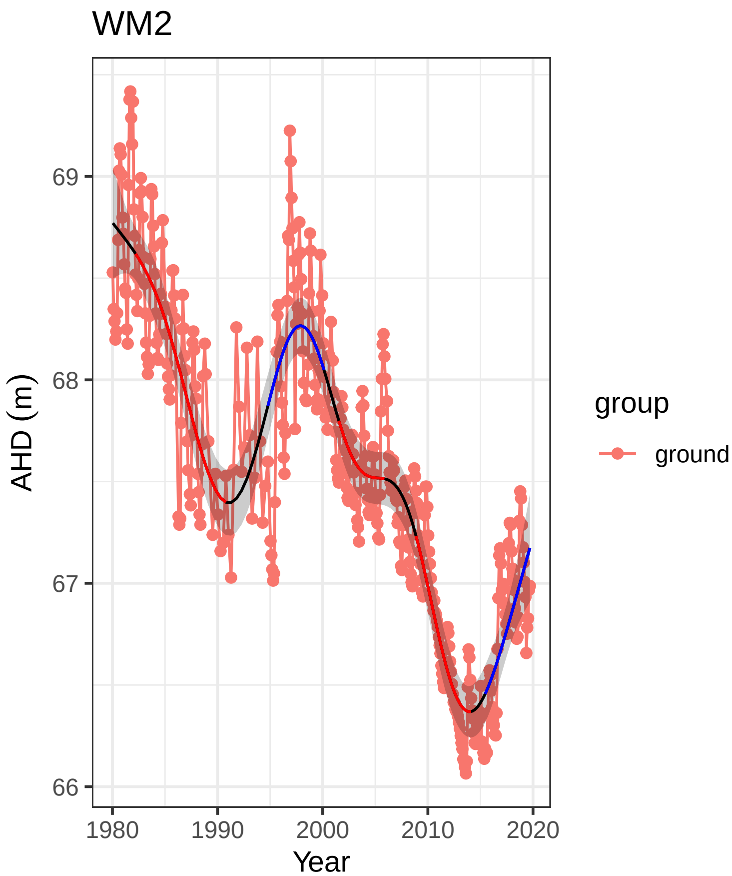

Figure 45: Ground and surface water levels recorded at bores and staff gauges in the vicinity of WM2

Table 22: Five year summaries of surface water level data at WM8

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	66.3	65.7	0.65	October	July	230
08/1999 - 07/2004	66.0	65.5	0.53	December	June	180
08/2004 - 07/2009	65.6	65.2	0.40	November	July	256
08/2009 - 07/2014	65.0	64.7	0.36	November	August	200
08/2014 - 07/2019	65.0	64.7	0.33	December	July	30

WM8

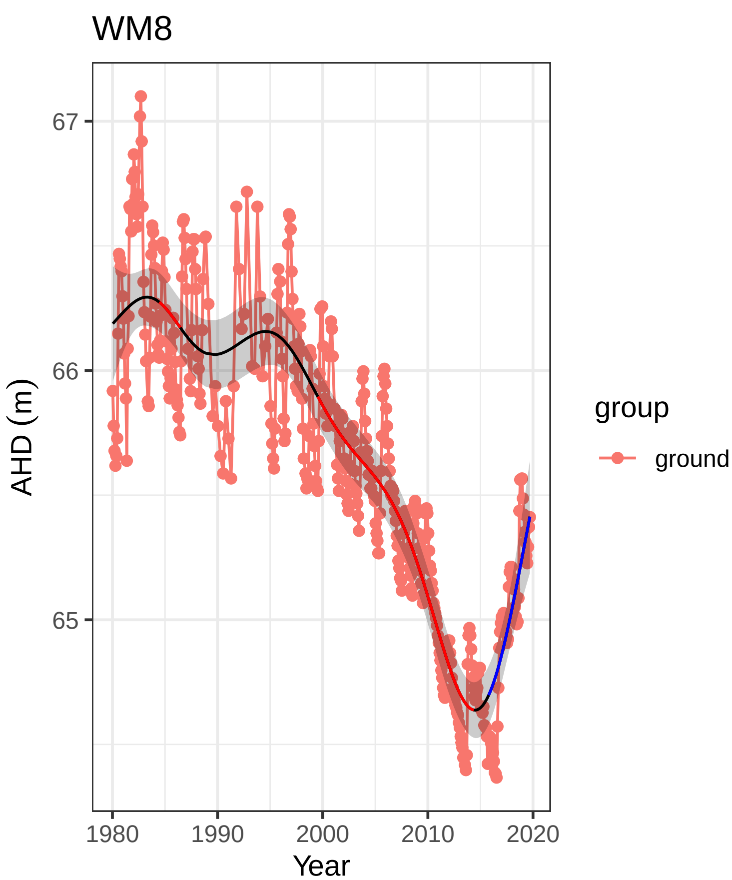

Figure 46: Ground and surface water levels recorded at bores and staff gauges in the vicinity of WM8

Table 23: Five year summaries of surface water level data at Yonderup

Period	Mean max seasonal level (mAHD)	Mean min seasonal level (mAHD)	Mean seasonal change (m)	Month of maximum	Month of minimum	Mean max to min (days)
08/1994 - 07/1999	6.0	5.9	0.07	August	September	82
08/1999 - 07/2004	6.0	5.9	0.06	September	February	144
08/2004 - 07/2009	5.9	5.9	0.06	April	April	130
08/2009 - 07/2014	5.9	5.7	0.19	September	April	212
08/2014 - 07/2019	5.8	5.6	0.25	September	March	218

Yonderup

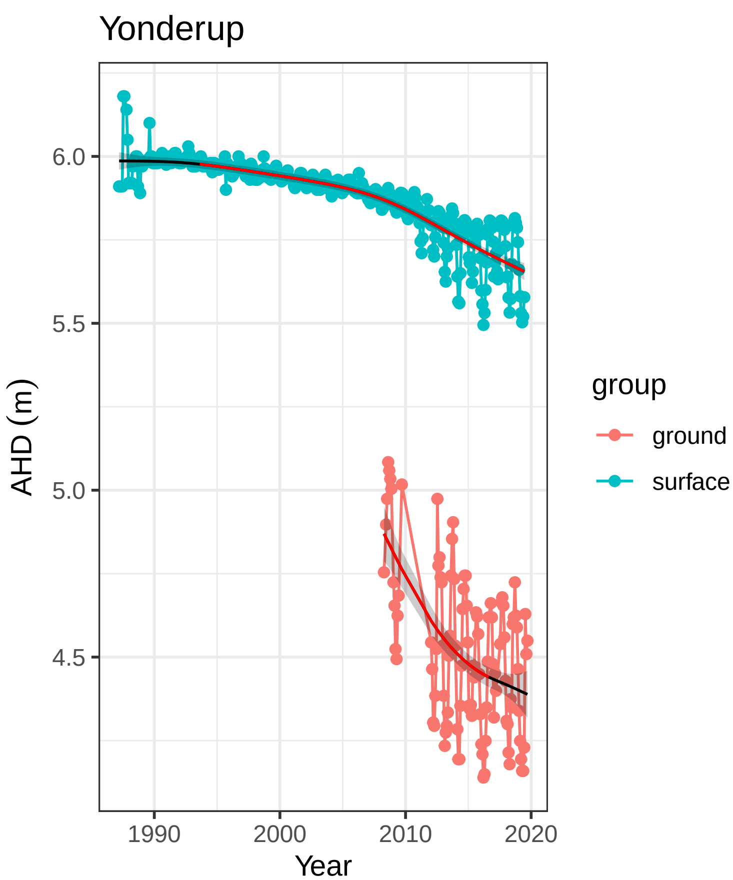

Figure 47: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Yonderup

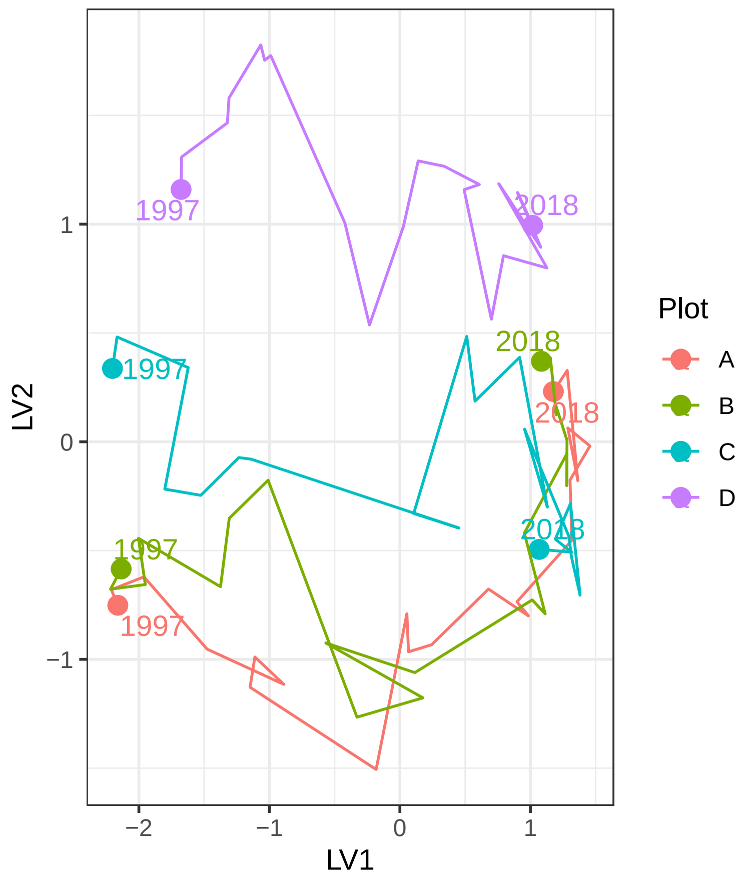

Figure 48: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

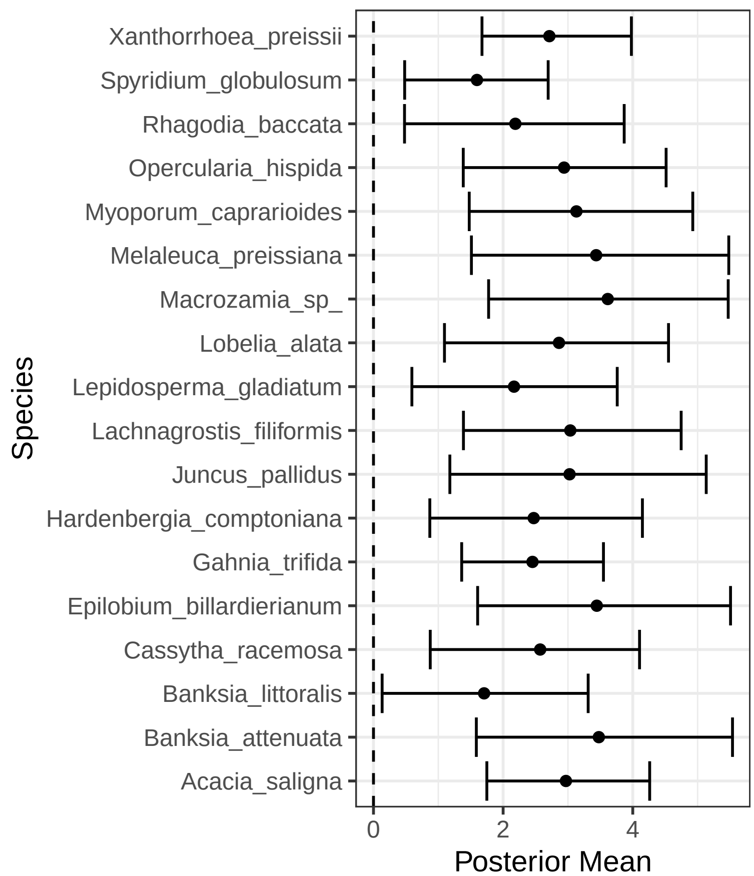

Figure 49: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown