Review of Water Thresholds - Gnangara

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Executive Summary

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)

Methods

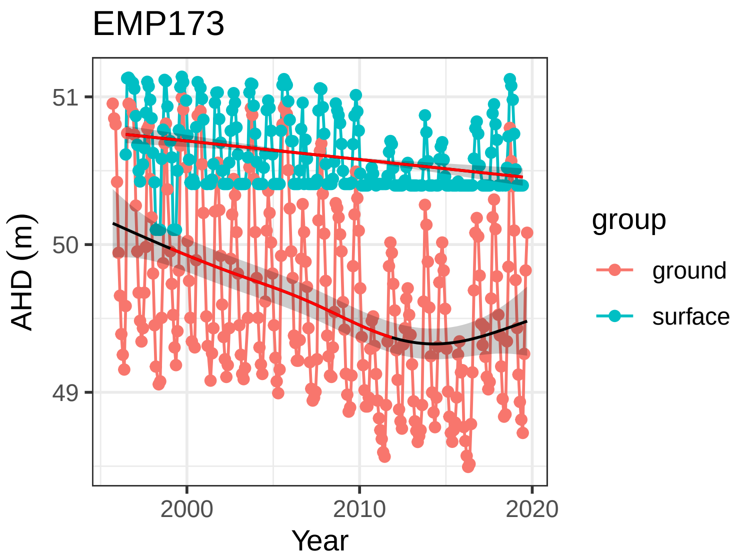

Figure 1: Ground and surface water levels recorded at bore 61613213 (red) and staff 6162628 (blue) for the Melaleuca Park 173 wetland

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 below 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

Individual wetland descriptions

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.

Hydrology

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.

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.

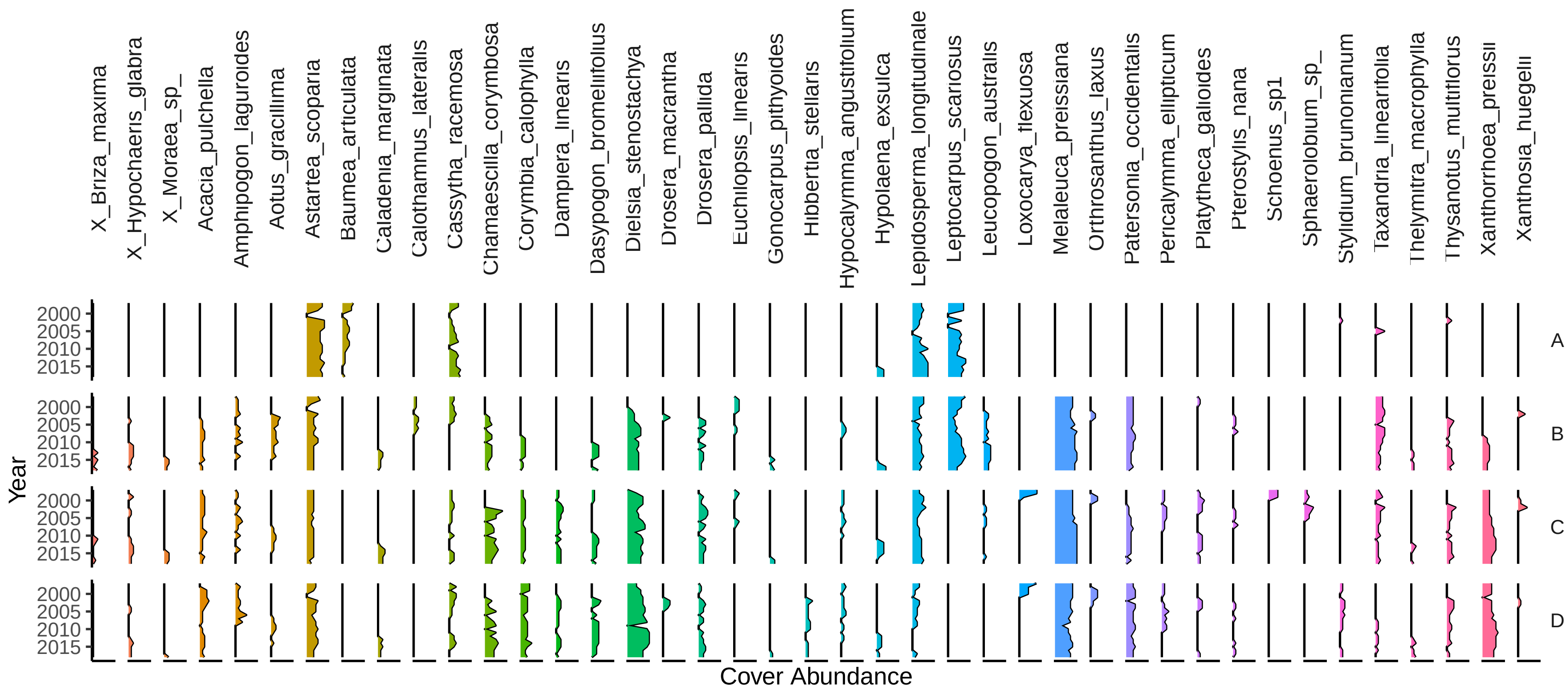

Figure 2: Cover abundances for each species across the four plots (A, B, C, D) at the Melaleuca Park 173 transect. Invasive species are denoted by 'X'. Only the most common species are included.

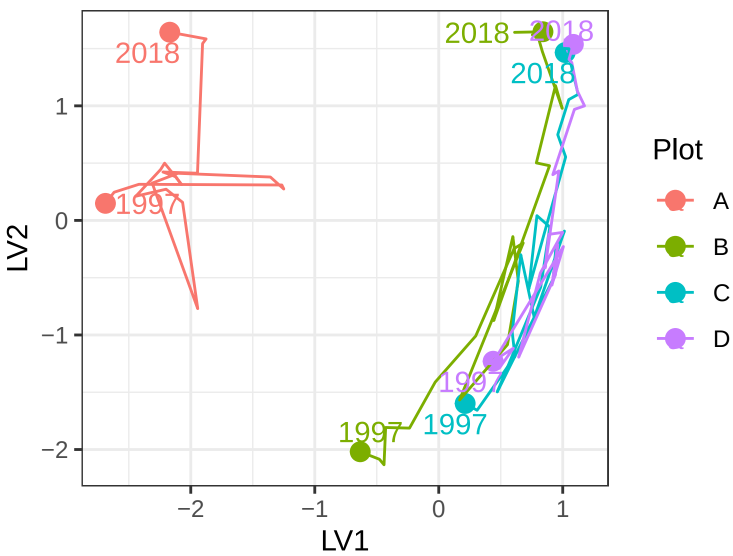

Figure 3: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

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		

	Likely effect of 2030 revised thresholds	Future Compliance
* To protect invertebrate communities dependent on the wetland and stream		No
* To protect the fish species, *Galaxiella nigrostriata*		No

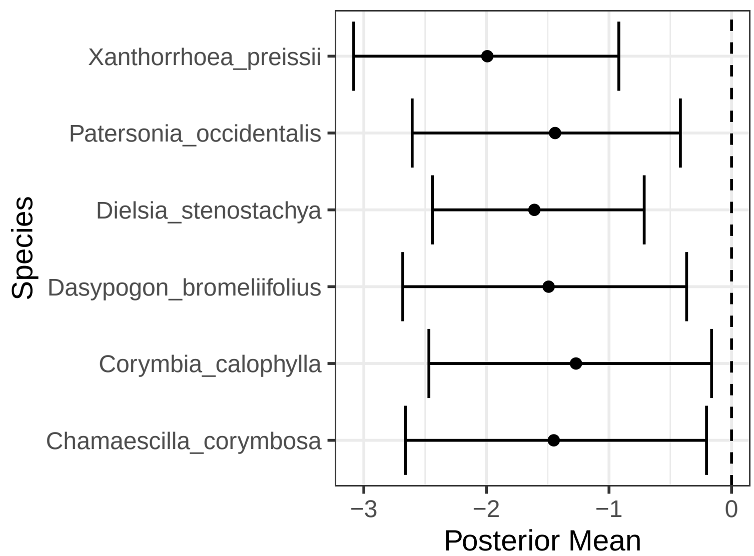

Figure 4: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 3: Five year summaries of surface water level data at EMP 78 recorded at the nearby bore 61613231

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)
08/1999 - 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

Melaleuca Park 78 (also referred to as EPP 78 or Dampland 78) is located north-west of the Lexia wetlands in the southern area of Melaleuca Park. The site is approximately 6.7 ha in area and represents a regionally significant wetland (HILL 1996). Melaleuca Park 78 is classified as a Dampland habitat, meaning the basin has seasonally waterlogged soils that are not often innundated with surface waters [See Semeniuk & Semeniuk - The Geomorphic Classification of Wetlands in Hill et al 1996]. The site is an important habitat for a unique assemblage of phreatophytic vegetation which supports native populations of fauna.

Hydrology

Water levels at the site have been declining since the beginning of monitoring in 1999 until 2014, although absolute minimum levels were recorded in 2016. Bore 61613231 indicates that ground waters in the dampland may have declined by about 1.3 m since 1999, although there has been a recent increase in ground water levels since 2016 due to increased rainfall (Figure 5). Current 5 year mean maximum and minimum ground water levels in the bore are about 1 m lower than when monitoring began in 1999, with peak levels occuring in October/November and minimums occuring between April-May (Table 3).

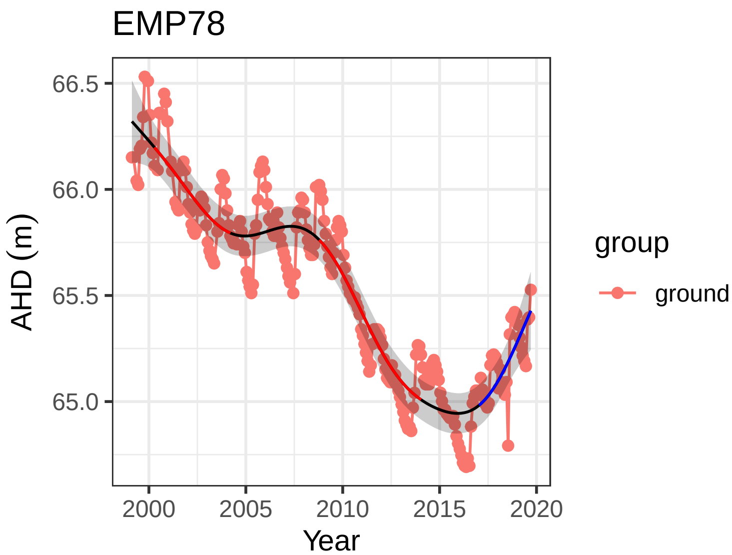

Figure 5: Ground water levels recorded at bore 61613231 in the vicinity of the Melaleuca Park 78 wetland

Vegetation dynamics

The vegetation transect has been monitored at Melaleuca Park 78 since 1997 and was last monitored in 2018 (Figure 6). The site is largely dominated by native species that include a dense understorey og *Beaufortia elegans*, *Pultenea reticulata* and *Kunzea glabrescens*. The overstorey is largely composed of *Melaleuca preissiana* throughout and *Banksia attenuata*, *Banksia ilicifolia* and *Banksia menziesii* in the higher parts of the basin. In 2006, the transect was heavily affected by a fire, but has since made some recovery. *Baumea articulata* disappeared from the transect during this period. A number of tree deaths were reported following the fire but there is evidence of recovery, paritcualry for low-lying stands of *M. preissiana*. Trajectories of compositional change reflect the post-fire recovery as recent plot assemblages are becoming more similar to those recorded before the fire (Figure 7).

Modelling revealed a number of species associated with low ground water levels (Figure 8). In particular, these results suggest that the natives *B. attenuata*, *Hibbertia subvaginata* and *M. preissiana* are likely to increase in cover abundance under a scenario of further decreasing ground waters. The cover abundance of exotics, including *Aira caryophyllea*, *Briza maxima*, *Ehrharta calycina*, *Hypochaeris glabra*, *Poa annua*, *Sonchus oleraceus* and *Ursinia anthemoides* are also likely to increase in cover abundance. It is also likely that the richness of exotic species will increase as ground water levels decrease.

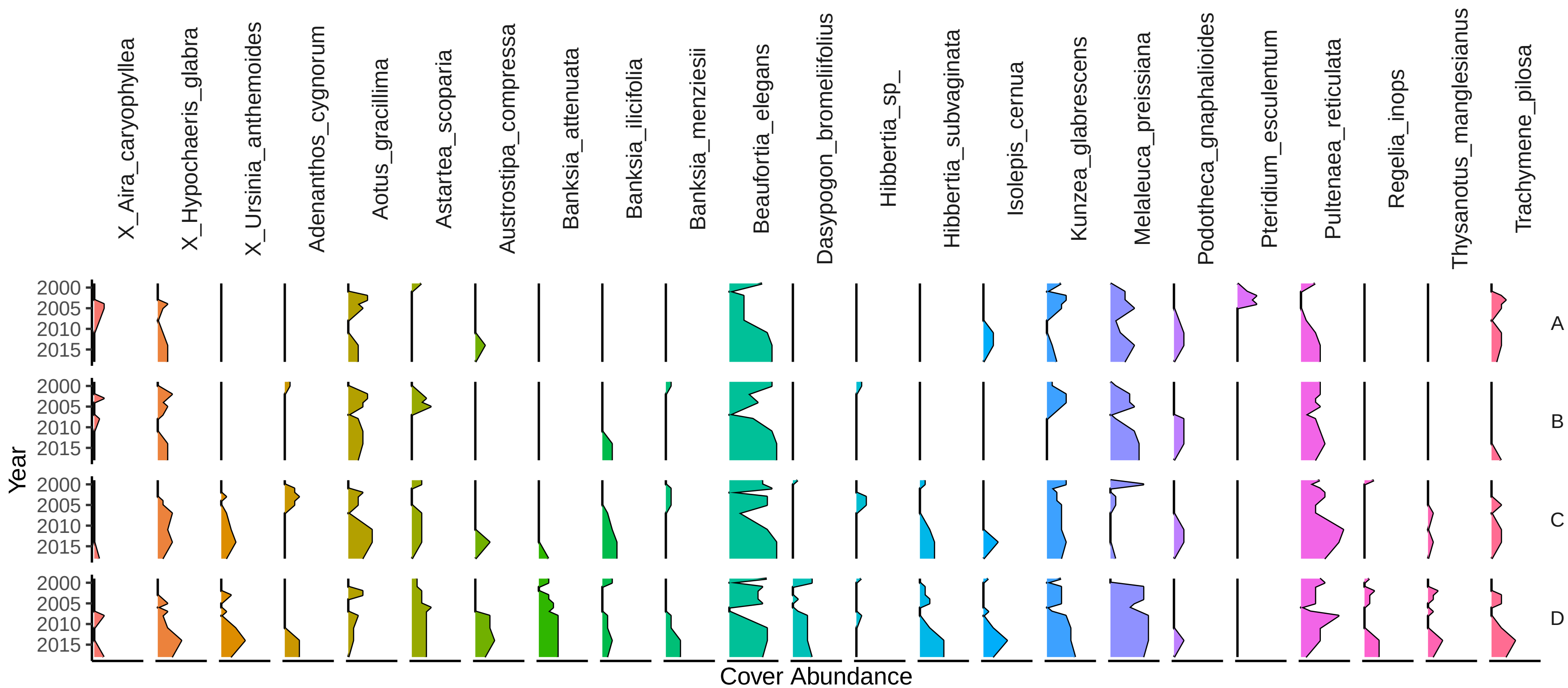

Figure 6: Cover abundances for each species across the four plots (A, B, C, D) at the Melaleuca Park 78 transect. Invasive species are denoted by 'X'. Only the most common species are included.

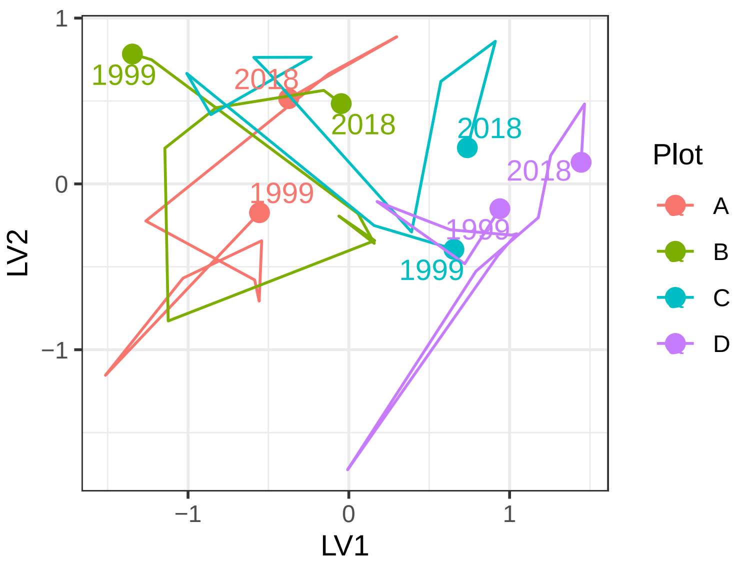

Figure 7: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

Revised water level threshold effects

Melaleuca Park 78 has been non-compliant with absolute minimum water level criteria since 2012.

Table 4: Ecological consequences of revised thresholds in terms of compliance of stated site values and site management objectives.

	Likely effect of 2030 revised thresholds	Future Complian
Site values		
Supports wetland vegetation		
Site management objectives		
Maintain wildlife and landscape values of the wetlands		
Maintain the existing areas of wetlands and wetland vegetation		

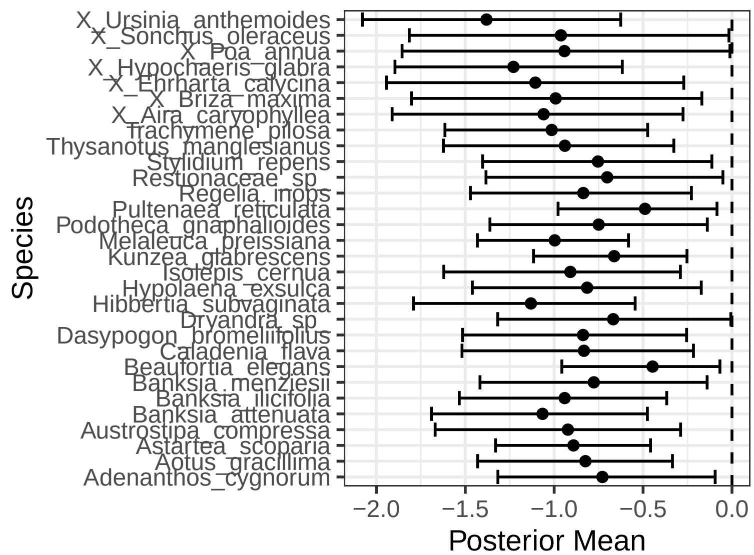

Figure 8: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 5: Five year summaries of surface water level data at Gingin Brook recorded at bore 61710078.

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 Brook

Gingin Brook is a new proposed in the Gingin water allocation plan (draft expected 2023). There is currently no baseline vegetation data for the site.

Hydrology

Ground waters at this site have significantly declined during the period between 1989 and 2015 by approximately 2.5 m (Figure 9). Mean seasonal maximum and minimum ground water levels have also decreased by 1.8 since 1994, with current monthly minimums generally occuring earlier in the year than in between 1994 and 1999 (Table 5).

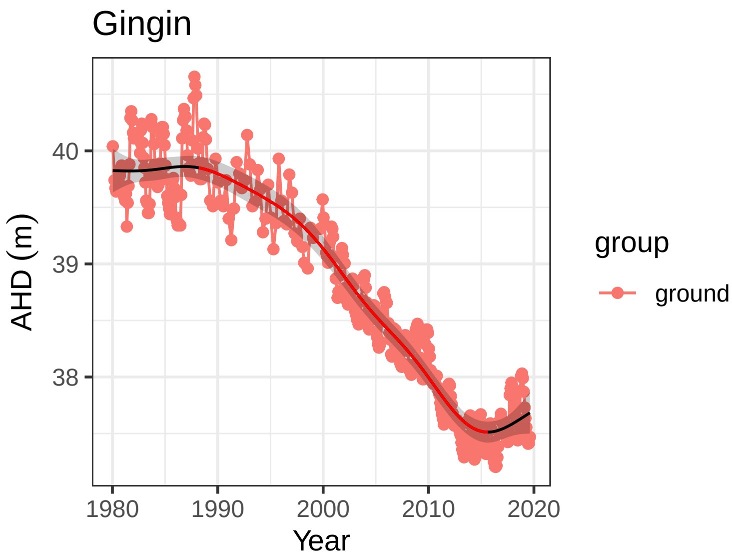

Figure 9: Ground water levels recorded at bore 61710078 in the vicinity of Gingin Brook

Table 6: Five year summaries of surface water level data at Lake Goollelal recorded at staff 6162517

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 hold significant value as a place of public enjoyment.

Hydrology

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 6). 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 surface 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 (61611870) as the lake is largely fed by groundwater (Figure 10). 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).

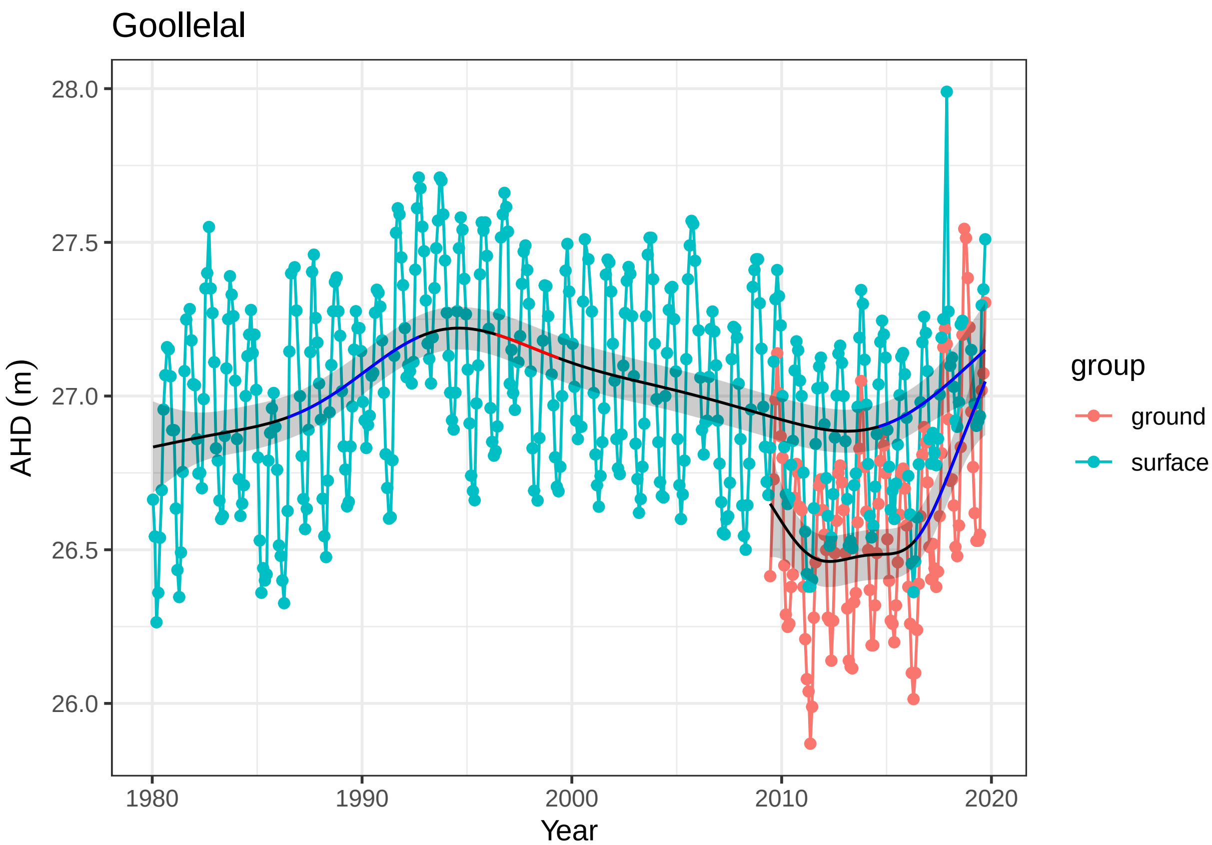

Figure 10: Ground and surface water levels recorded at bore 61611870 (red) and staff 6162517 (blue) for Lake Goollelal

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 *M. rhaphiophylla/E. rudis* complex continues throughout the transect, which has also remained relatively stable in terms of cover abundance since 2002. There is a high richness of exotic vegetation species present at the lake. Generally, these exotic species have increased in abundance during the survey period (Figure 11).

Ordination reveals that Plot A has a distinct assemblage to the other plots but has displayed similar vegetation compositional changes (Figure 12). Shifts in compositional change have 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. Plot D displays a different pattern, probably due to the record of *B. articulata* in 1997 [SHOULD CONFIRM THIS WITH GRANT] and the high cover abundance of exotic species. Many species are predicted to increase in cover abundance with declining surface water levels, while *B. articulata* is likely to increase in cover abundance (Figure 13). Native species thought to increase in cover abudnace with declining surface water levels include *Pennisetum clandestinum*, and *Microtis media*, while cover abundance of *M. rhaphiophylla* and *E. rudis* will likely remain stable or decrease slightly. Many exotic species are likely to increasse in cover abundance under a scenario of declining surface waters, including *Briza maxima*, *Fumaria capreolata*, *Setaria palmifolia* and *Sparaxis bulbifera*.

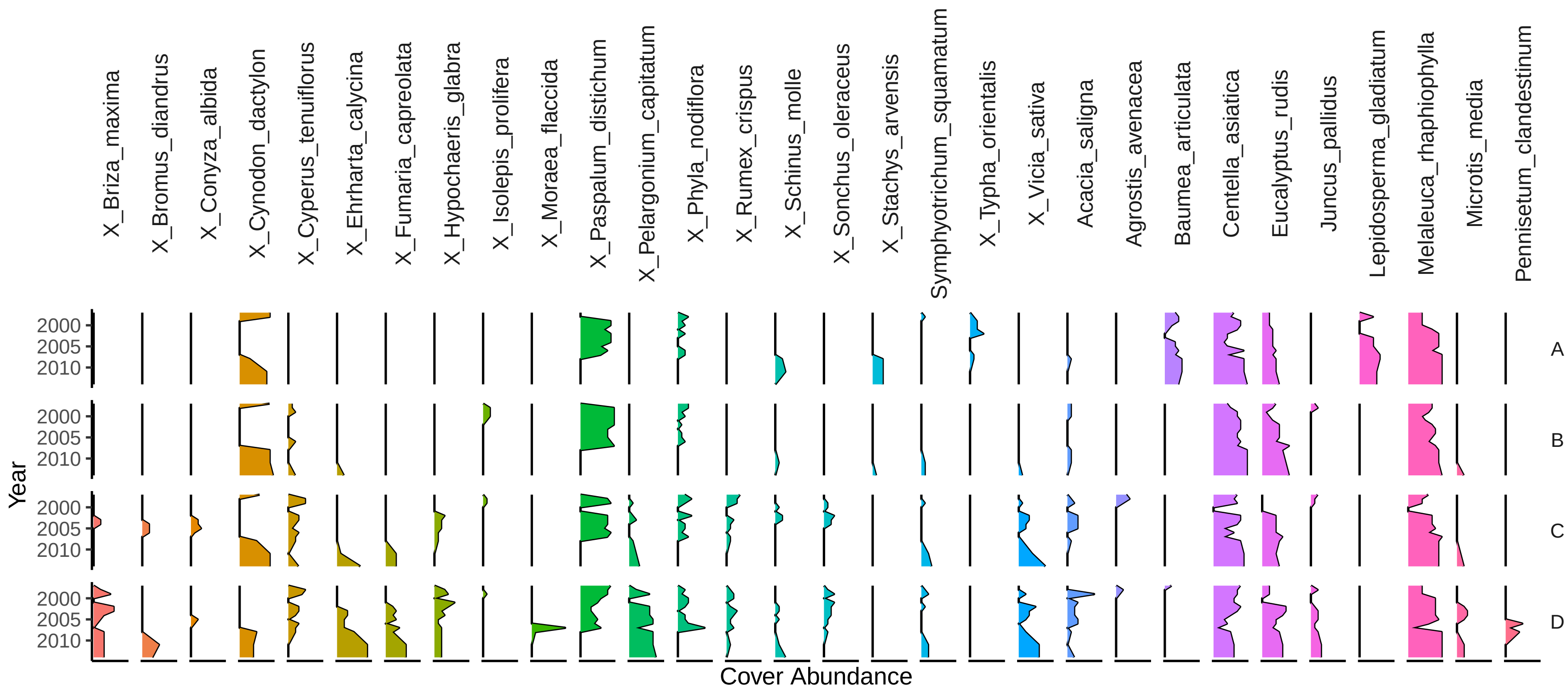

Figure 11: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Goollelal transect. Invasive species are denoted by 'X'. Only the most common species are included.

Aquatic invertebrates

Revised water level threshold effects

Table 7: 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*)		
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		

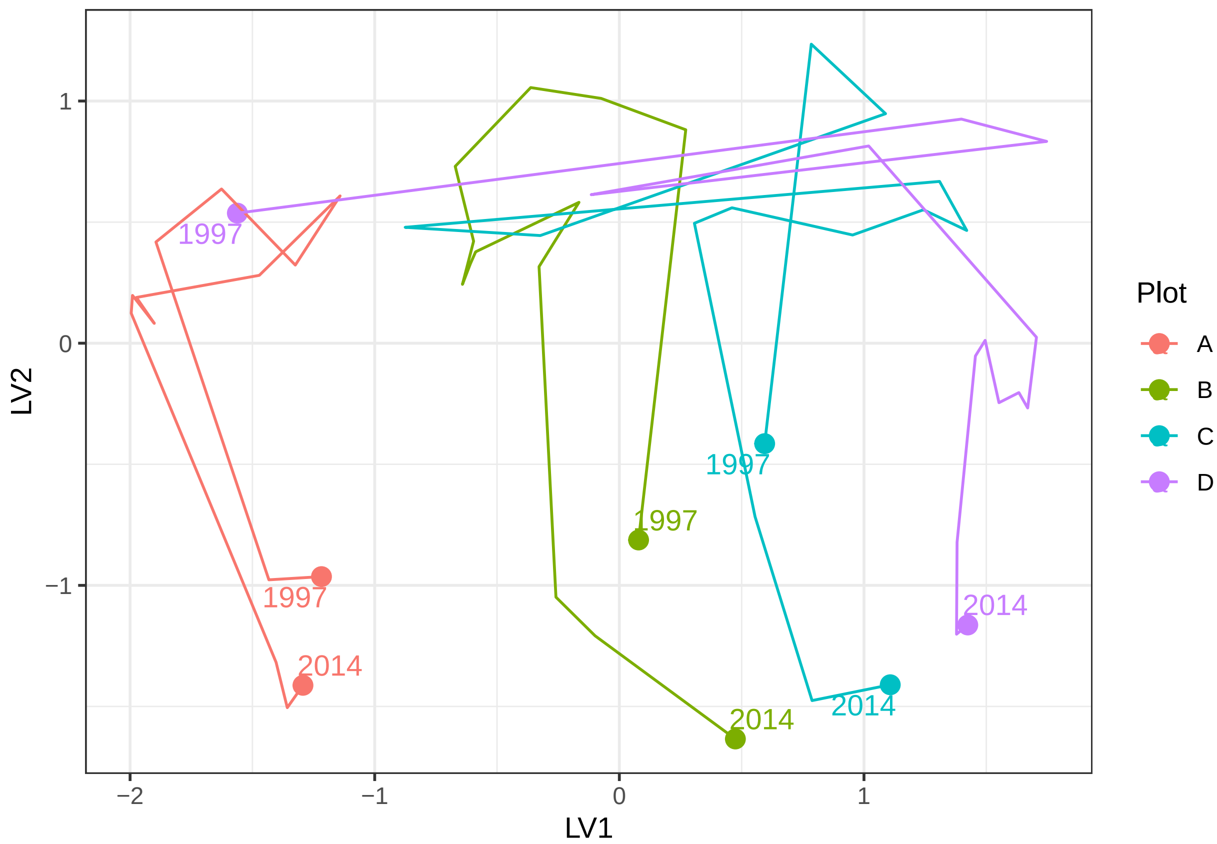

Figure 12: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

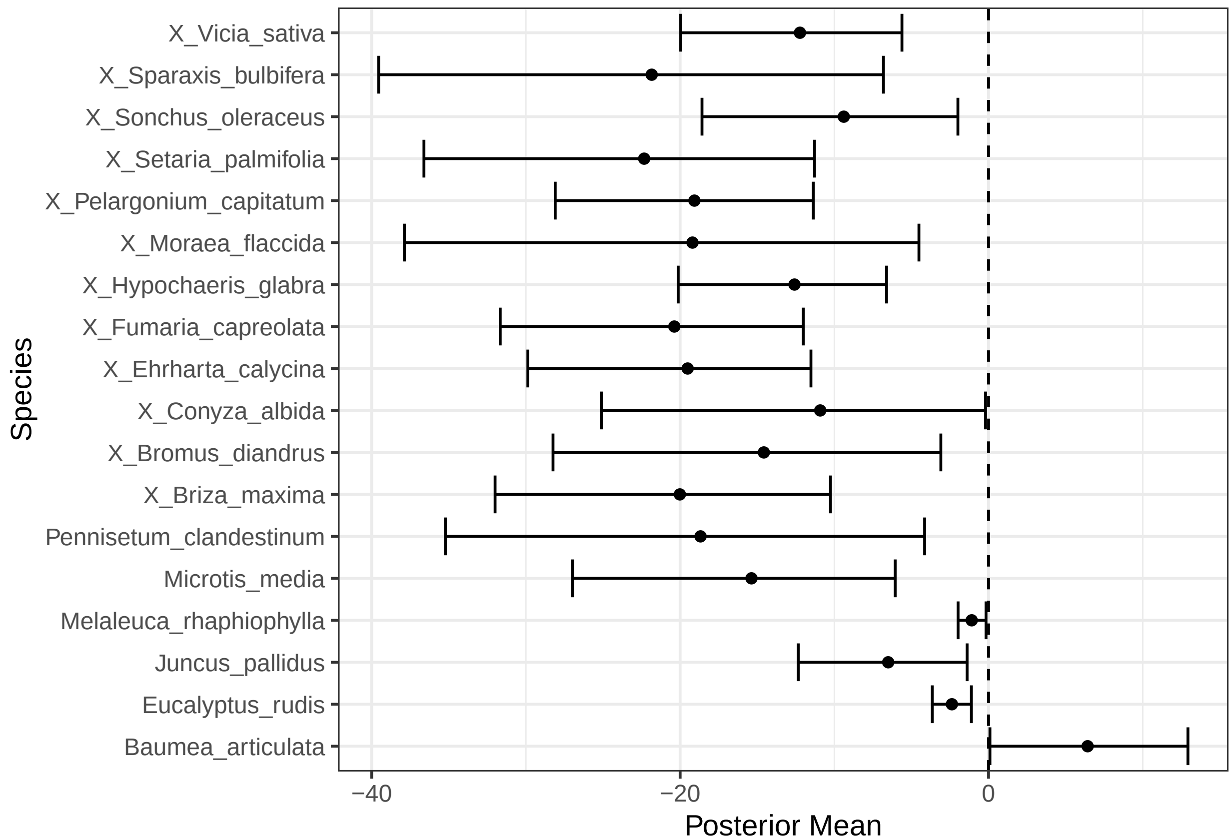

Figure 13: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

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

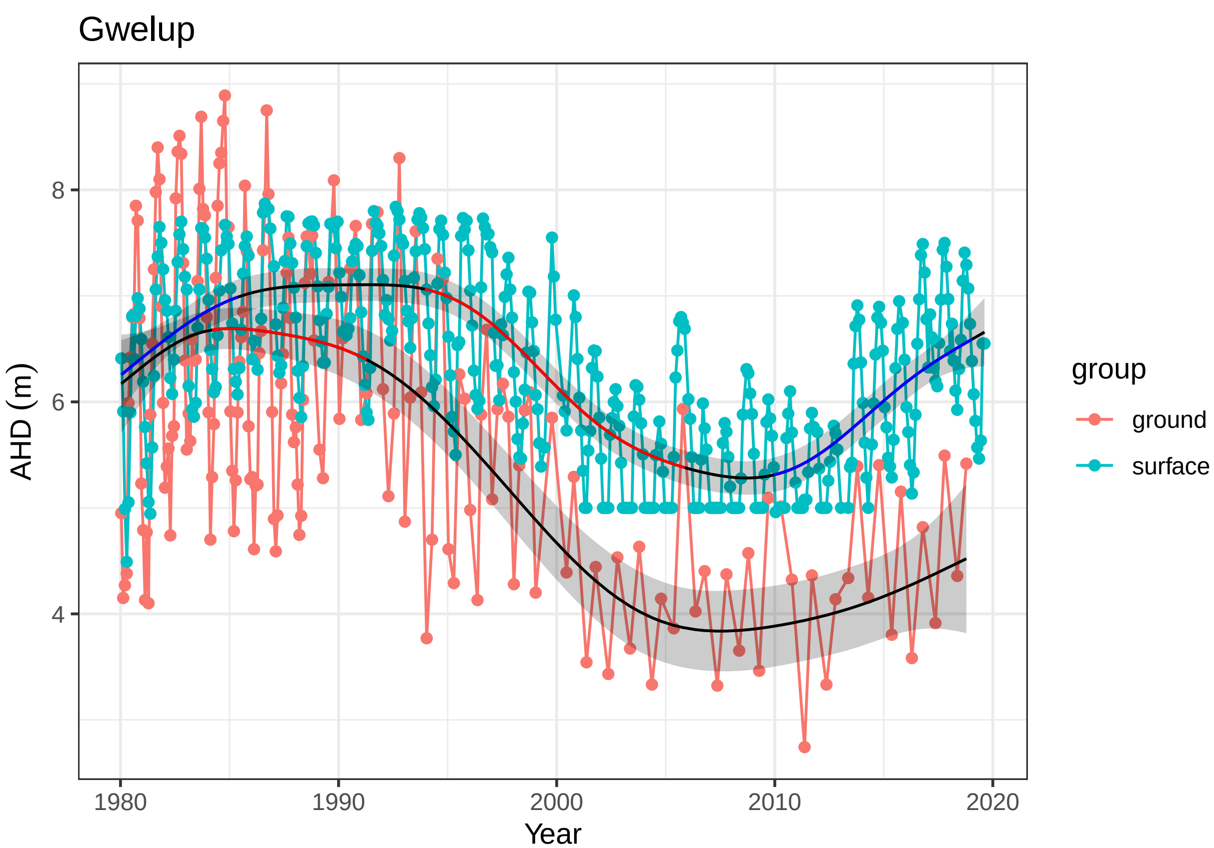

Figure 14: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Gwelup

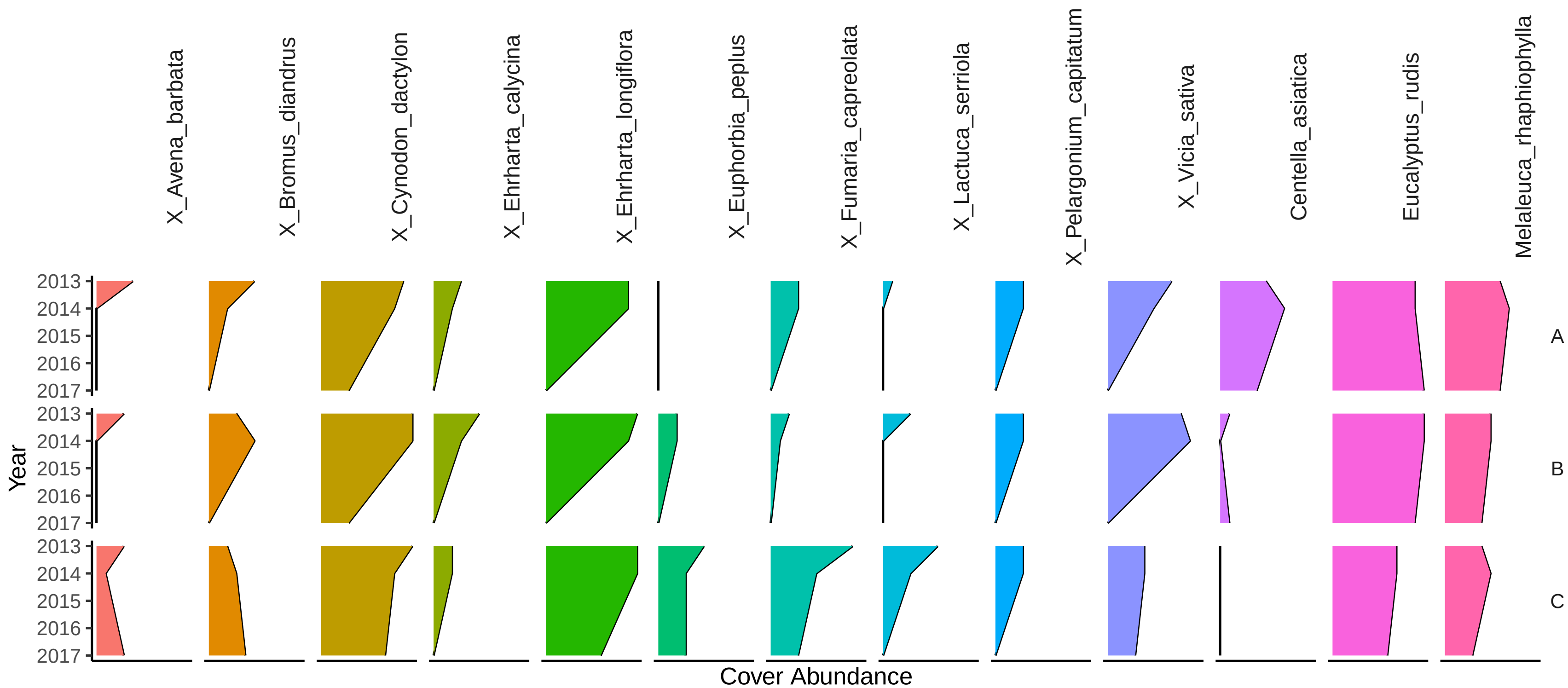

Figure 15: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Gwelup transect. Invasive species are denoted by 'X'. Only the most common species are included.

Table 9: 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

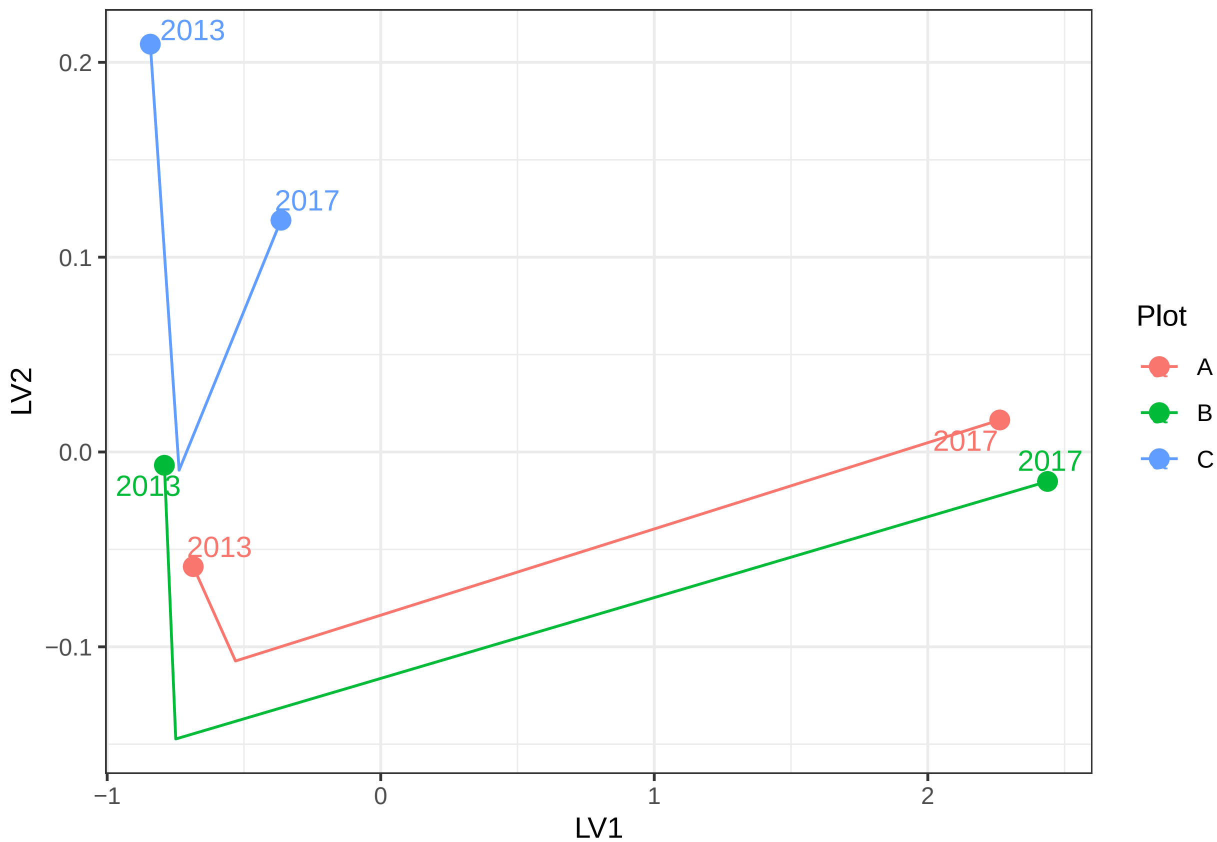

Figure 16: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

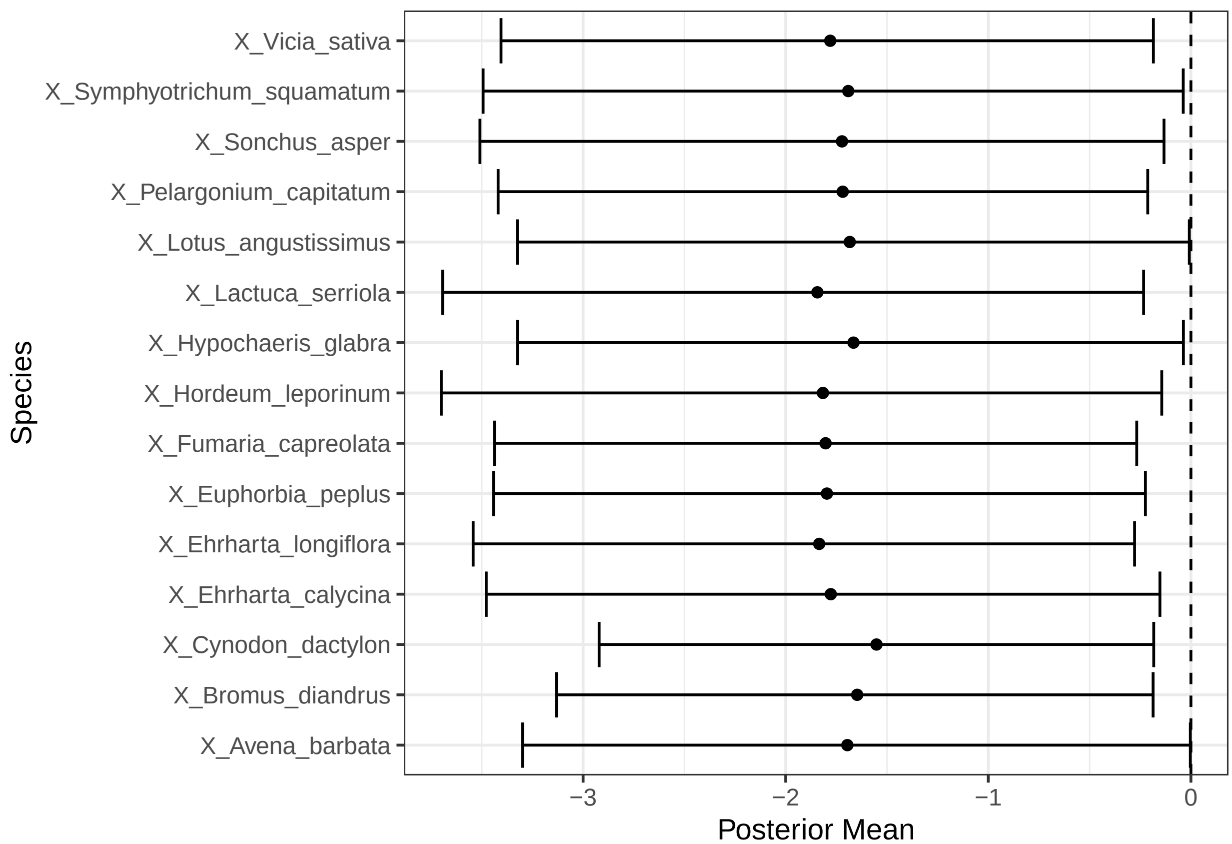

Figure 17: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

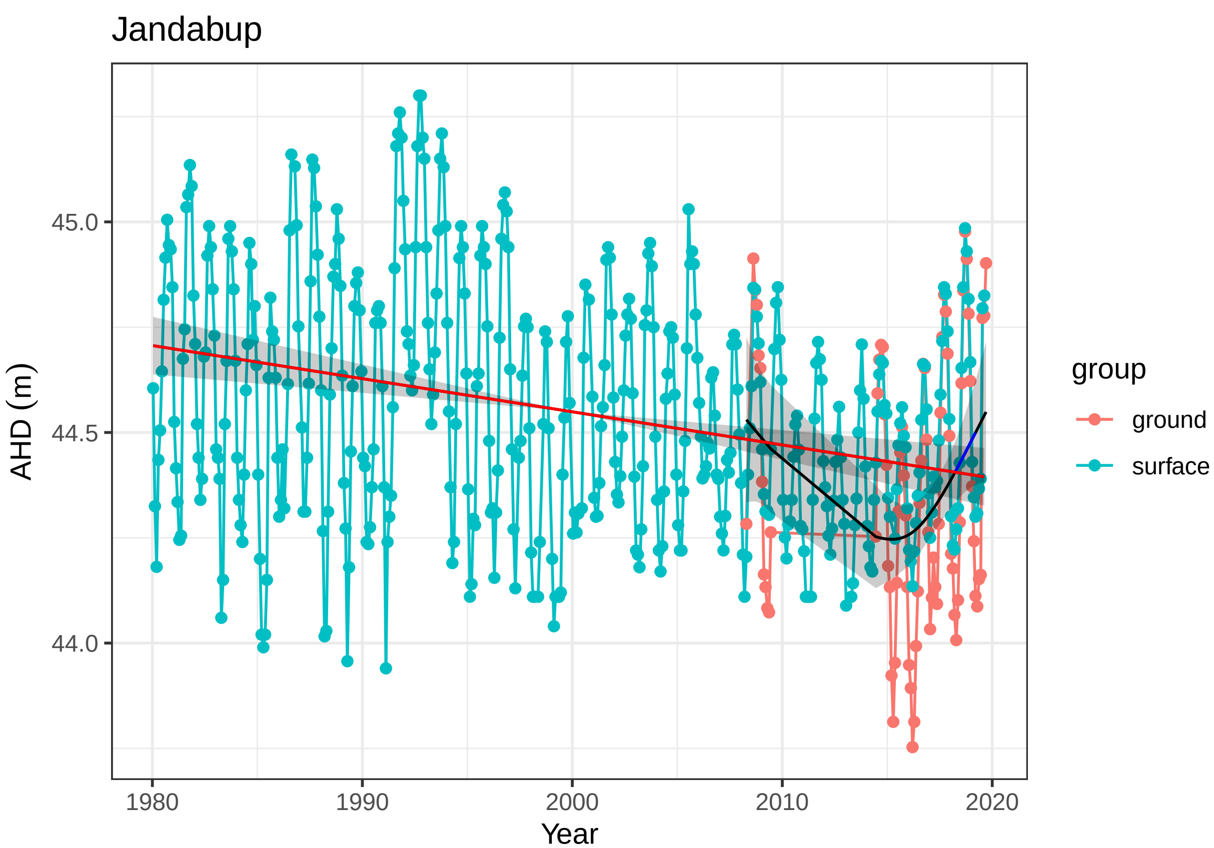

Figure 18: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Jandabup

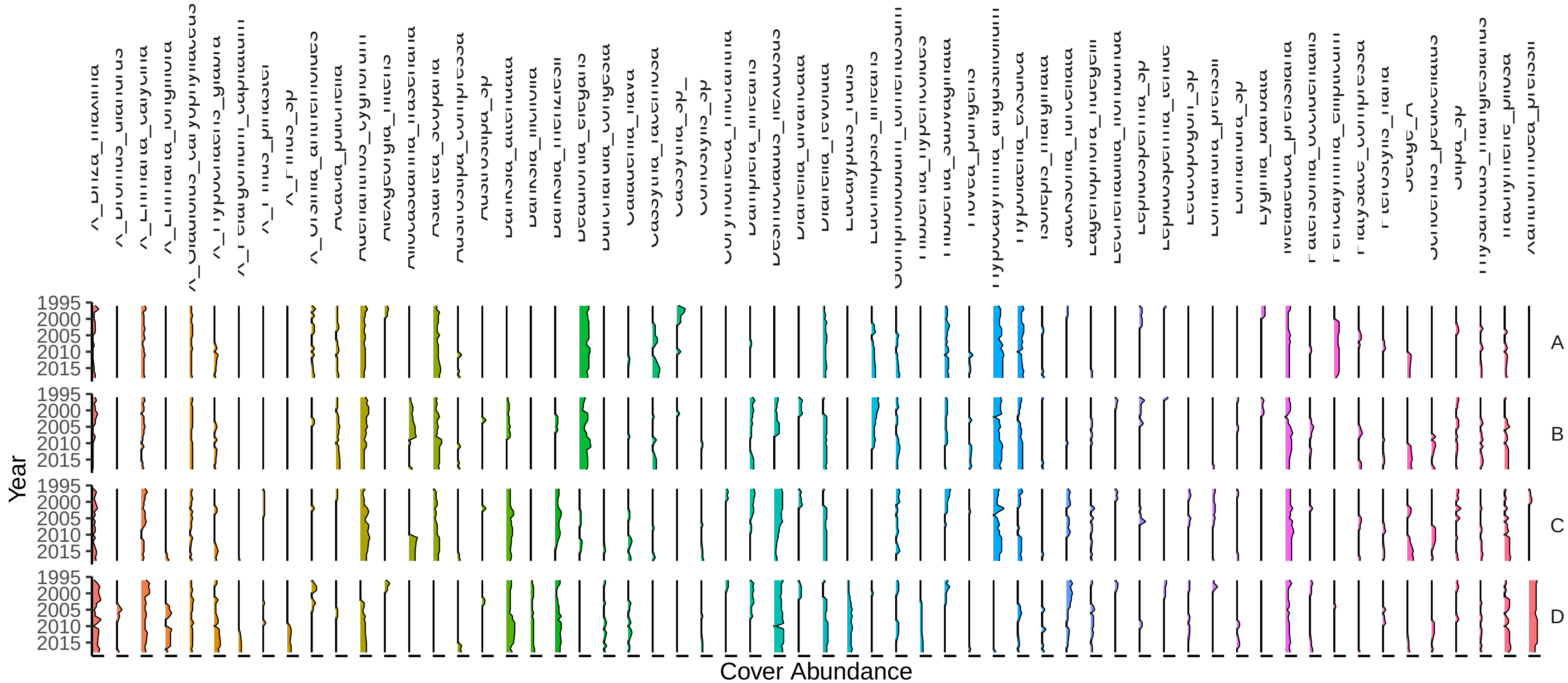

Figure 19: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Jandabup transect. Invasive species are denoted by ‘X’. Only the most common species are included.

Table 10: 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.

Hydrology

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.

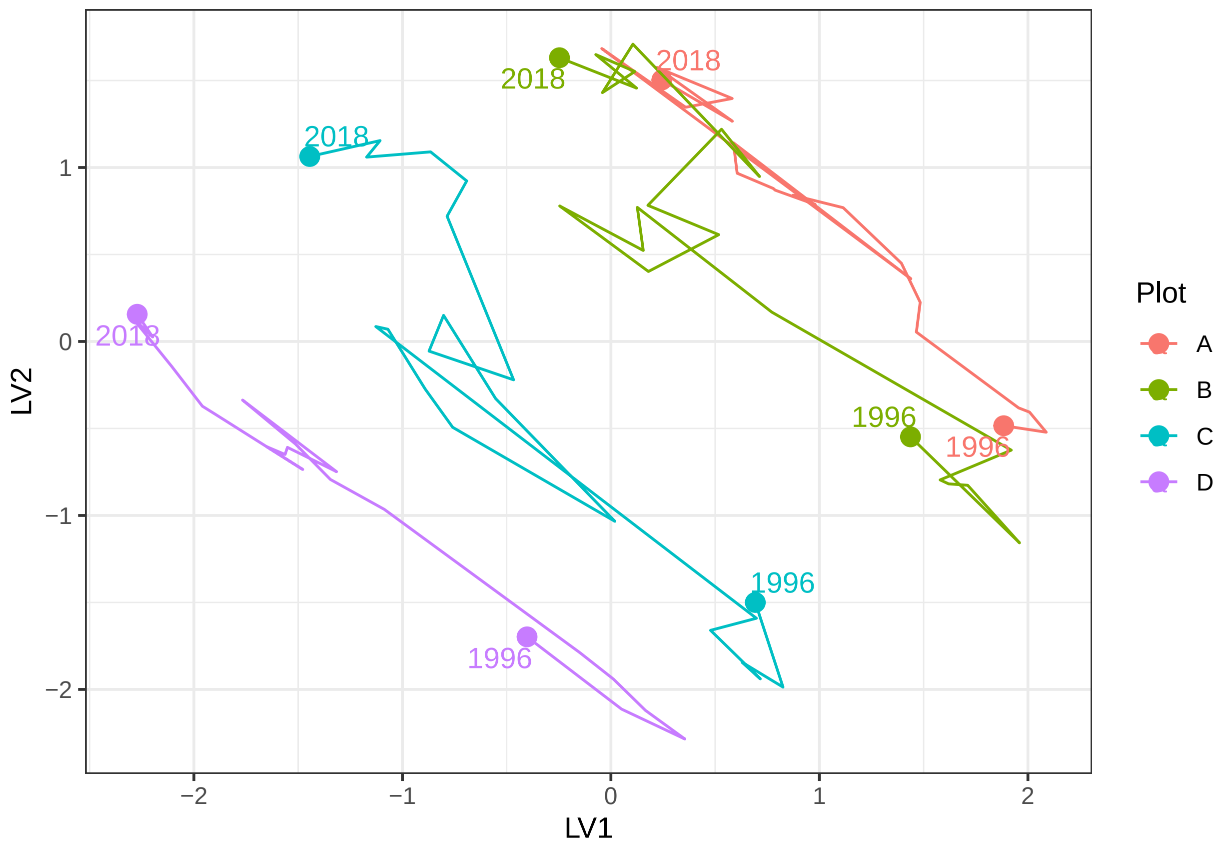

Figure 20: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

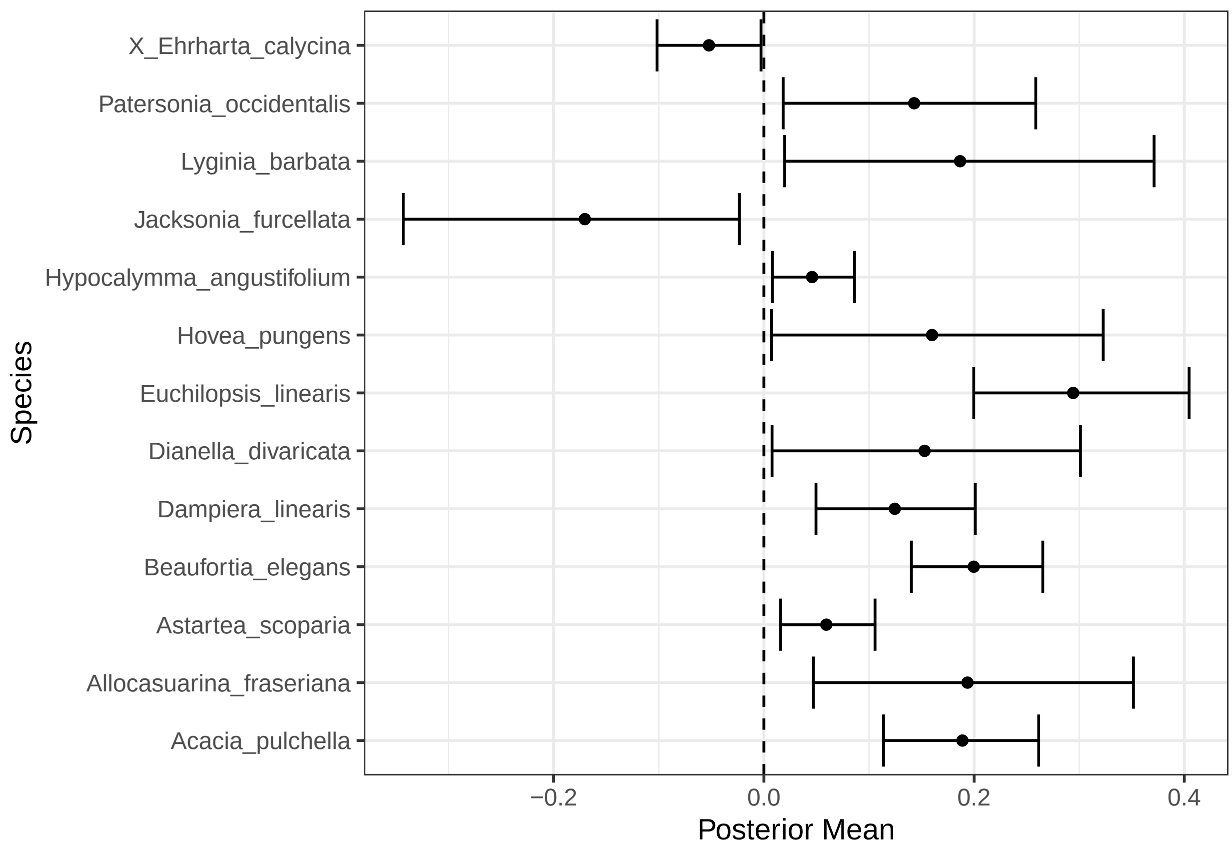

Figure 21: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

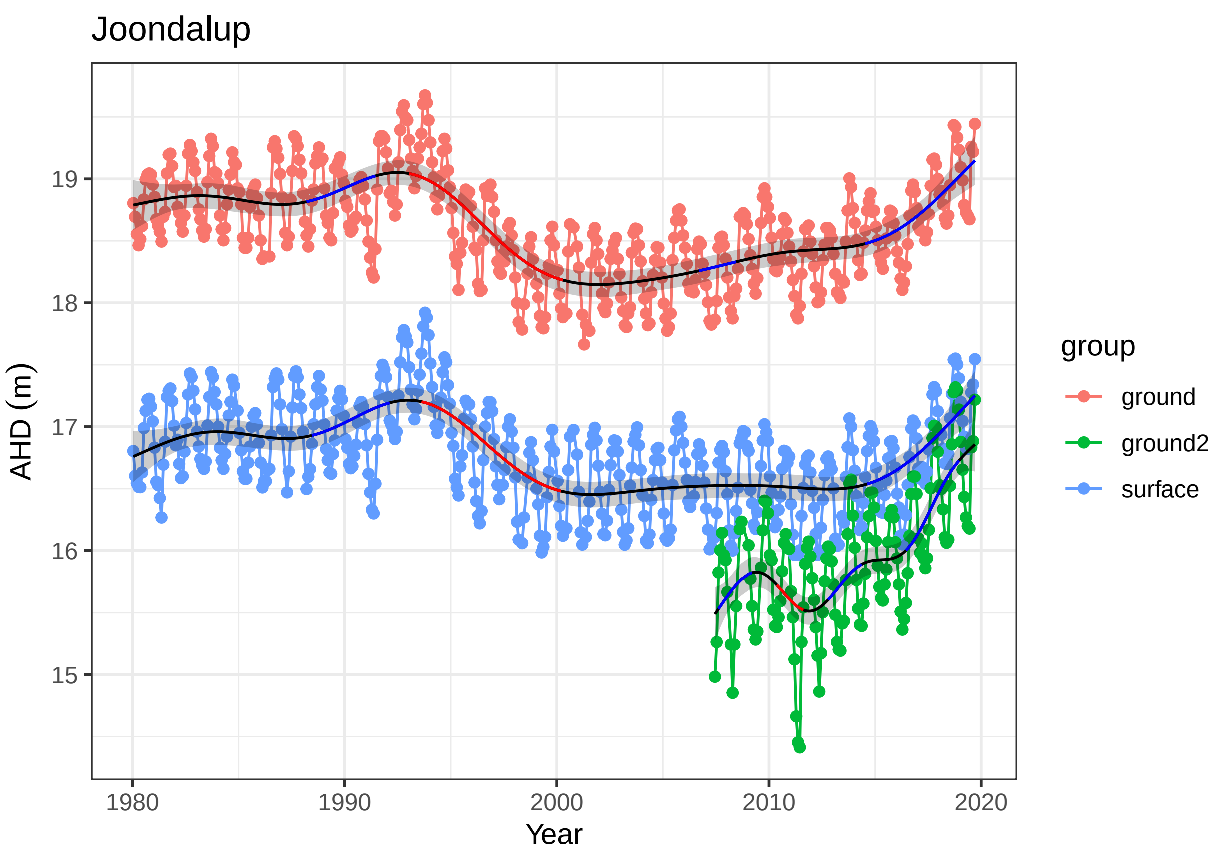

Figure 22: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Joondalup

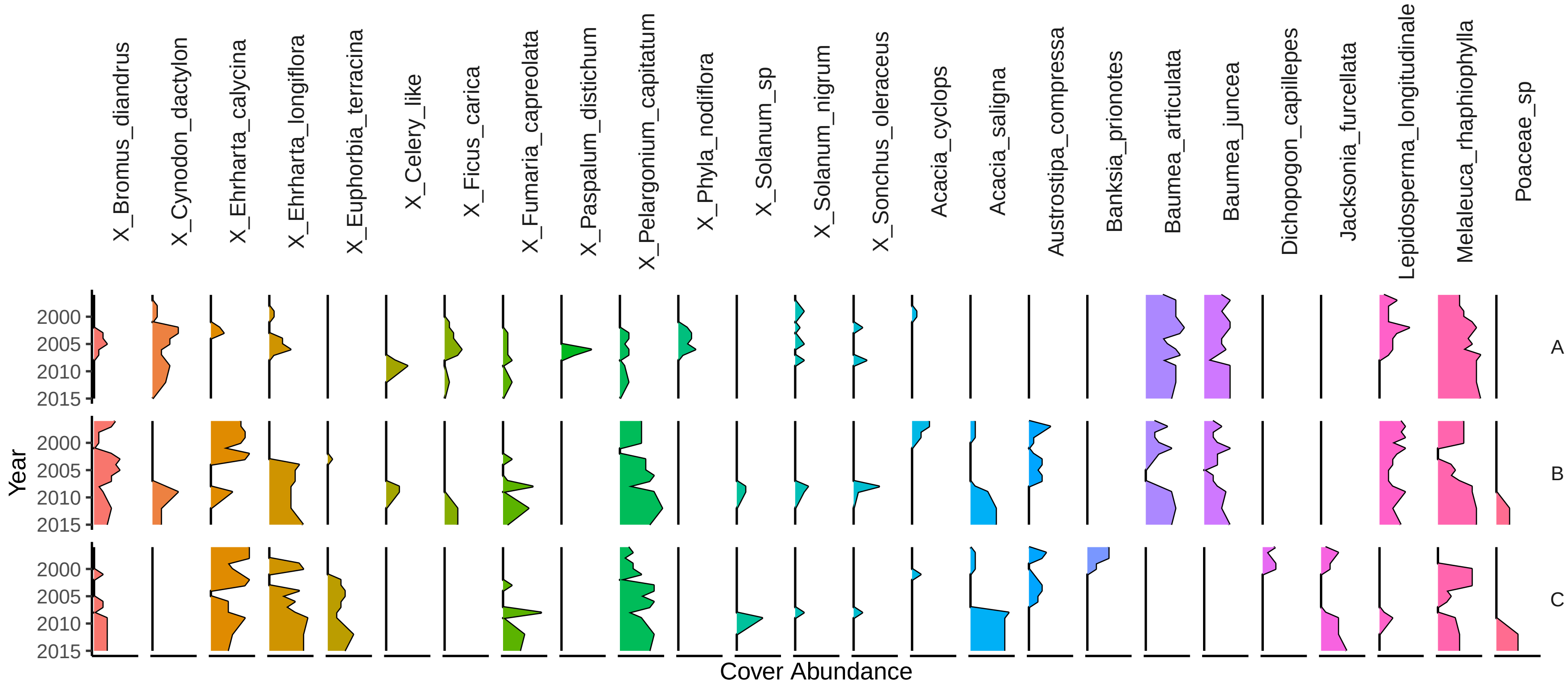

Figure 23: Cover abundances for each species across the four plots (A, B, C, D) at the northern Lake Joondalup transect. Invasive species are denoted by 'X'. Only the most common species are included.

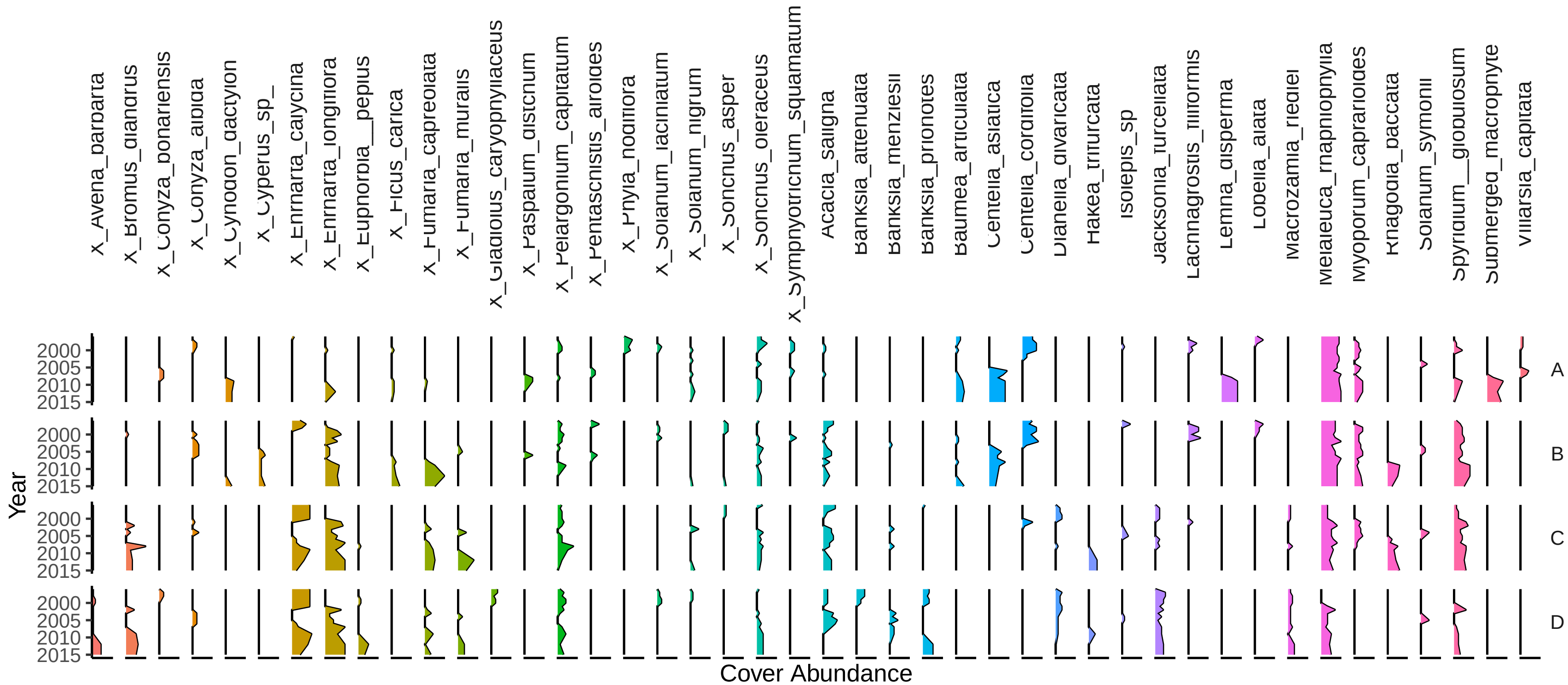

Figure 24: Cover abundances for each species across the four plots (A, B, C, D) at the southern Lake Joondalup transect. Invasive species are denoted by 'X'. Only the most common species are included.

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 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]

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 11: 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		

	Likely effect of 2030 revised thresholds	Future Compliance
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		
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

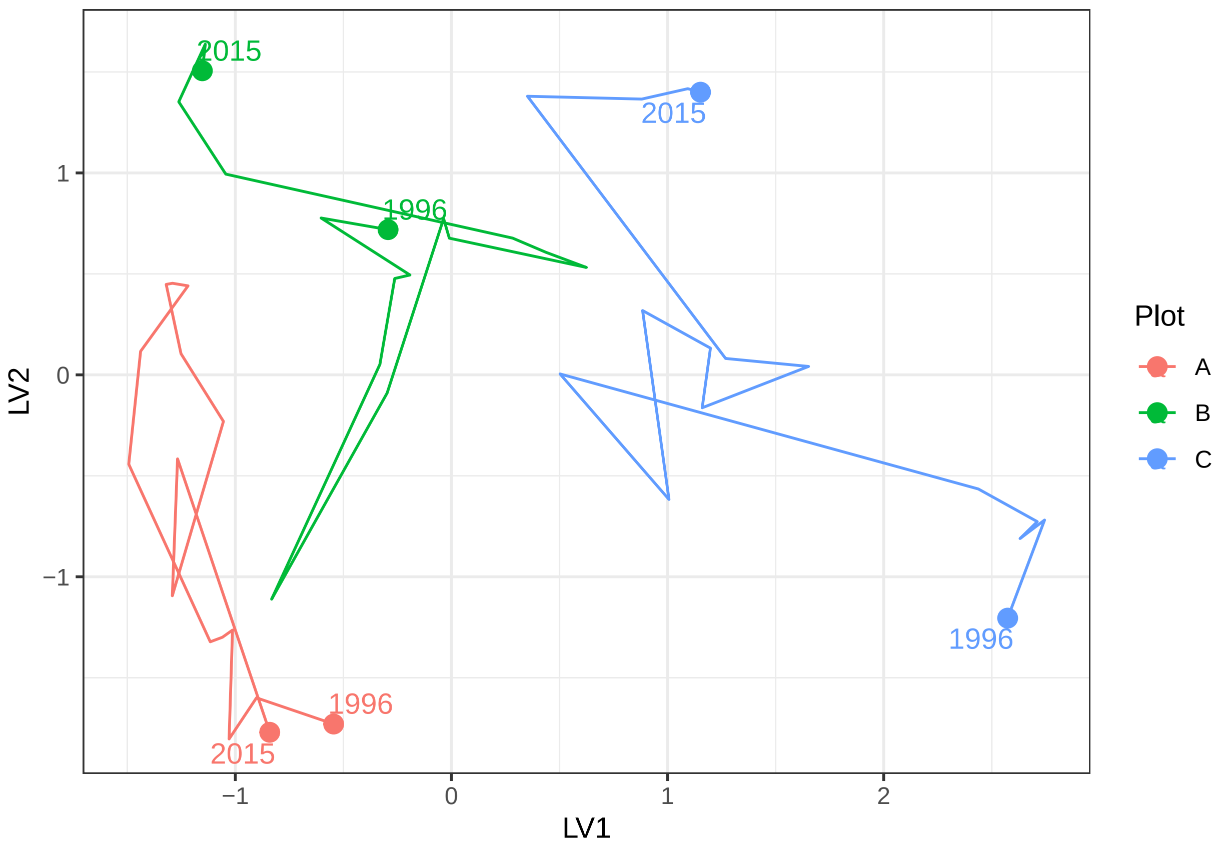

Figure 25: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for at the northern Joondalup transect

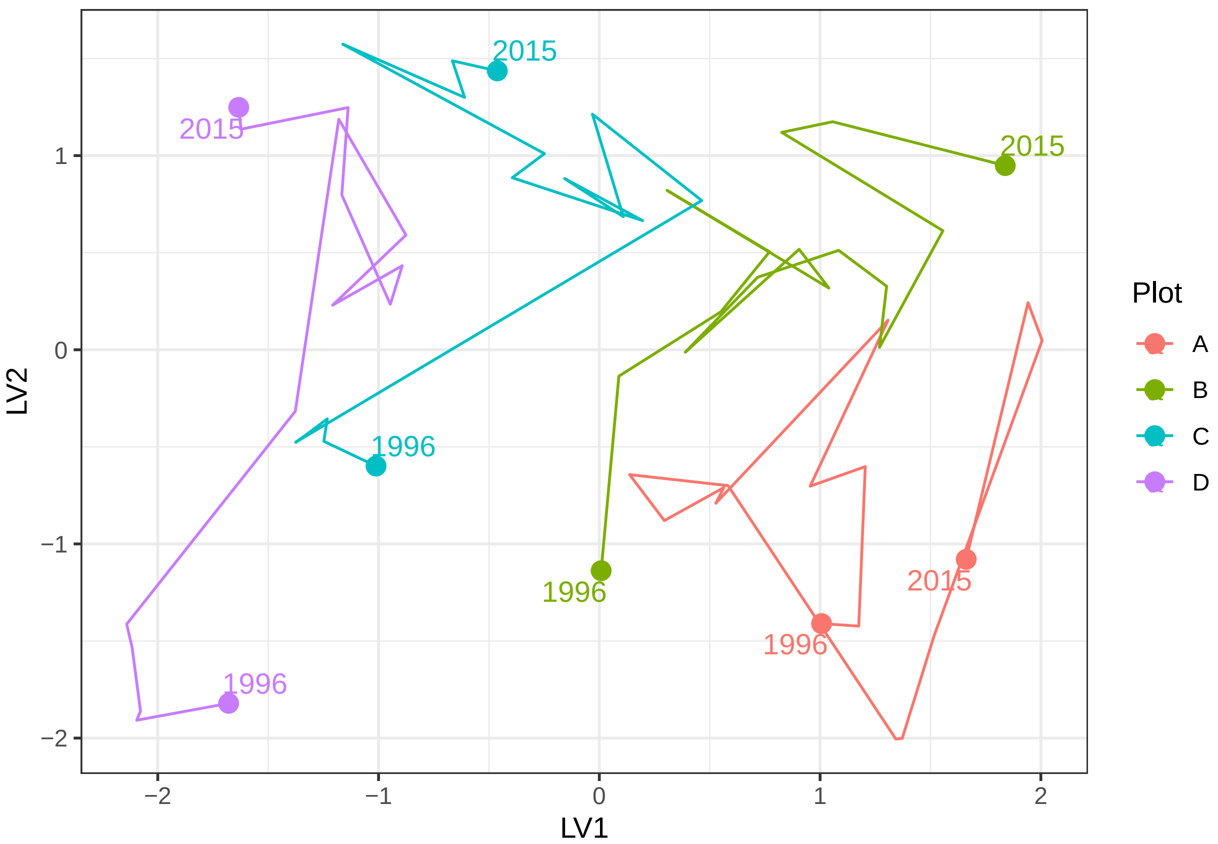

Figure 26: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for at the southern Joondalup transect

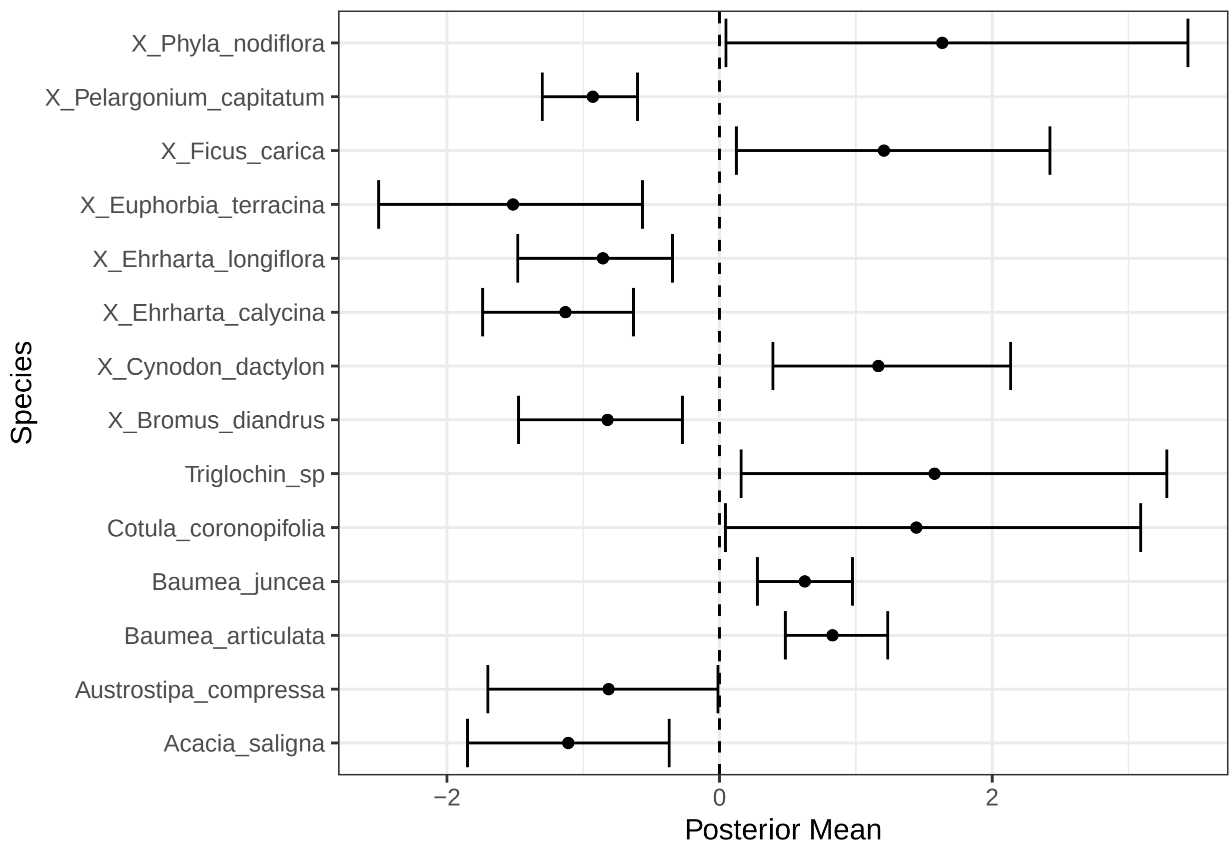

Figure 27: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

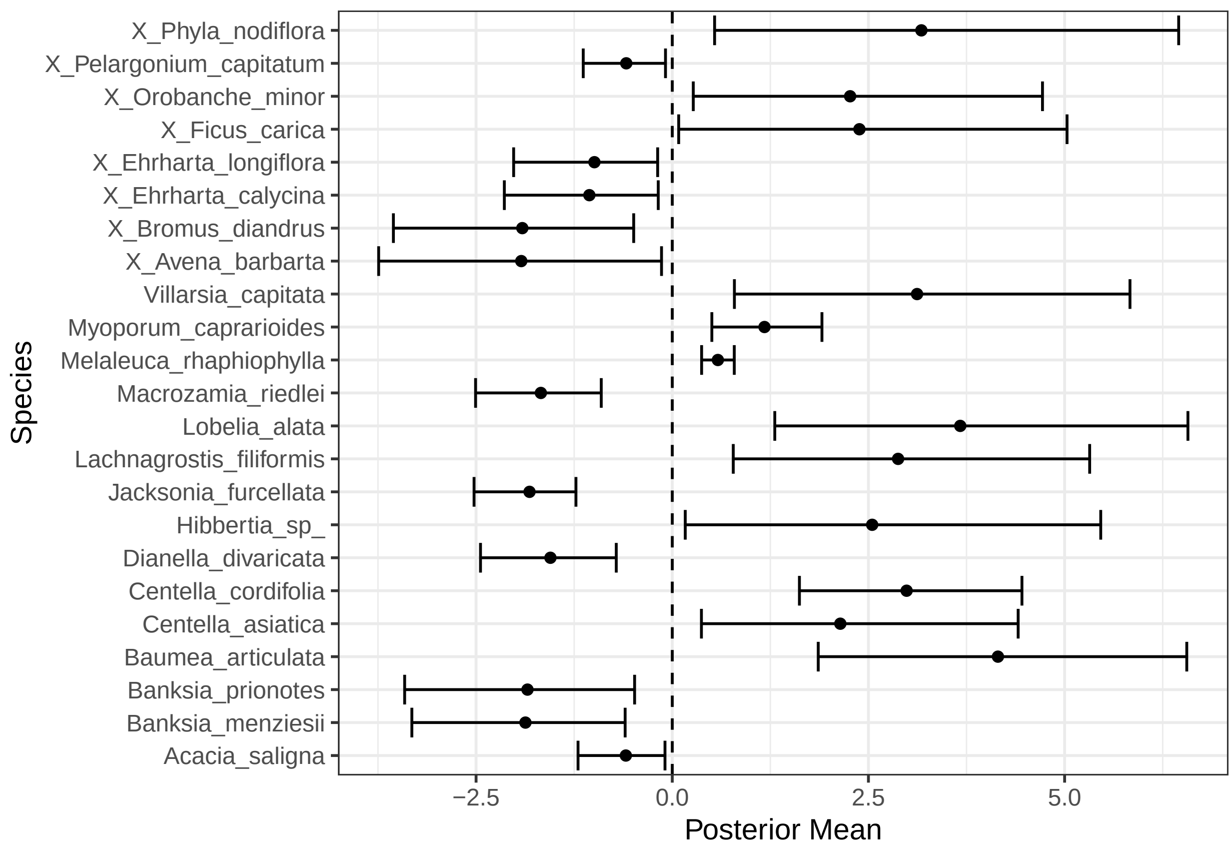

Figure 28: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

Table 12: 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

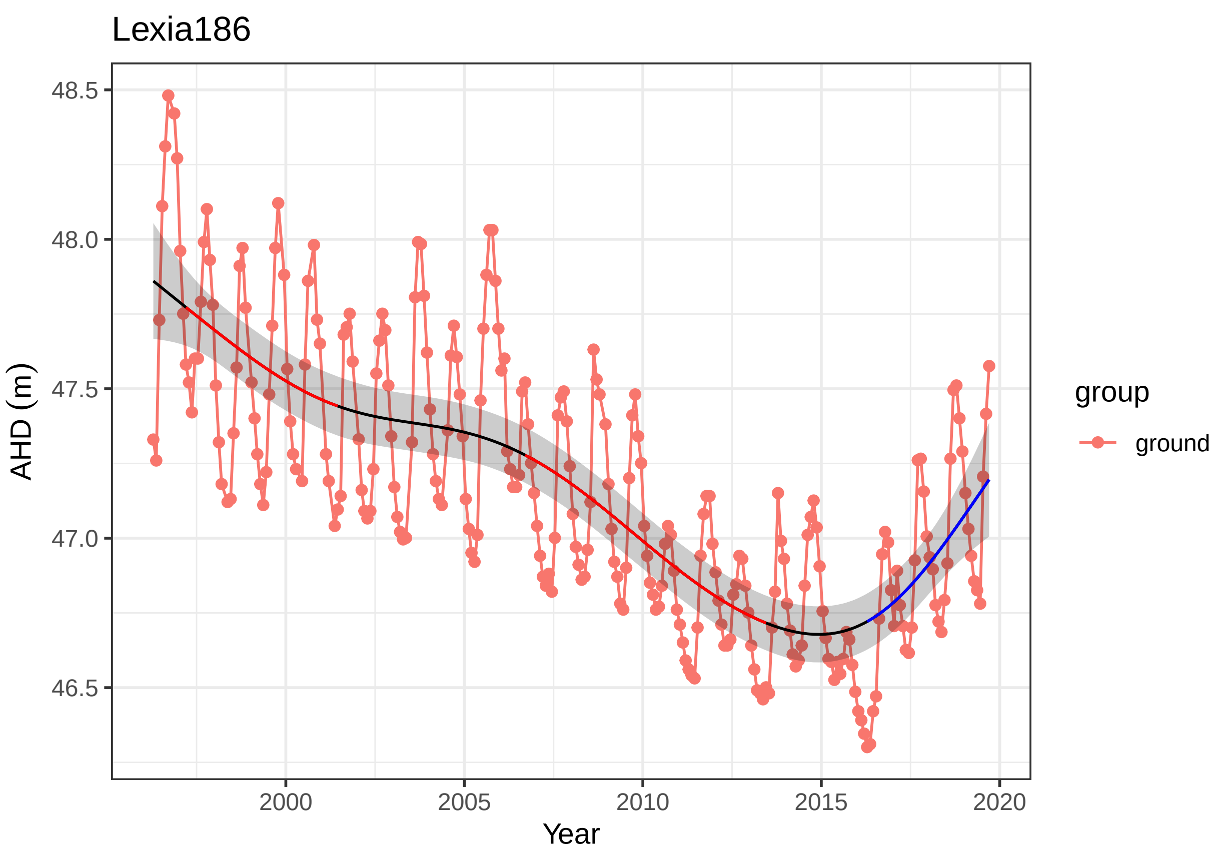

Figure 29: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Lexia 186

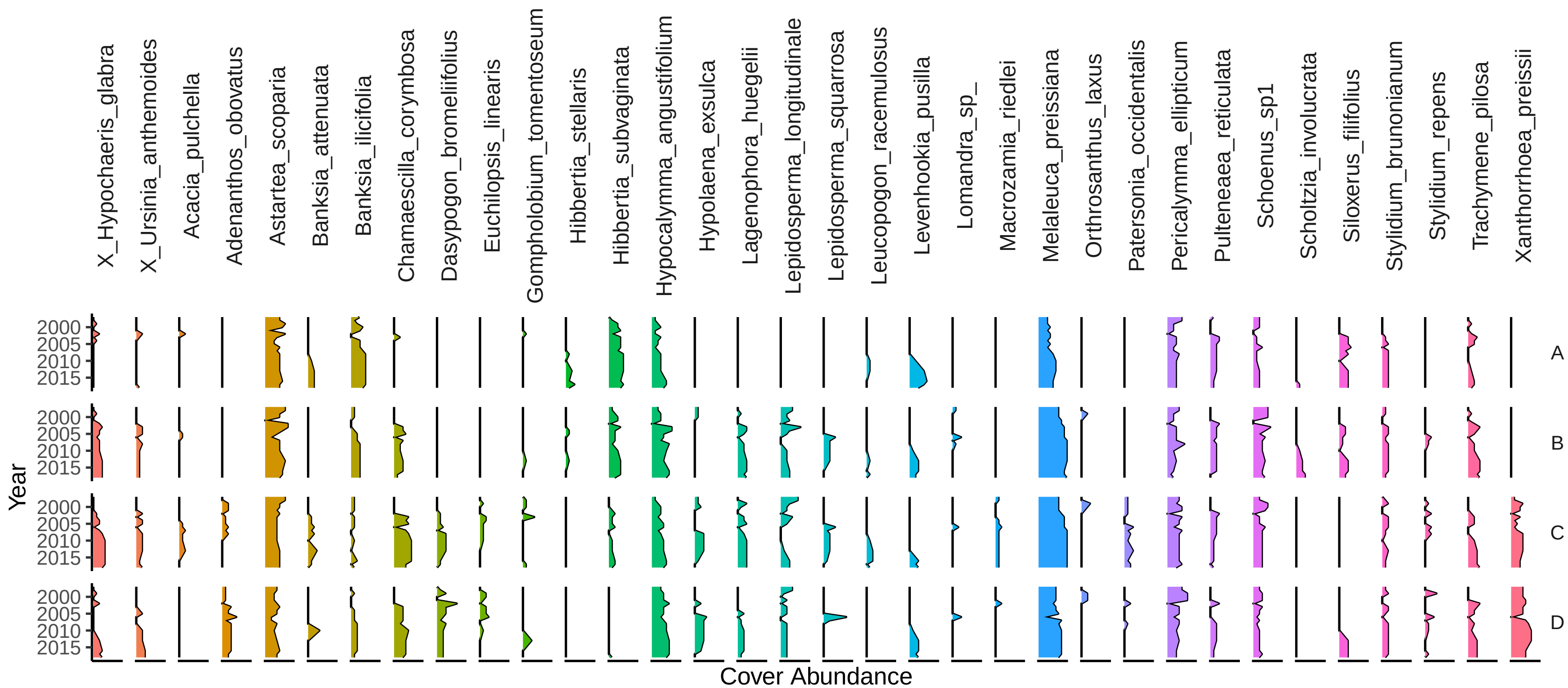

Figure 30: Cover abundances for each species across the four plots (A, B, C, D) at the Lexia 186 transect. Invasive species are denoted by 'X'. Only the most common species are included.

Table 13: 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

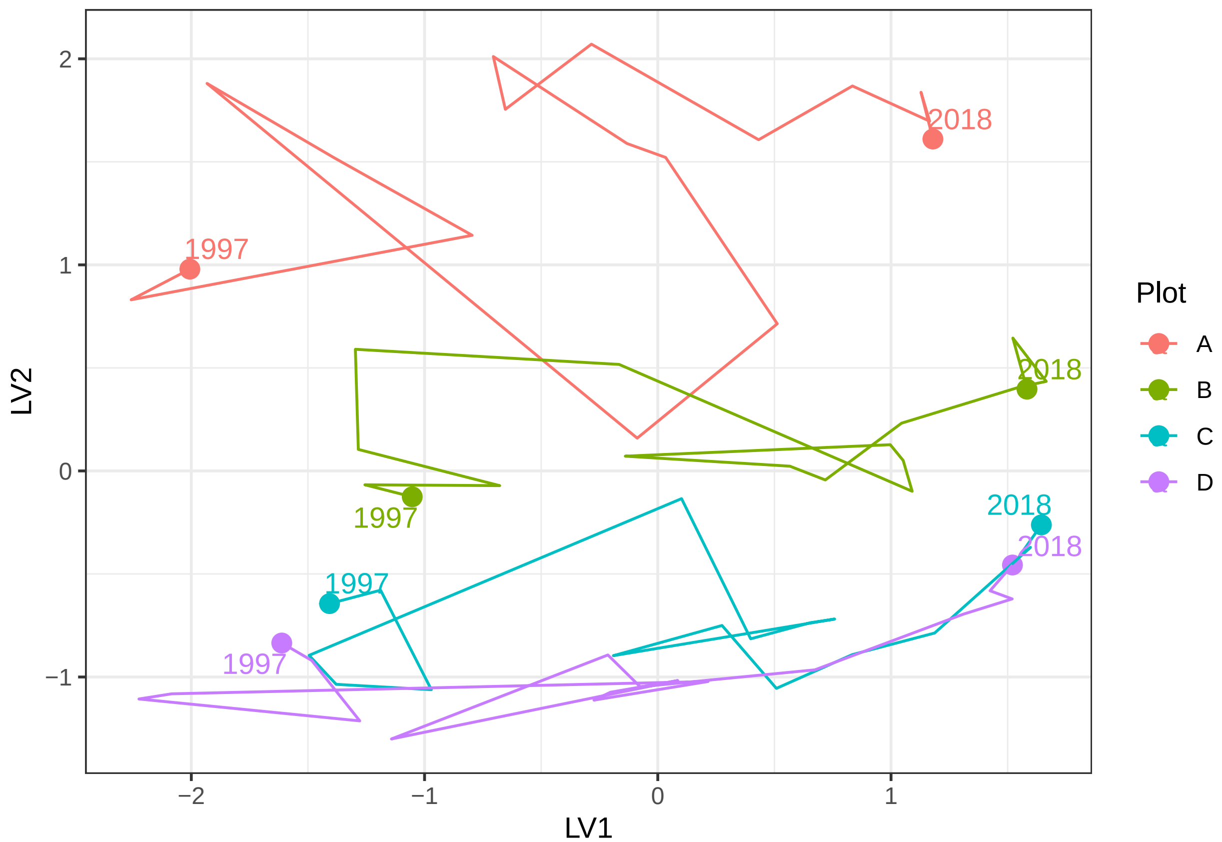

Figure 31: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

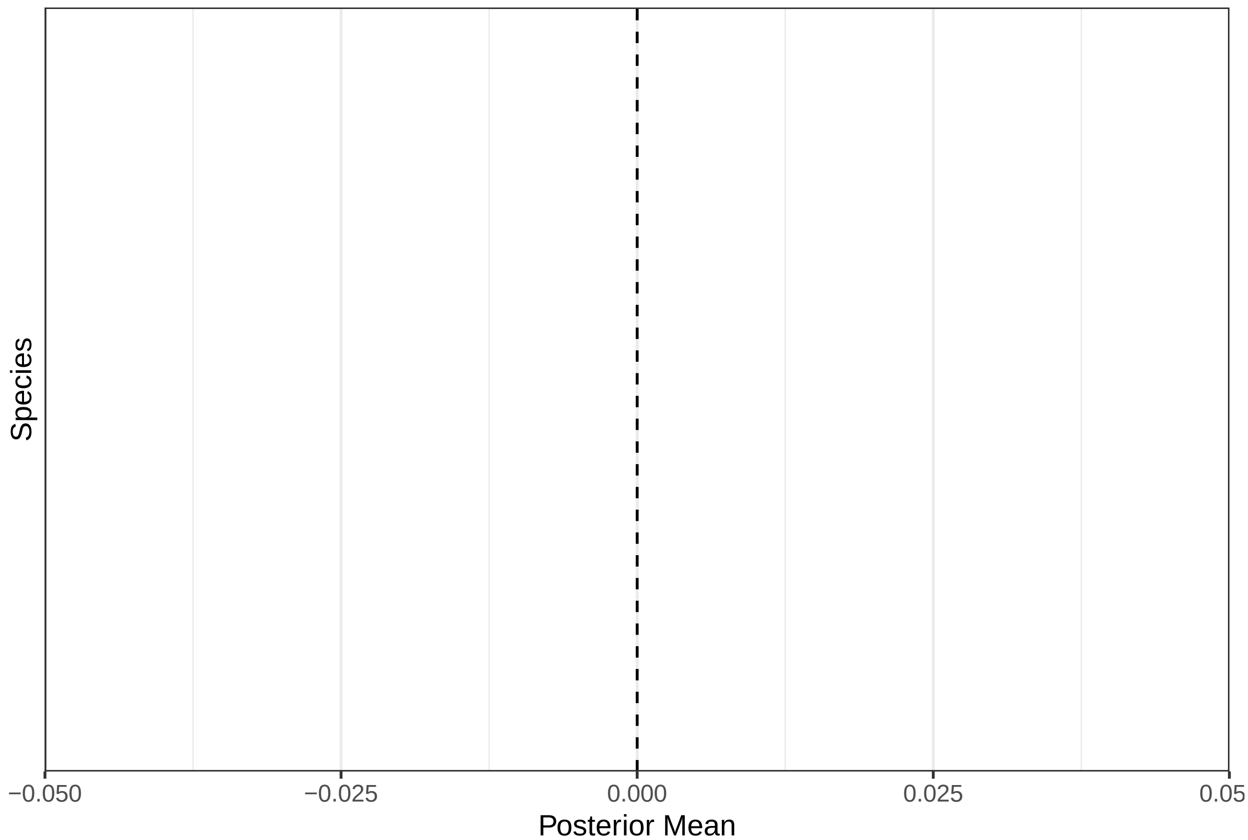

Figure 32: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

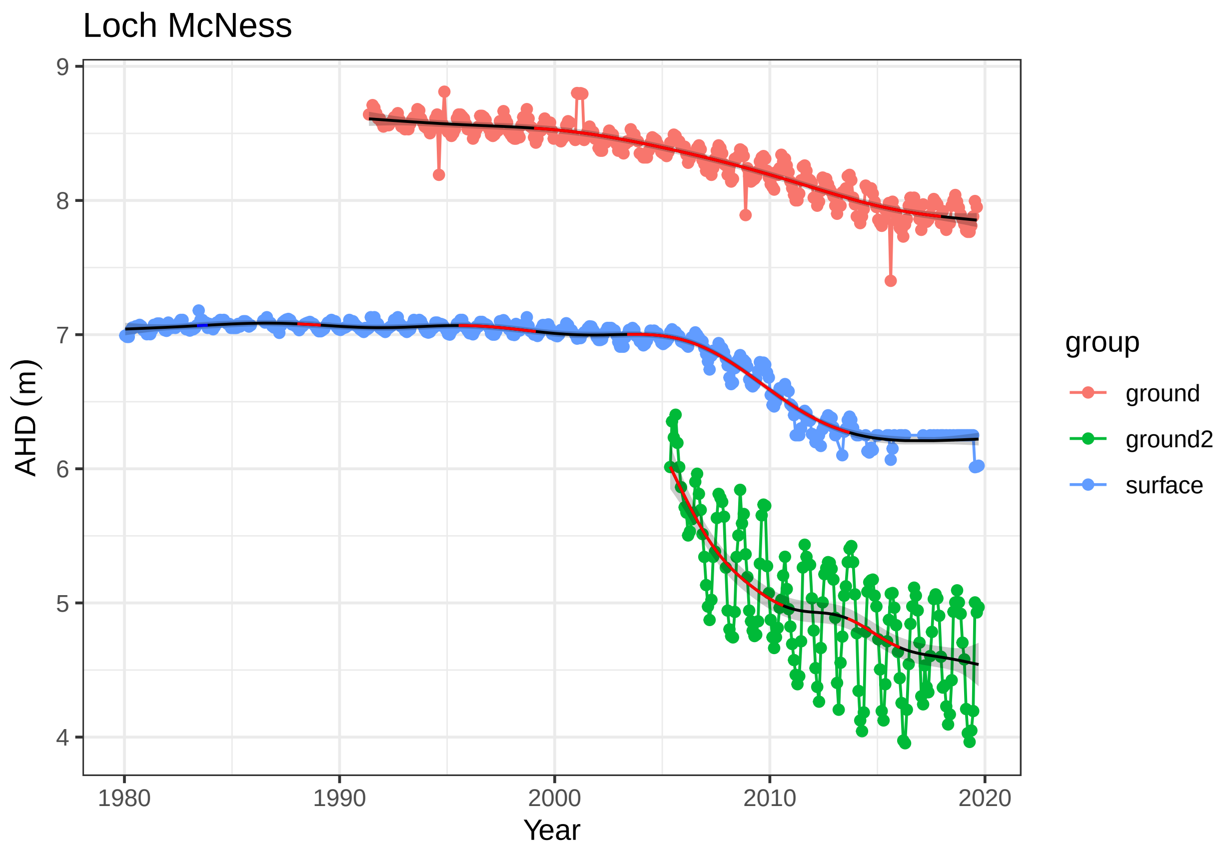

Figure 33: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Loch McNess

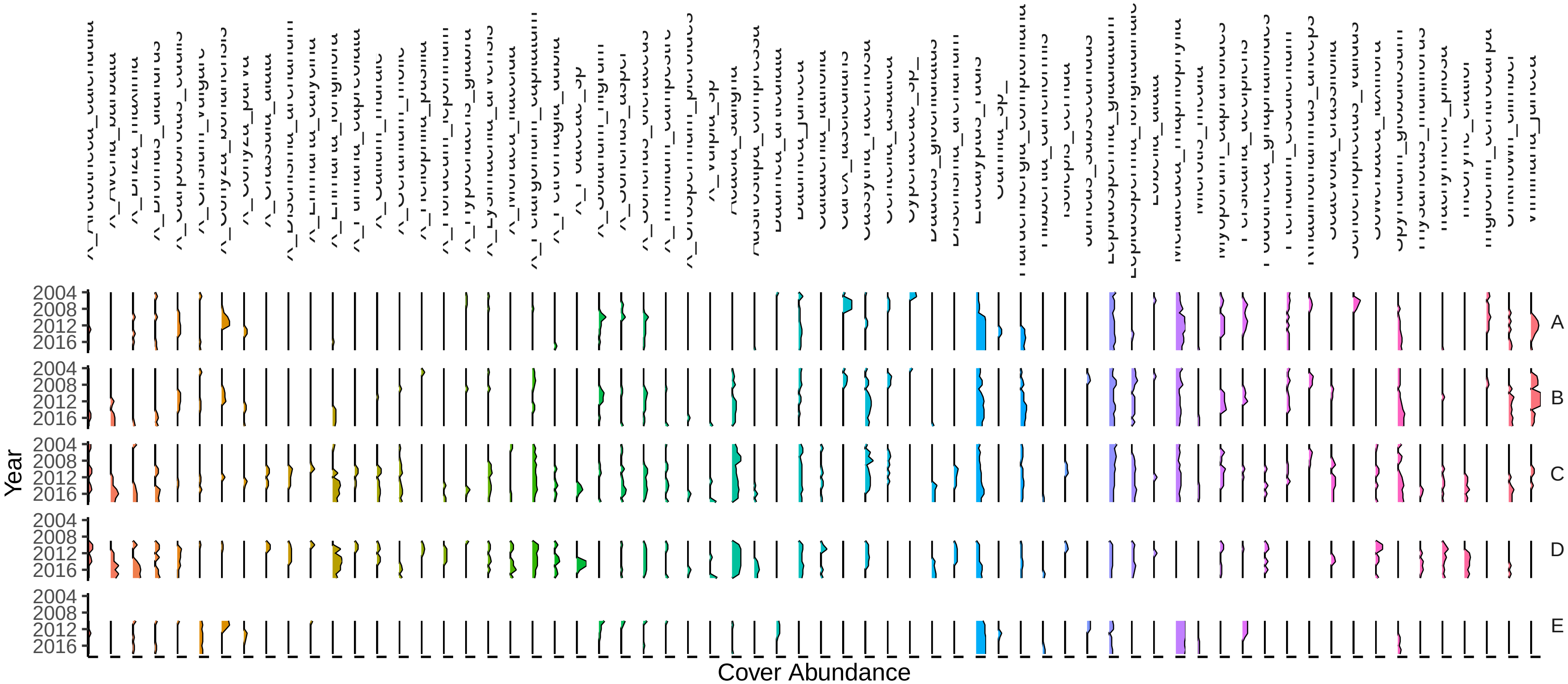

Figure 34: Cover abundances for each species across the four plots (A, B, C, D) at the Loch McNess transect. Invasive species are denoted by 'X'. Only the most common species are included.

Table 14: 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

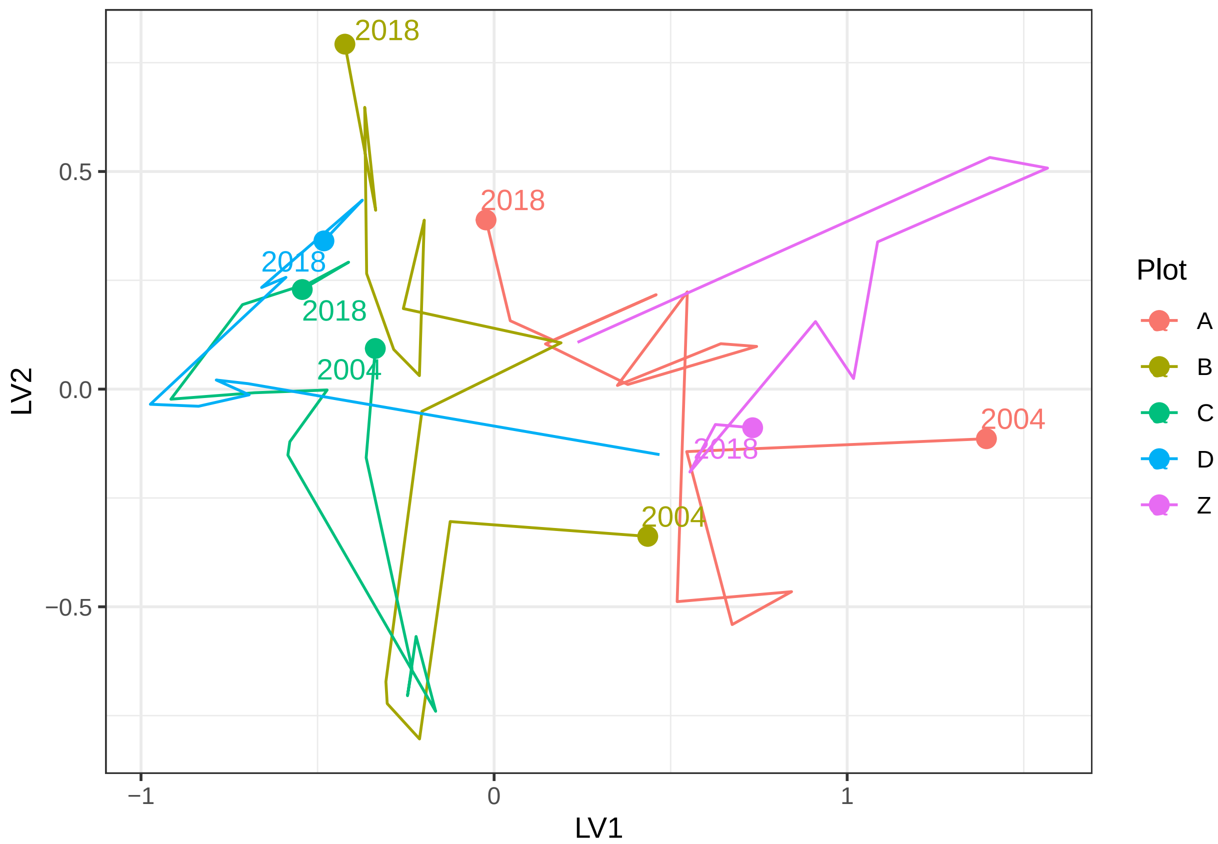

Figure 35: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

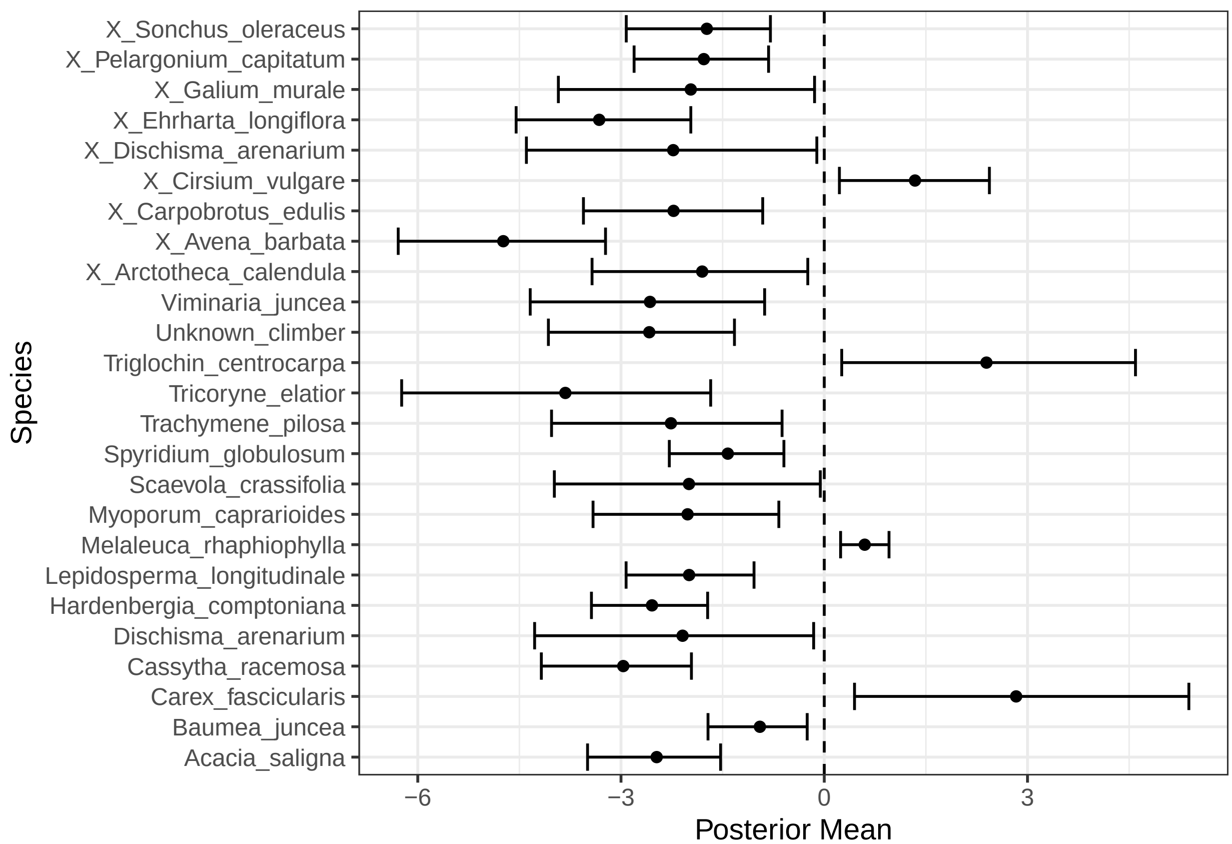

Figure 36: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

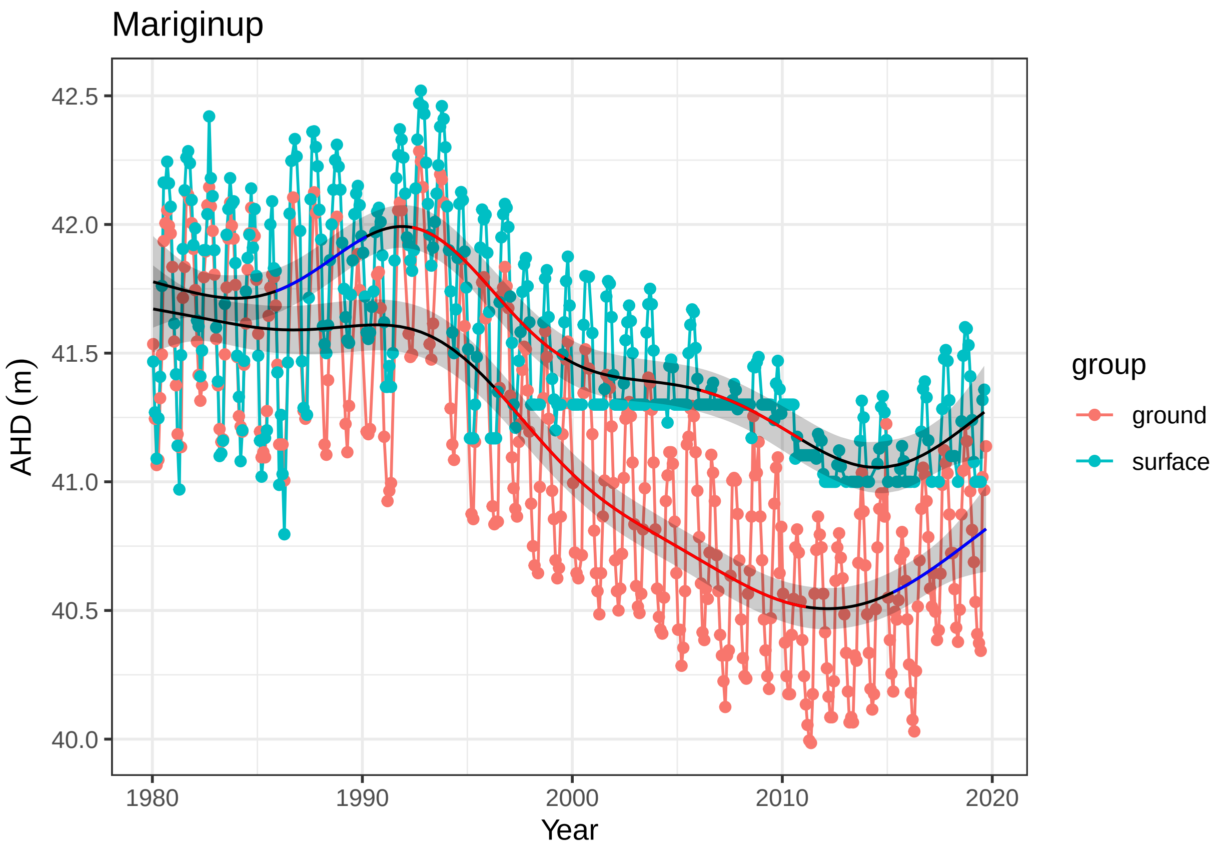

Figure 37: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Mariginiup

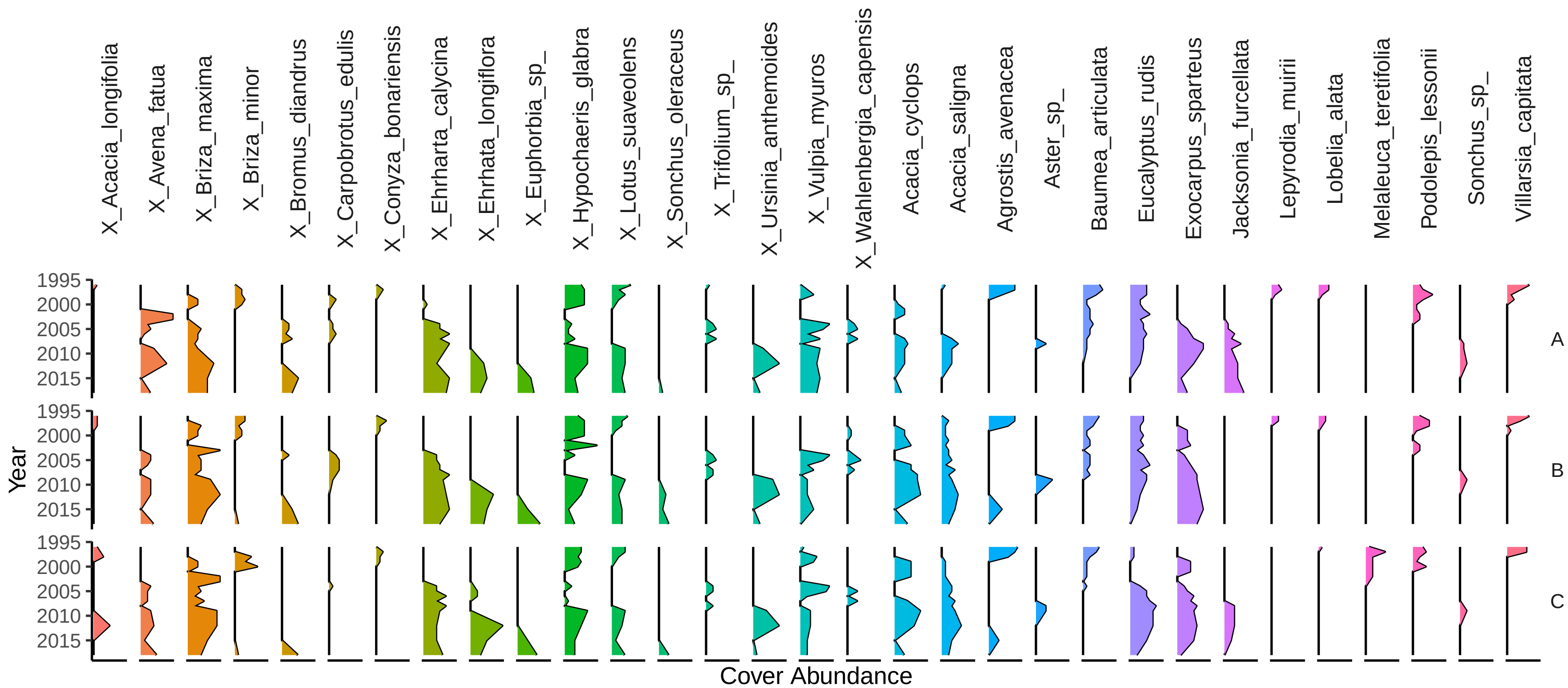

Figure 38: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Mariginiup transect. Invasive species are denoted by 'X'. Only the most common species are included.

Table 15: 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

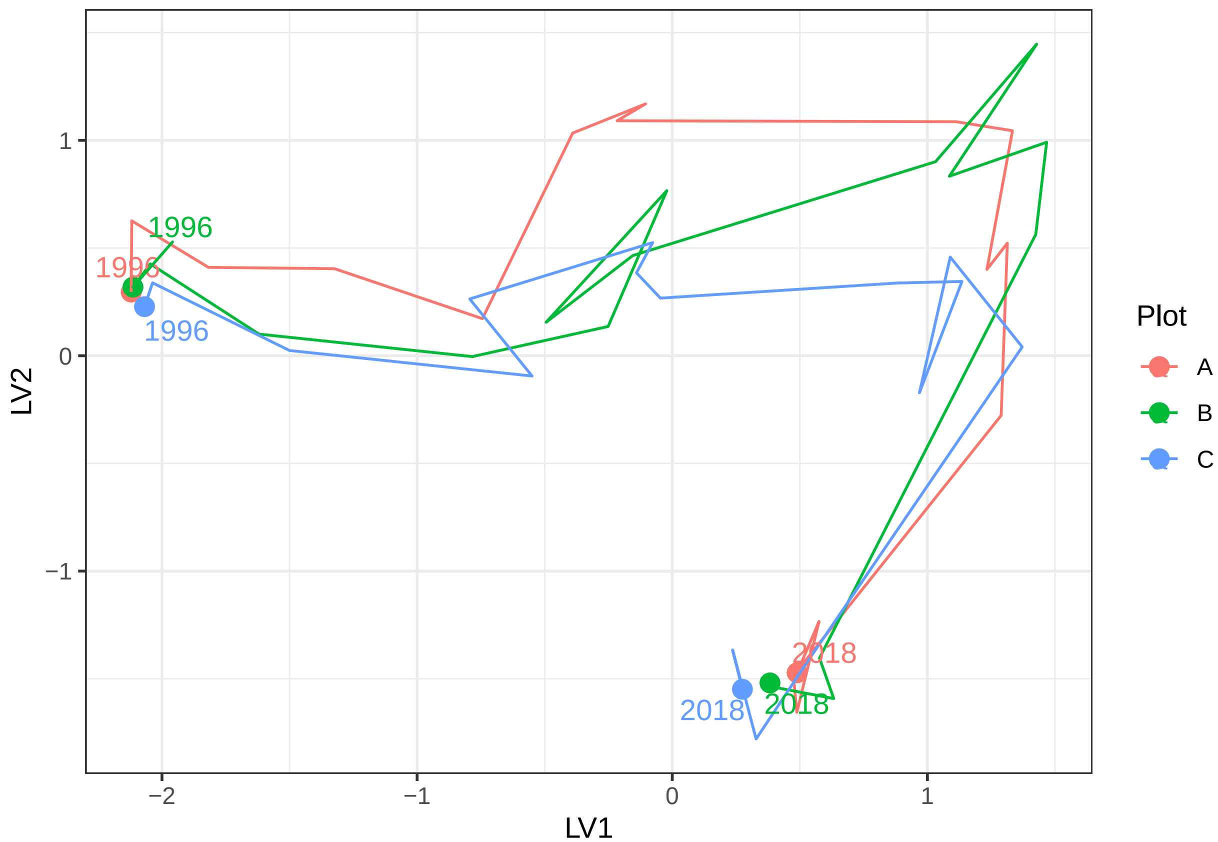

Figure 39: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

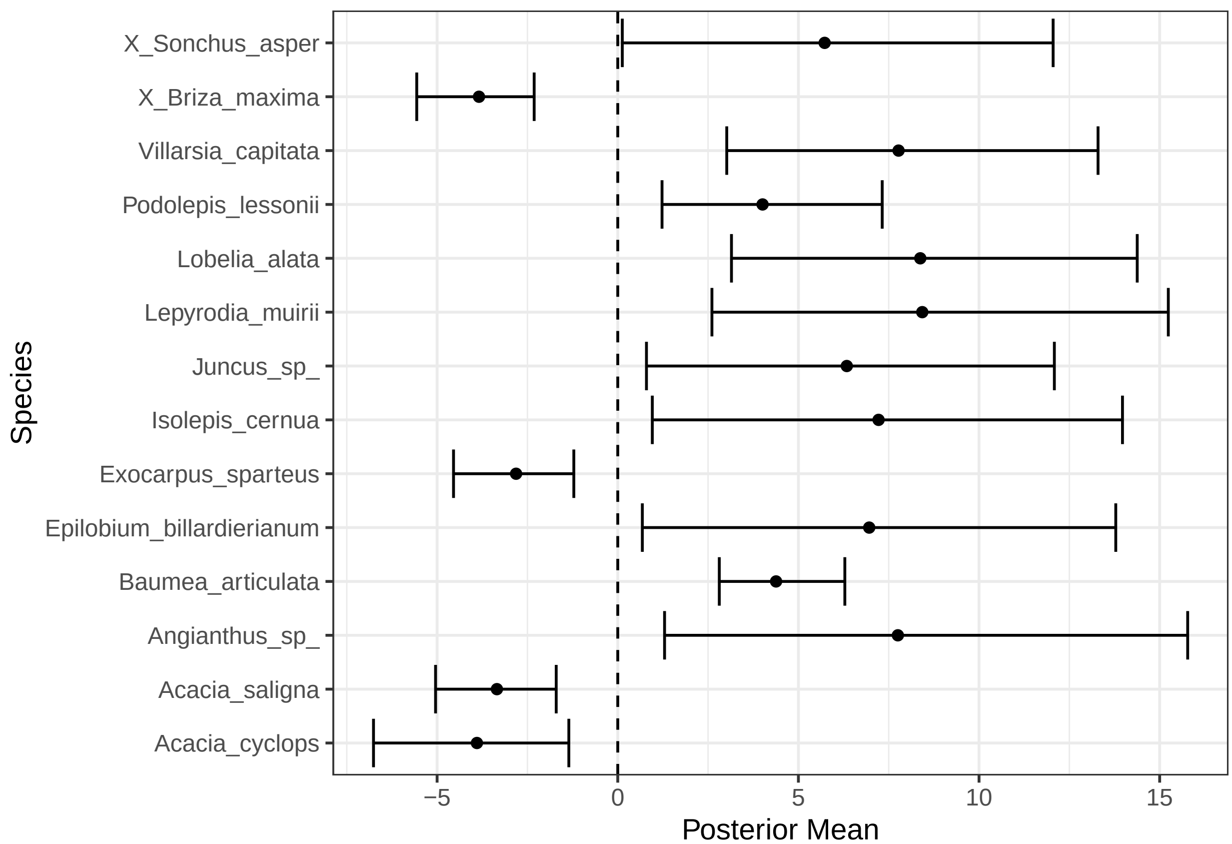

Figure 40: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

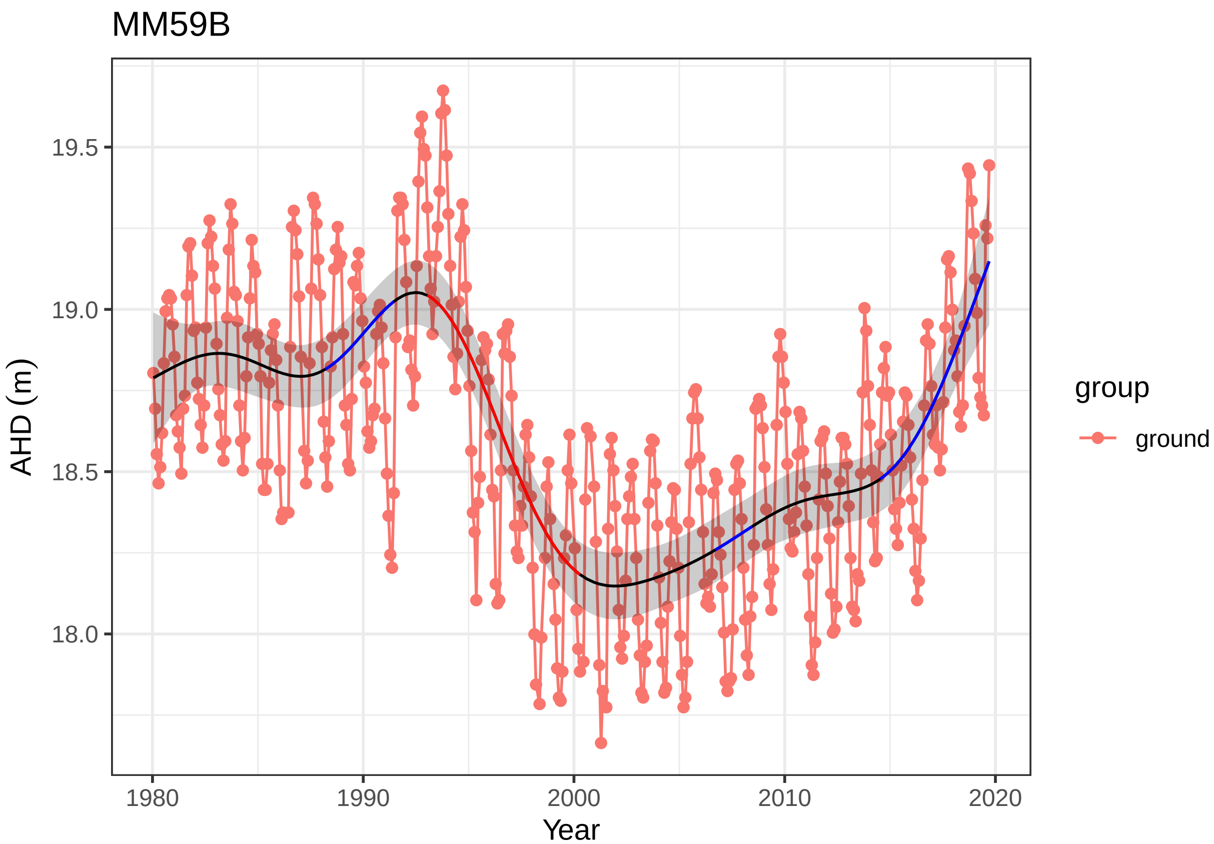

Figure 41: Ground and surface water levels recorded at bores and staff gauges in the vicinity of MM59B

Table 16: 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

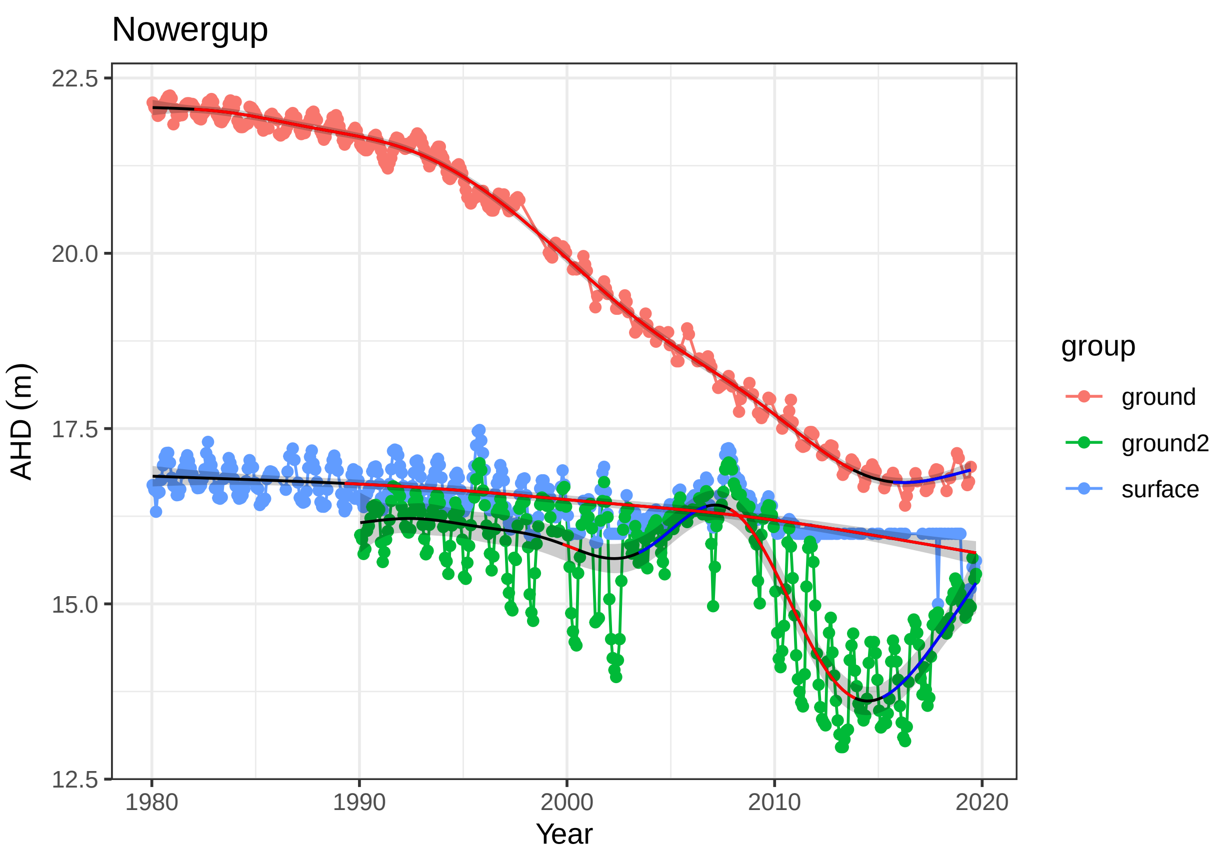

Figure 42: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Nowergup

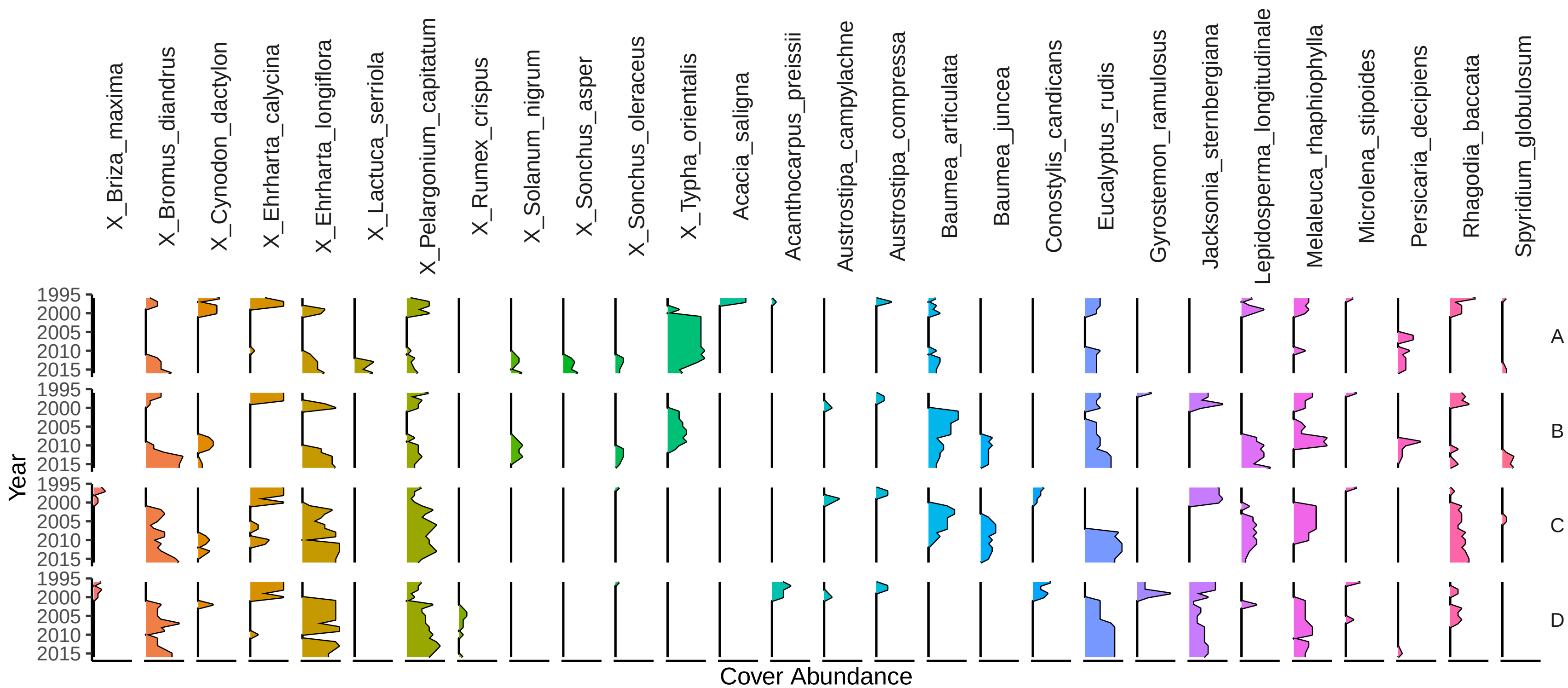

Figure 43: Cover abundances for each species across the four plots (A, B, C, D) at the northern Lake Nowergup transect. Invasive species are denoted by 'X'. Only the most common species are included.

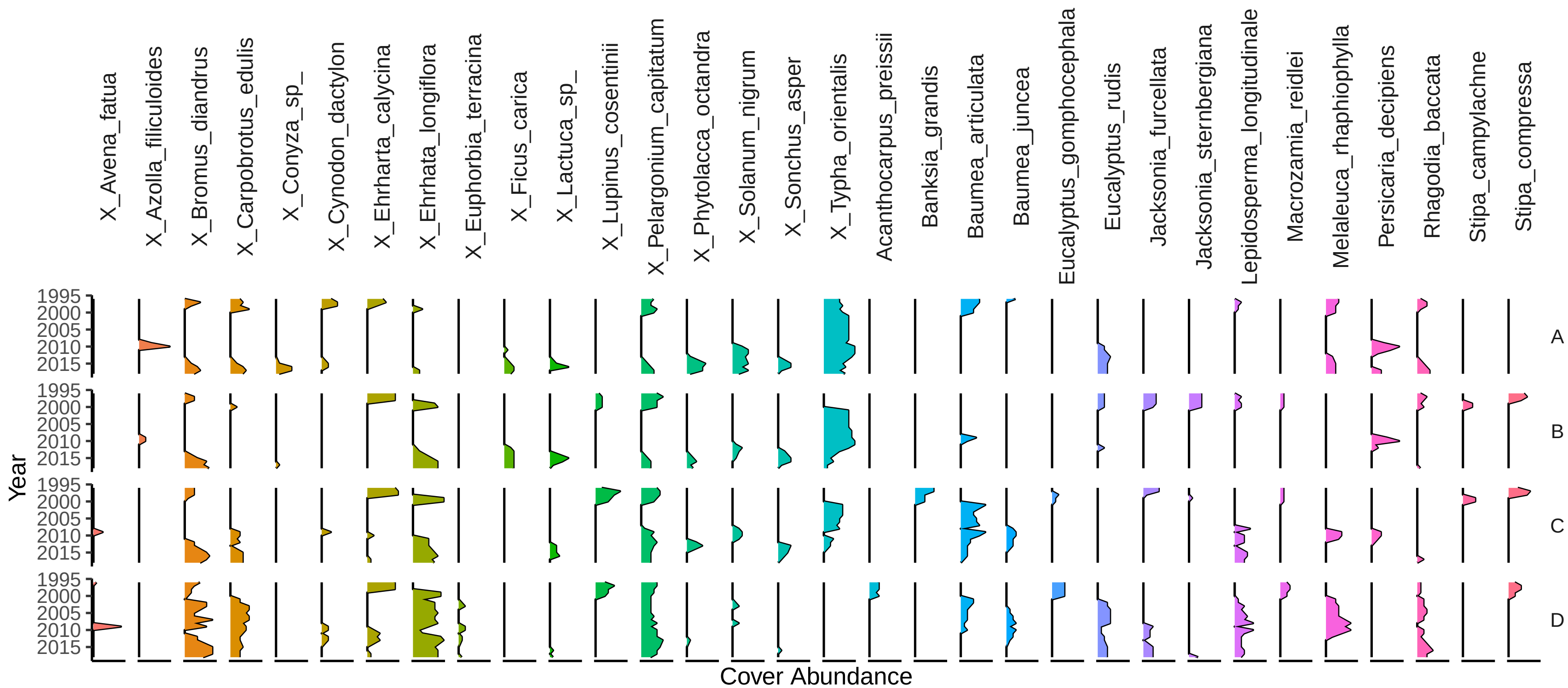

Figure 44: Cover abundances for each species across the four plots (A, B, C, D) at the souther Lake Nowergup transect. Invasive species are denoted by ‘X’. Only the most common species are included.

Table 17: 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

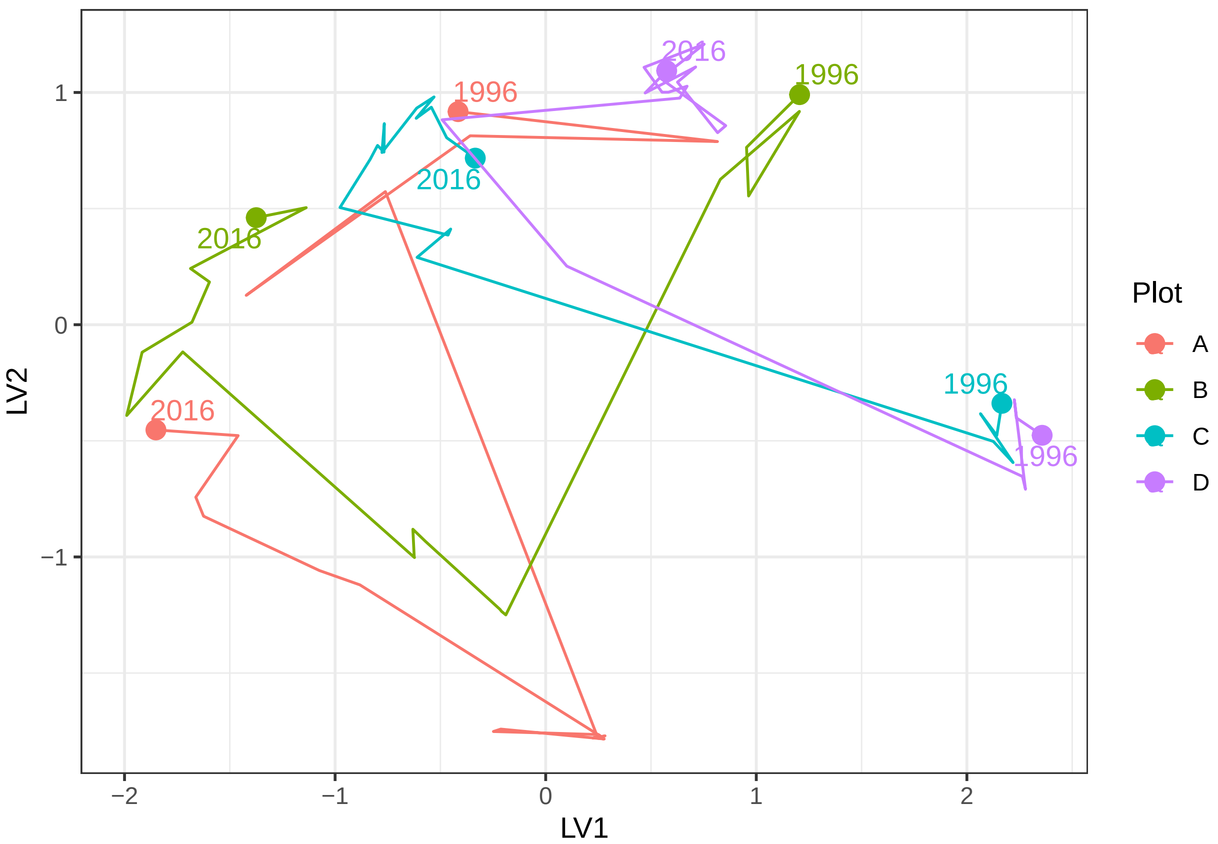

Figure 45: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

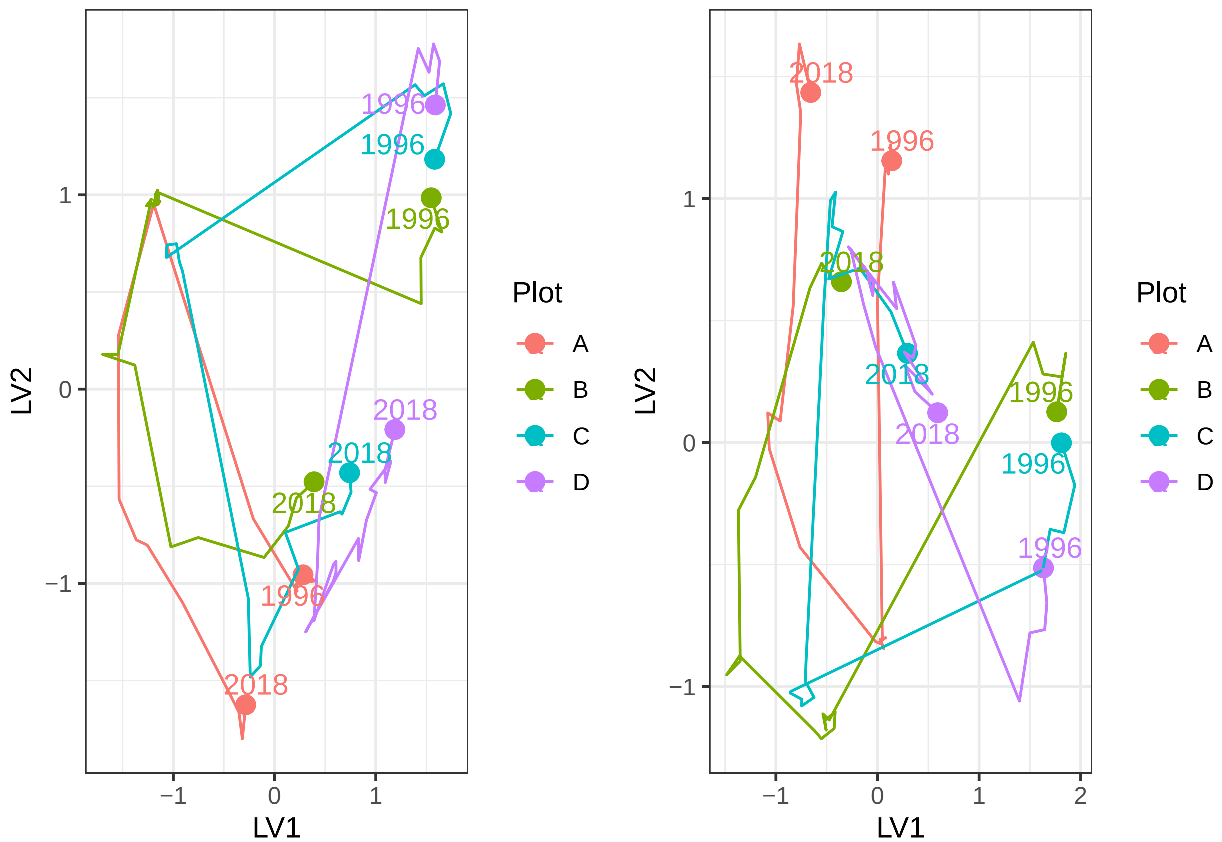

Figure 46: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

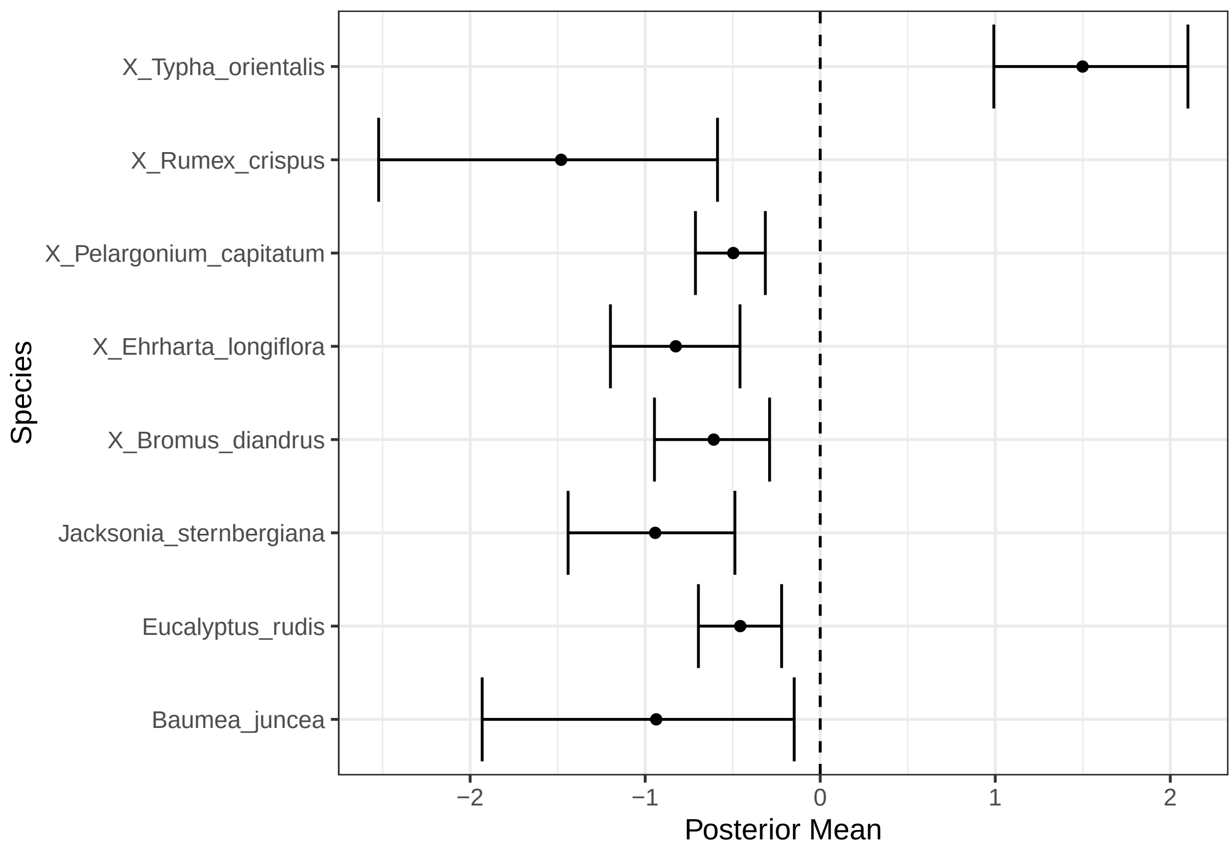

Figure 47: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

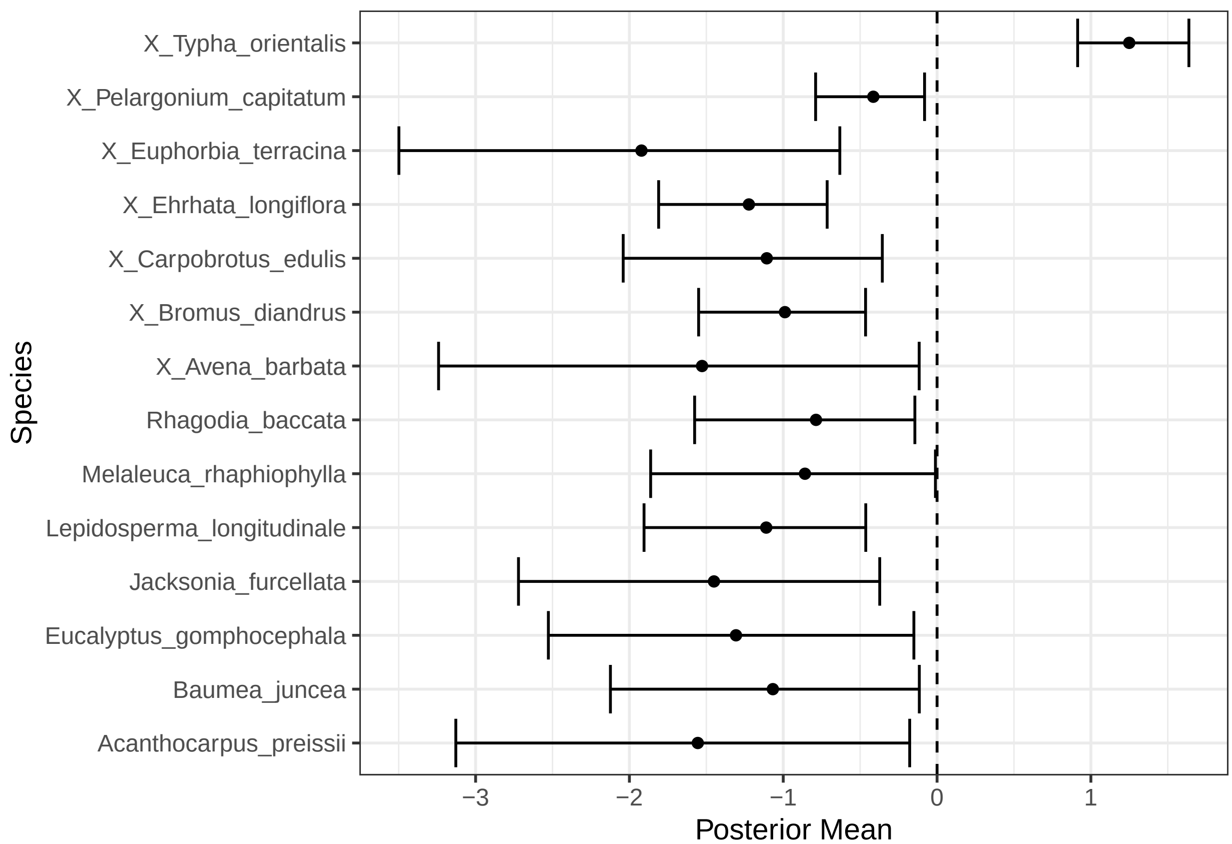

Figure 48: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

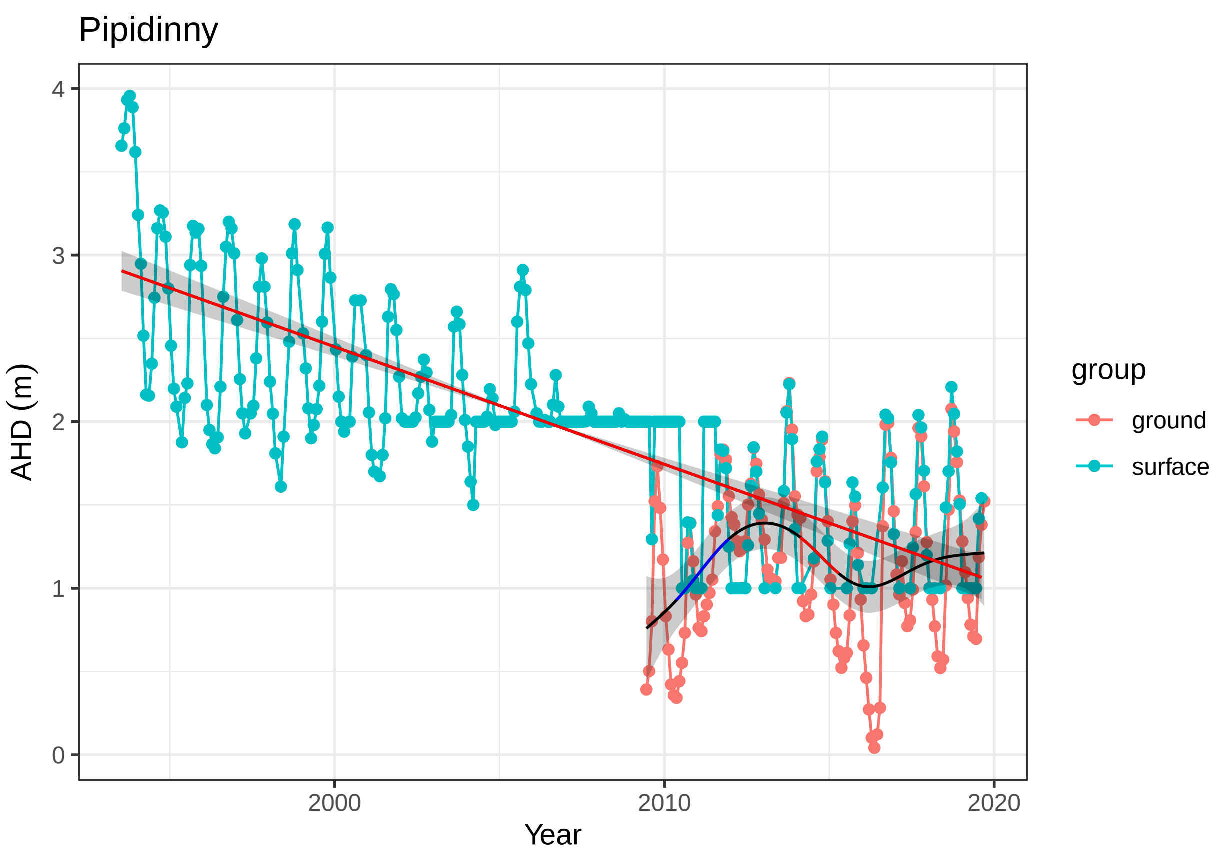

Figure 49: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Pipidinny

Table 18: 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

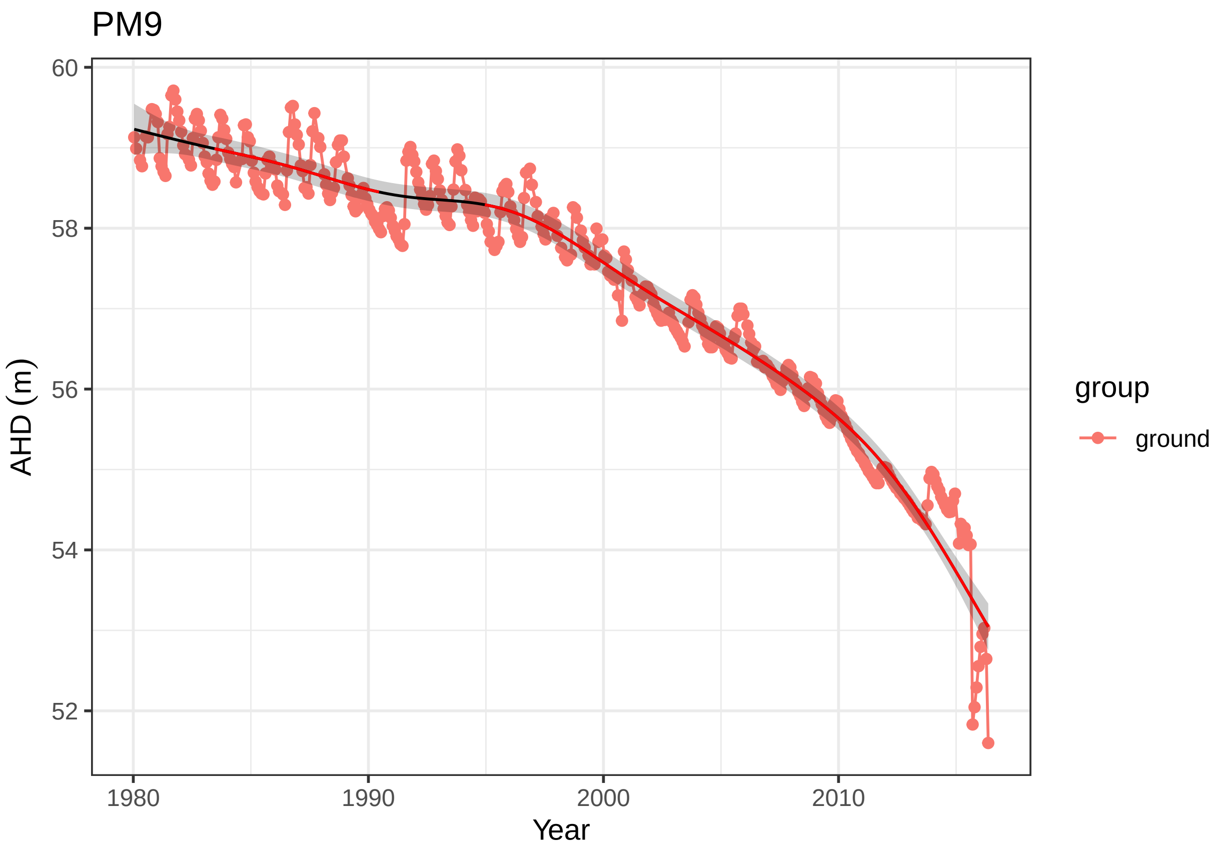

Figure 50: Ground and surface water levels recorded at bores and staff gauges in the vicinity of PM9

Table 19: 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

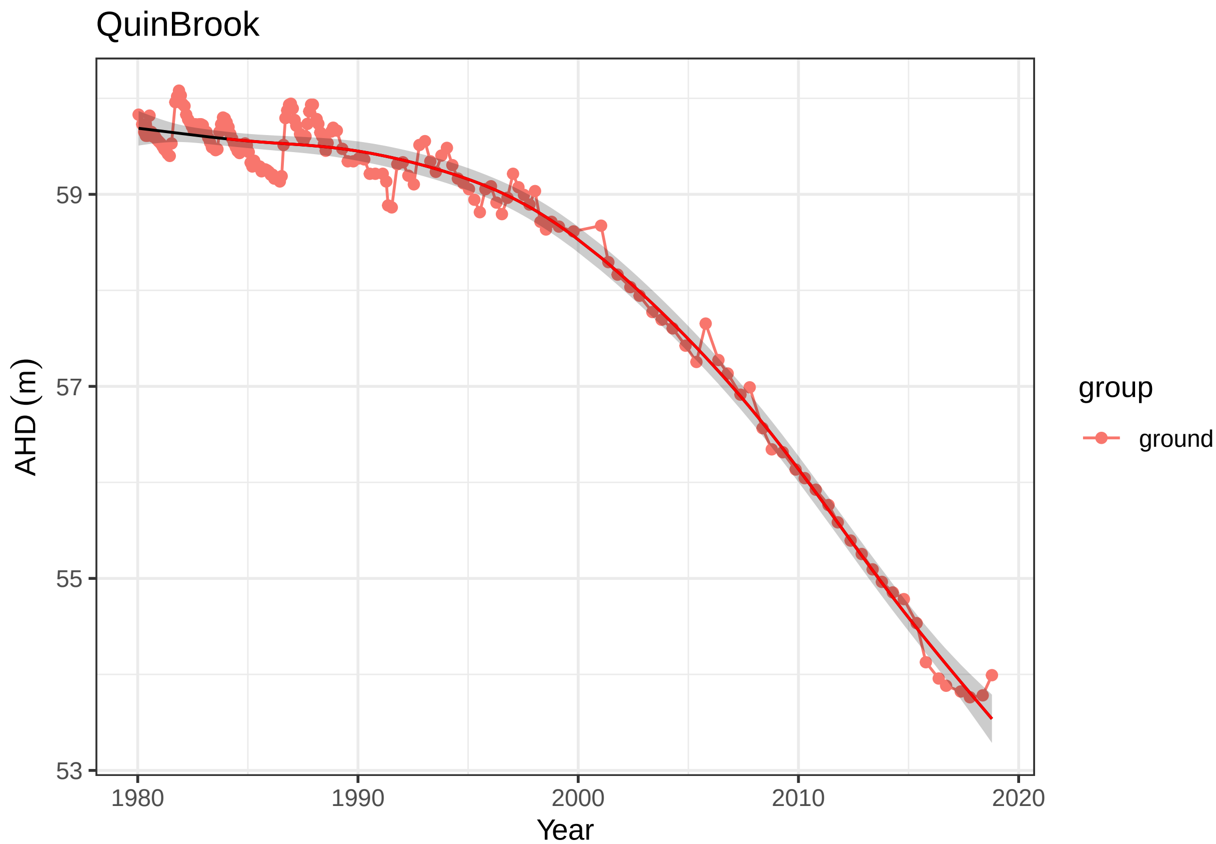

Figure 51: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Quin Brook

Table 20: 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

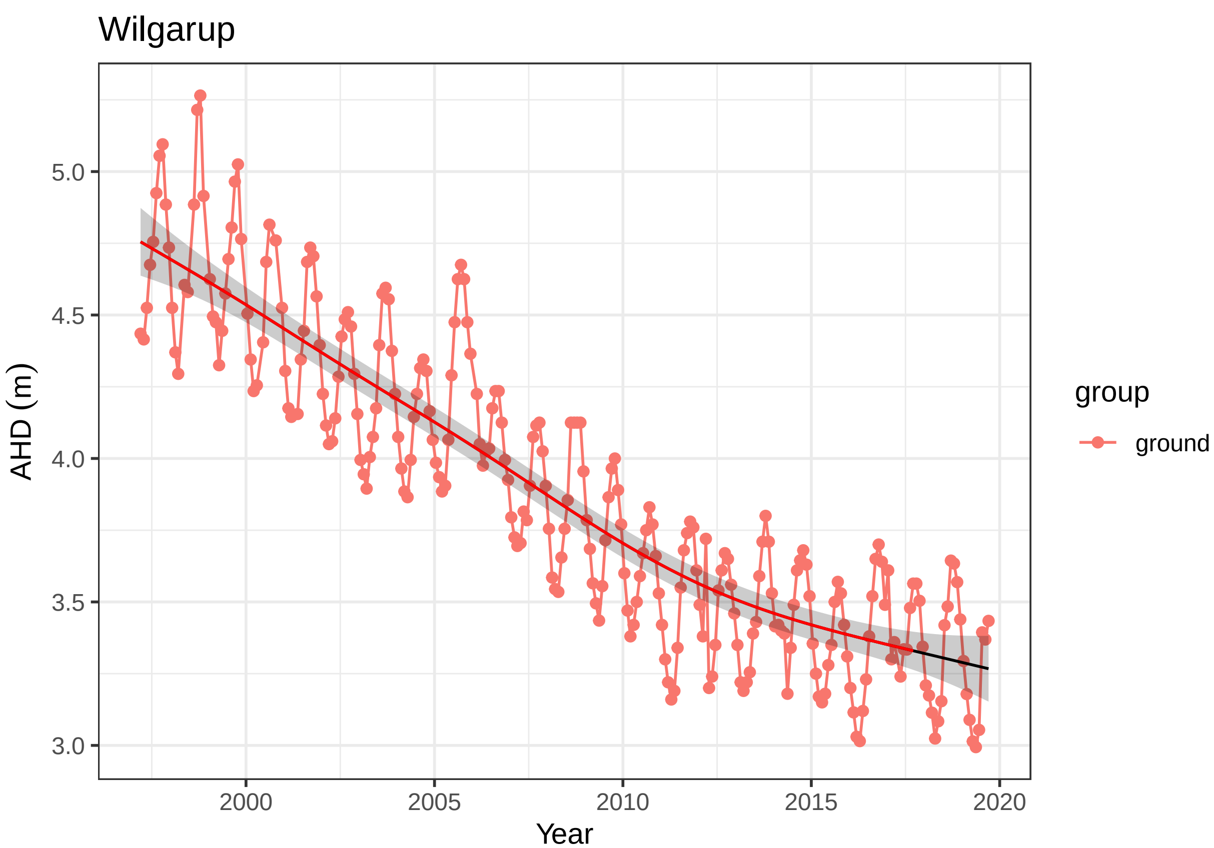

Figure 52: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Wilgarup

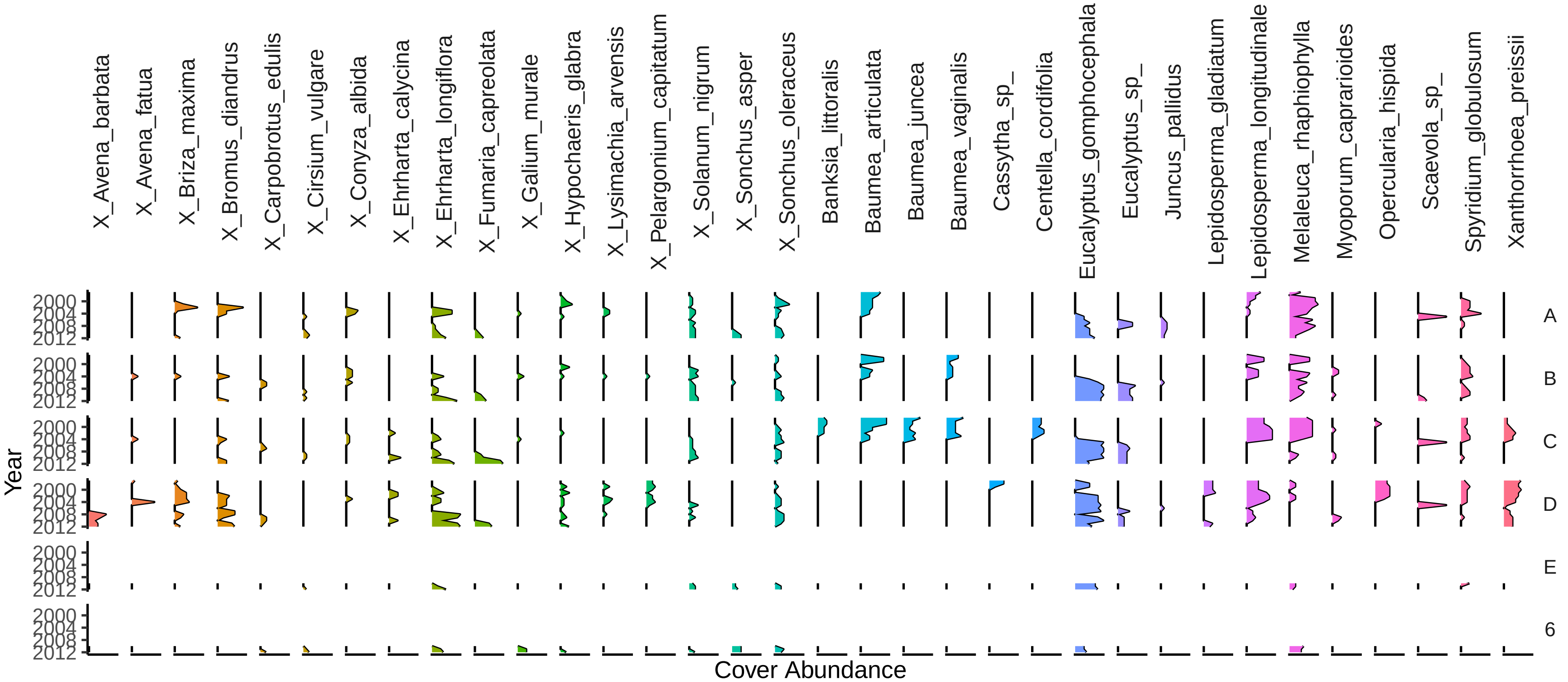

Figure 53: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Wilgarup transect. Invasive species are denoted by 'X'. Only the most common species are included.

Table 21: 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

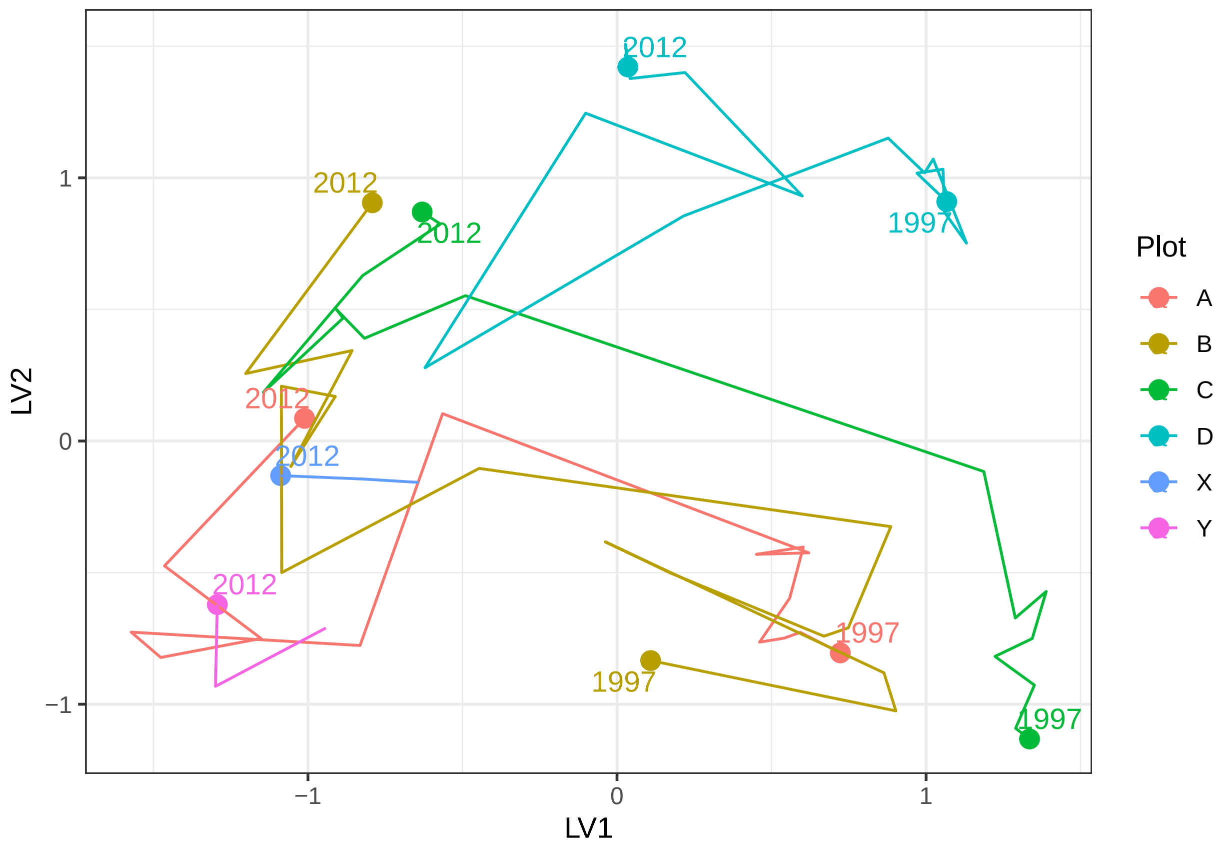

Figure 54: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

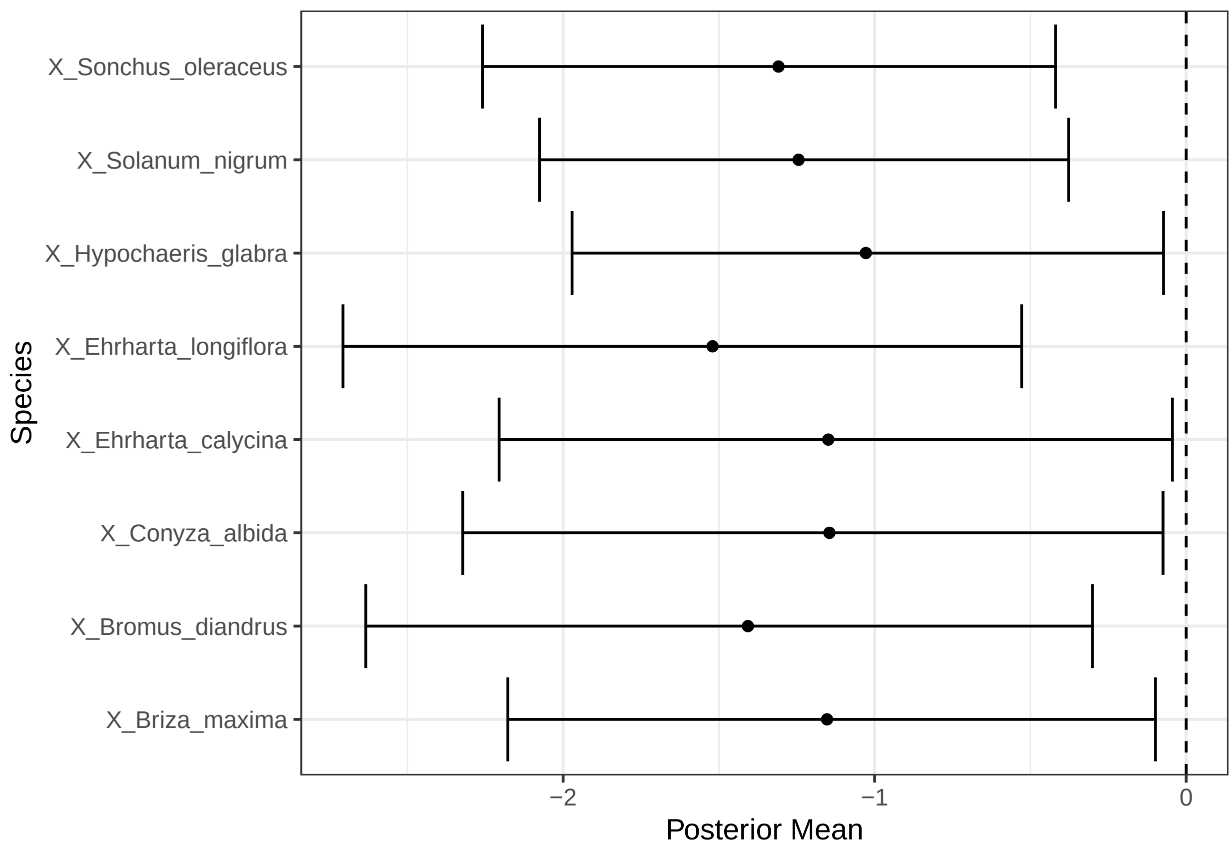

Figure 55: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown

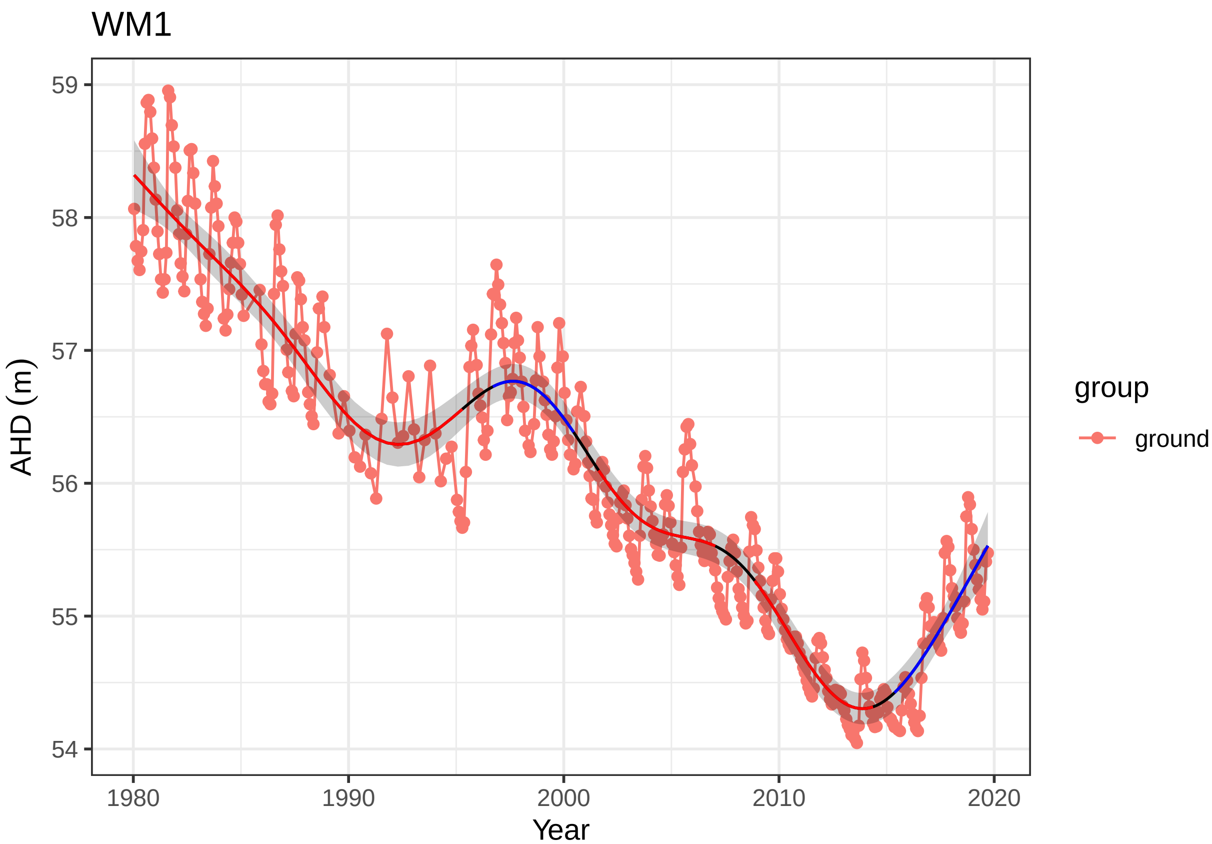

Figure 56: Ground and surface water levels recorded at bores and staff gauges in the vicinity of WM1

Table 22: 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

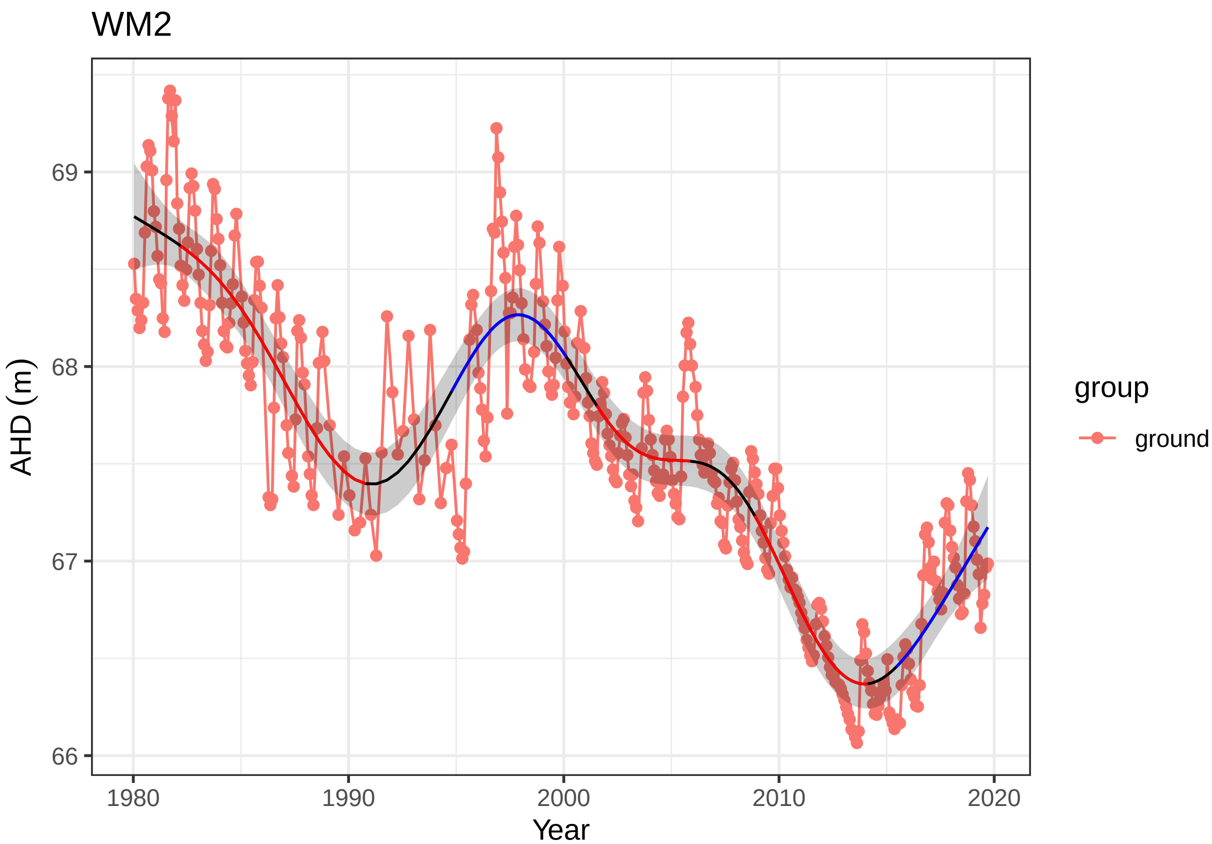

Figure 57: Ground and surface water levels recorded at bores and staff gauges in the vicinity of WM2

Table 23: 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

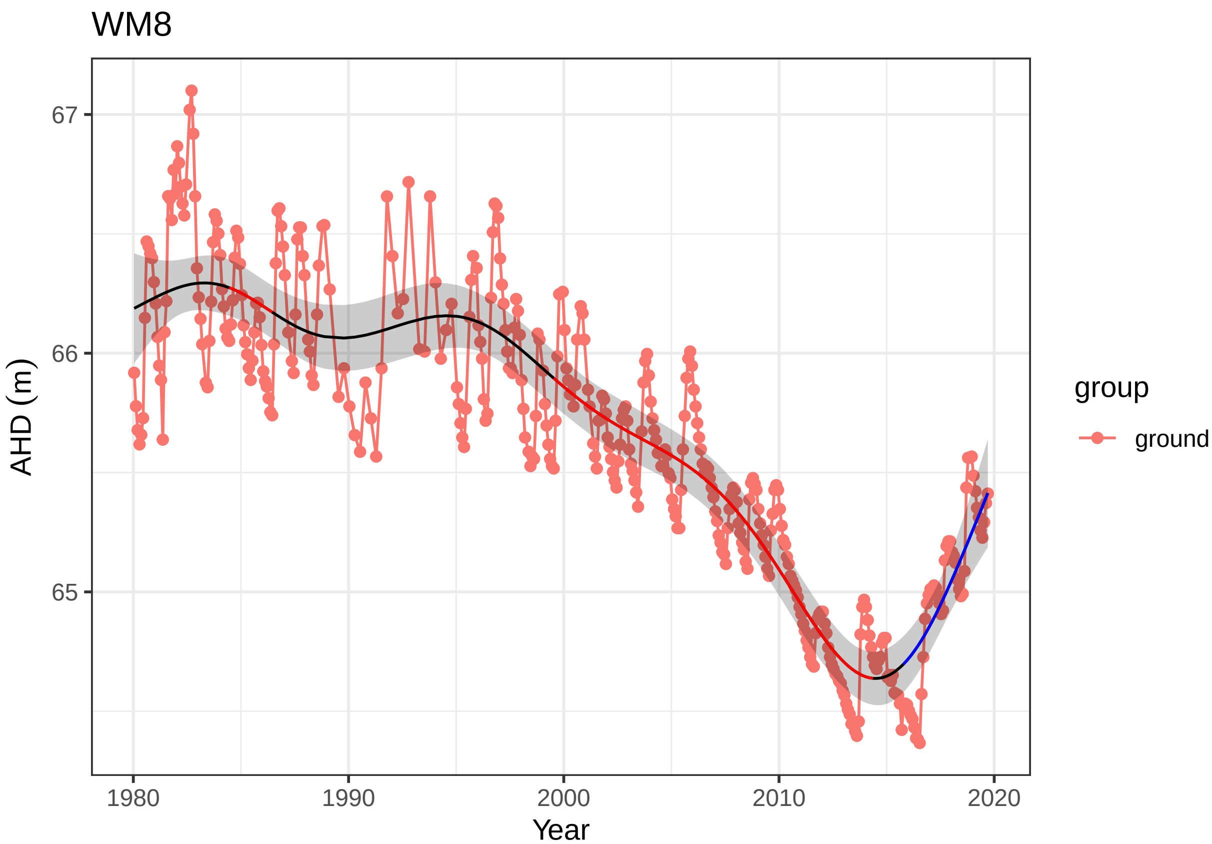

Figure 58: Ground and surface water levels recorded at bores and staff gauges in the vicinity of WM8

Table 24: 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

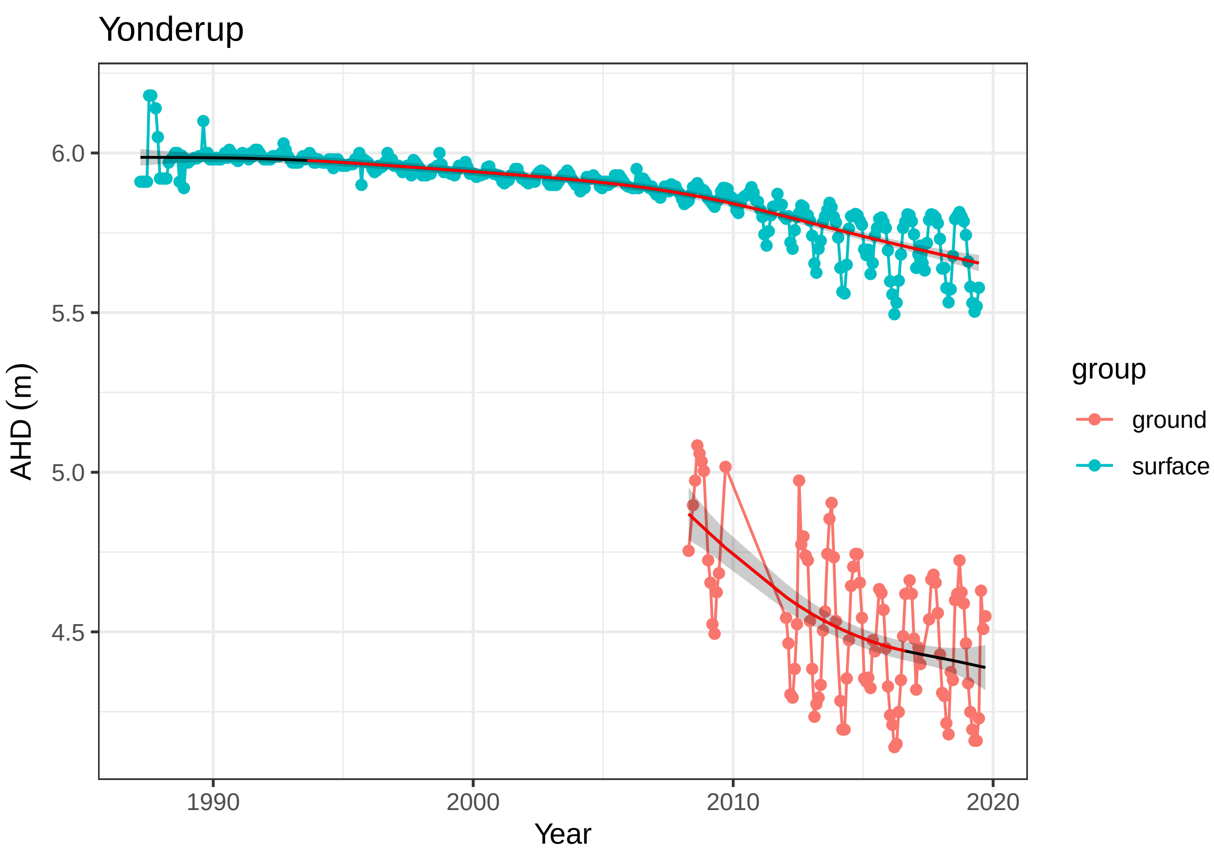

Figure 59: Ground and surface water levels recorded at bores and staff gauges in the vicinity of Yonderup

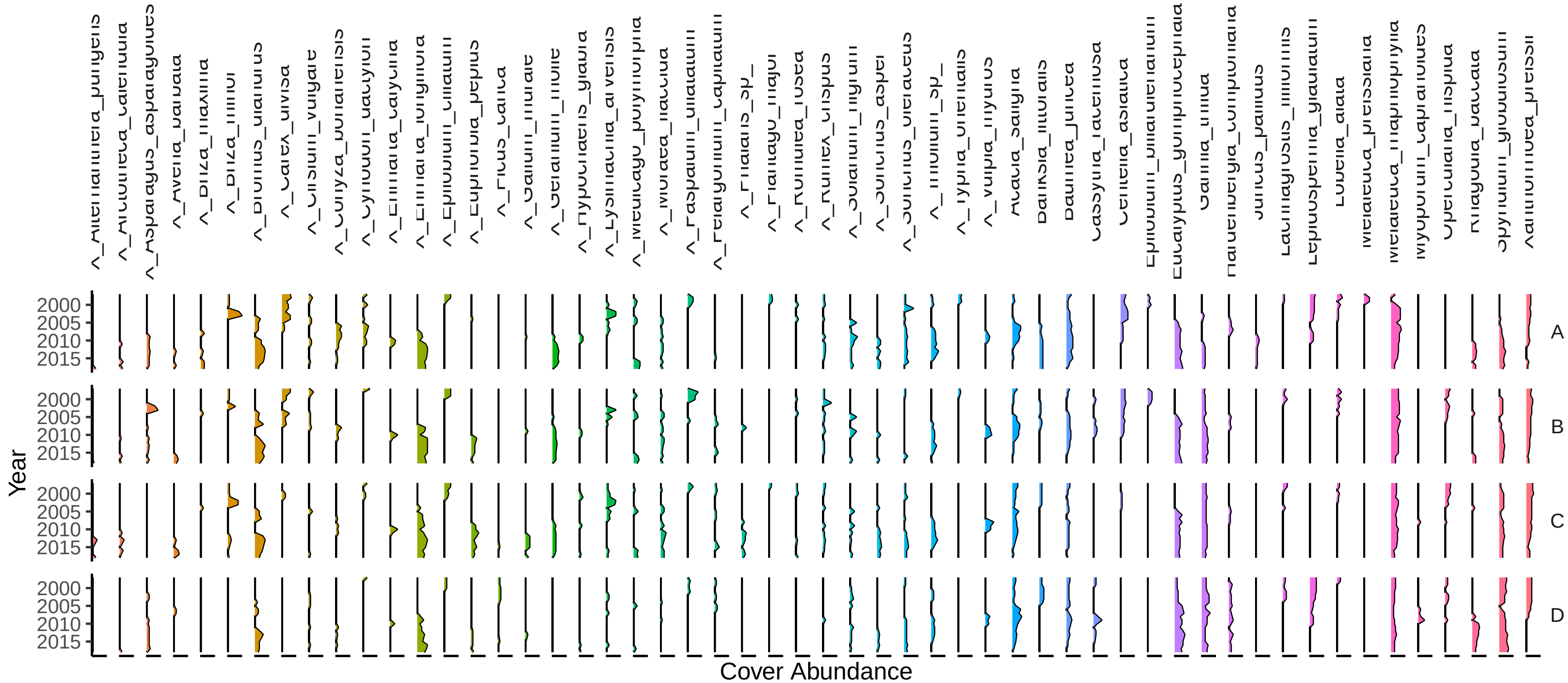

Figure 60: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Yonderup transect. Invasive species are denoted by ‘X’. Only the most common species are included.

Summary

Overview

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References

#AppendiX

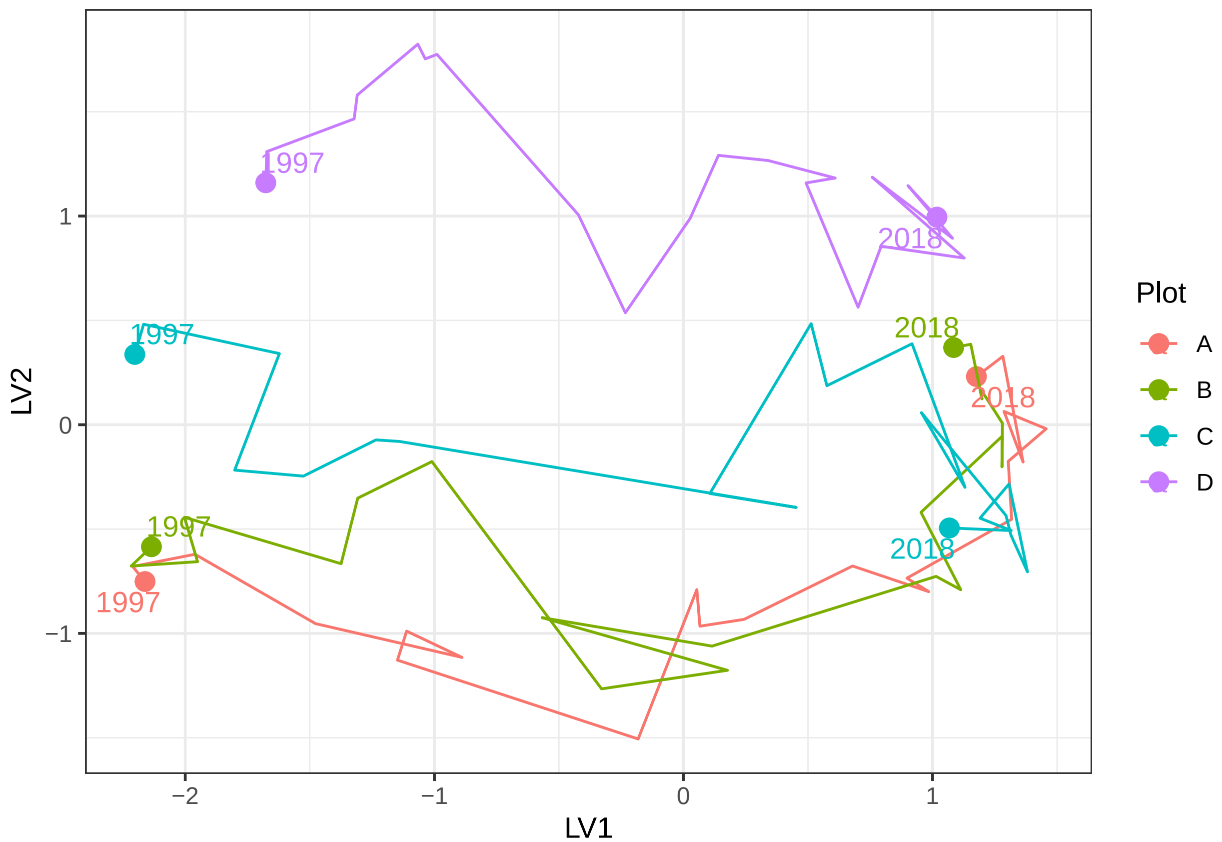

Figure 61: Ordination plot with full residual model on the left and a model on the right showing residual variation after the effect of groundwater levels were accounted for

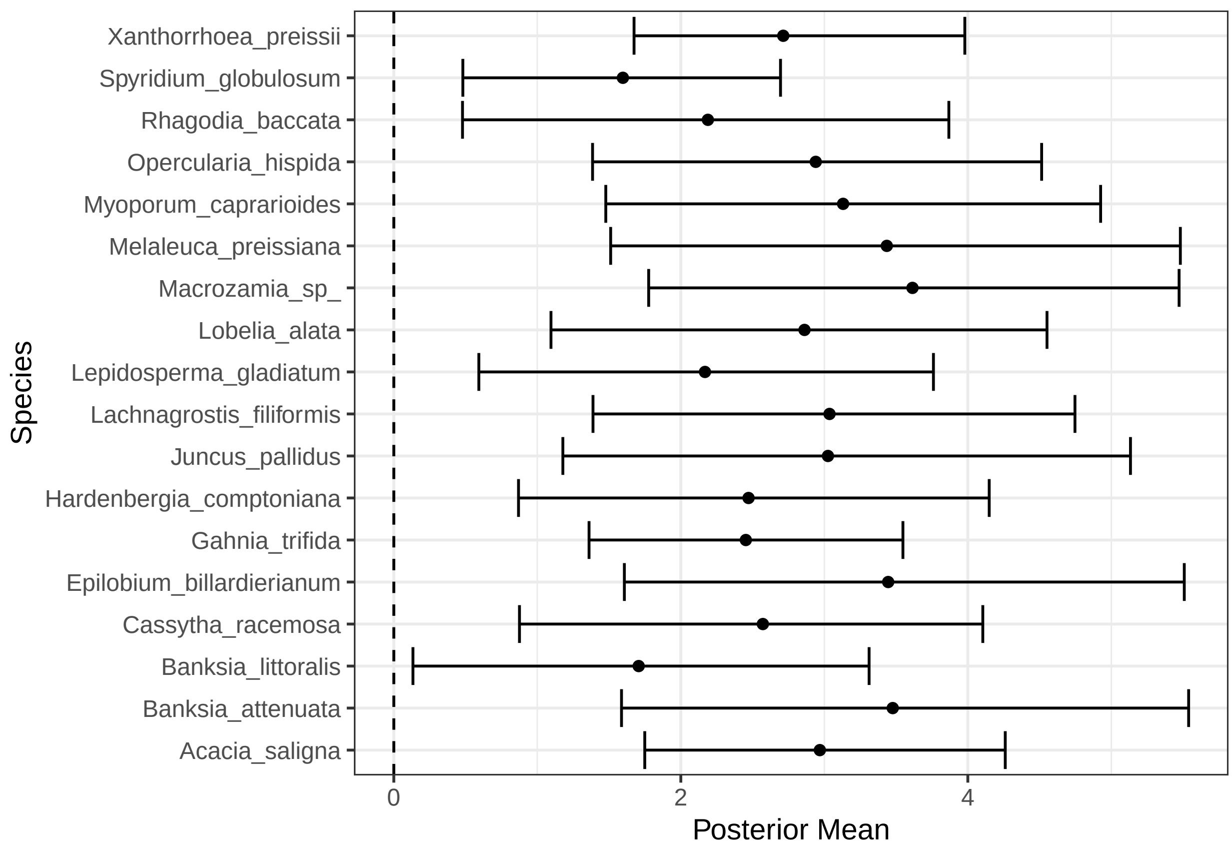

Figure 62: Mean regression coefficients (dots) and 95% credible intervals (bars) for effect of groundwater level on vegetation species cover abundances. Only those species with coefficients significanlty different to zero are shown