Review of Water Thresholds - Gnangara

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September 18 2019

Executive Summary

[SUMMARY TABLE OF OUTCOMES]

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)

[OUTLINE OF REPORT STRUCTURE]

[TABLE OF WETLANDS <- THE DUNE COMPLEX THEY BELONG TO, WHETHER VEG/INVERT MONITORING, COORDINATES]

Methods

[VEG MONITORING - LIST OF RECENT REPORTS]

[INVERT MONITORING]

[STATISTICAL METHODS USED IN THIS REPORT]

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). Normally, the site represents a permanently filled lake that is fed from a series of springs along the western margin of the basin [Invert REPORT & FROEND ref]. 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 in recent decades, 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). Surface water level measurements are now unreliable at staff 6162628 due to water levels usually being below the minimum level of the staff. 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 (2014-2019) suggests that ground waters are reaching annual minimums earlier in the year than in previous seasons.

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.

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

COMMENT ON REVISED WATER THRESHOLDS HERE> WHAT ARE THE PREDICTIONS> HOW WILL IT IMPACT VEG AND INVERTS. OTHER IMPACTS. MANAGMENT OBJECTIVES?

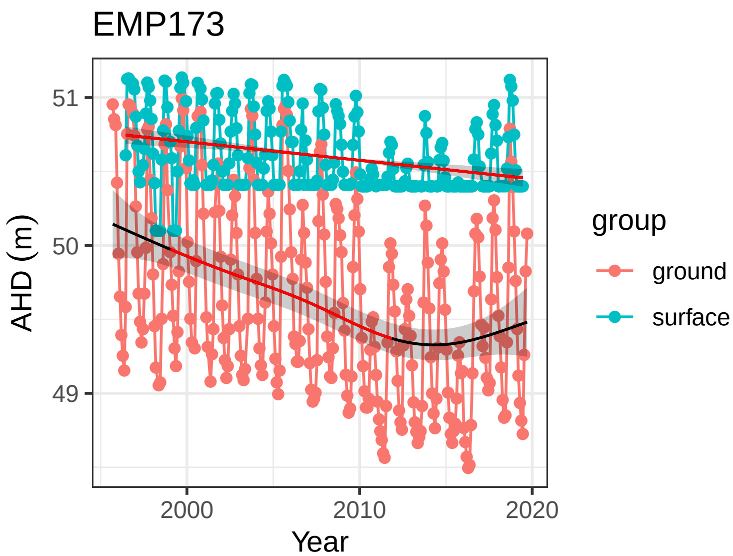

Figure 1: Ground and surface water levels for Melaleuca Park 173 recorded at bore 61613213 (red) and staff 6162628 (blue). The minimum recordable water level for the staff gaugue is 50.4 mAHD. Blue dots at 50.4 mAHD represent water levels below the minimum level measurable by the staff. Red segments on fitted line represent statistically significant periods of declining water levels.

Table 1: Five year summaries of ground water level data at Melaleuca Park 173. Data is based from bore 61613213 due to many readings on surface water staff 6162628 being below the minimum reading level of 50.4 mAHD.

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

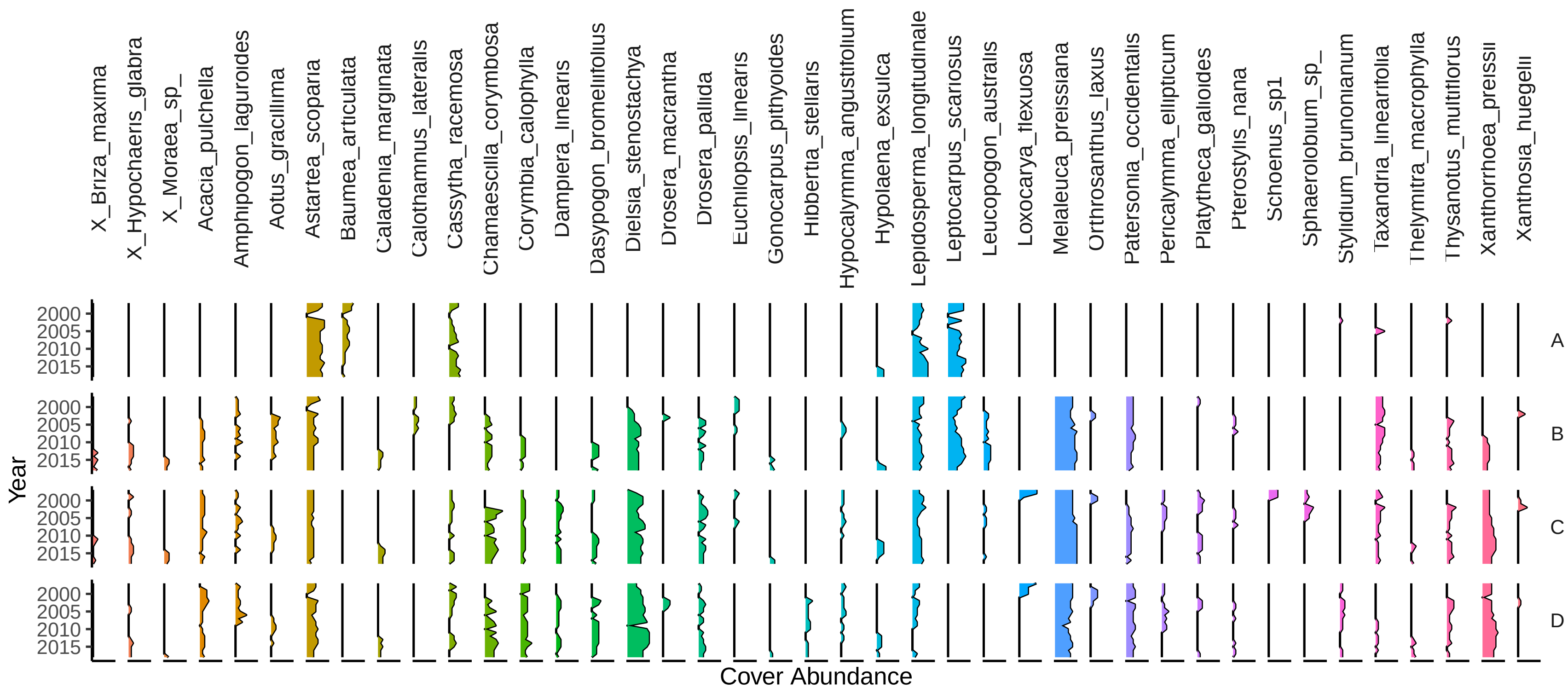

Figure 2: Cover abundances for each species across the four plots (A, B, C, D) at the Melaleuca Park 173 transect recorded for the survey period. Invasive species are denoted by 'X'. Only the most common species are included.

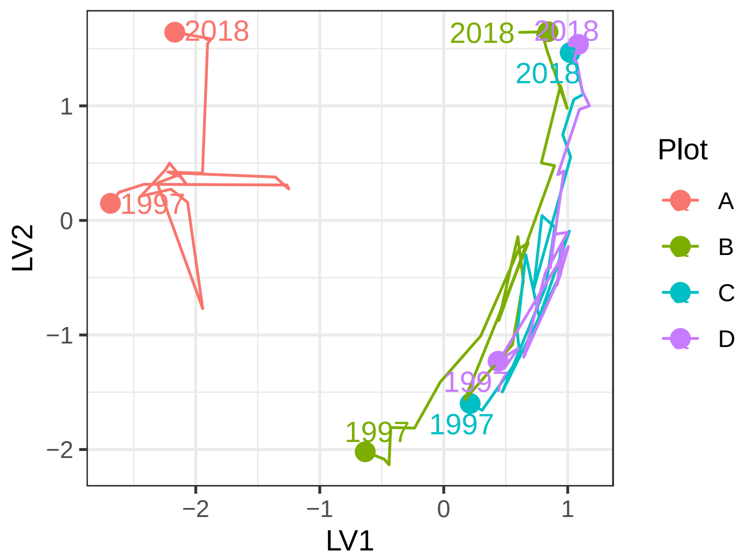

Figure 3: Unconstrained ordination based on the latent variable model for each surveyed year for Melaleuca Park 173. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

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

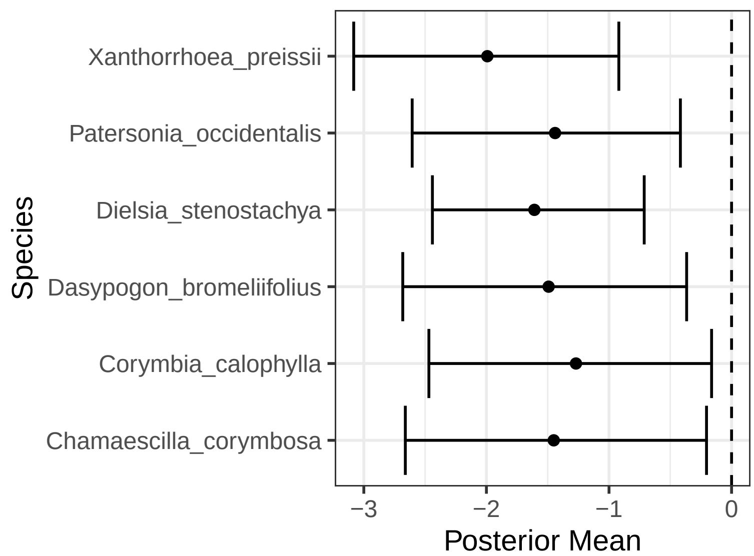

Figure 4: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Melaleuca Park 173 on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline. Only those species with coefficients significanlty different to zero are shown.

Melaleuca Park 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 inundated 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 provides important habitat for 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 occurring in October/November and minimums occurring between April-May (Table 3).

Vegetation dynamics

The vegetation transect has been monitored at Melaleuca Park 78 since 1997 and was last surveyed in 2018 (Figure 6). The site is largely dominated by native species that include a dense understorey of *Beaufortia elegans*, *Pultenea reticulata* and *Kunzea glabrescens*. The overstorey is largely composed of *Melaleuca preissiana* throughout the transect 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 the vegetation 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, particularly for low-lying stands of

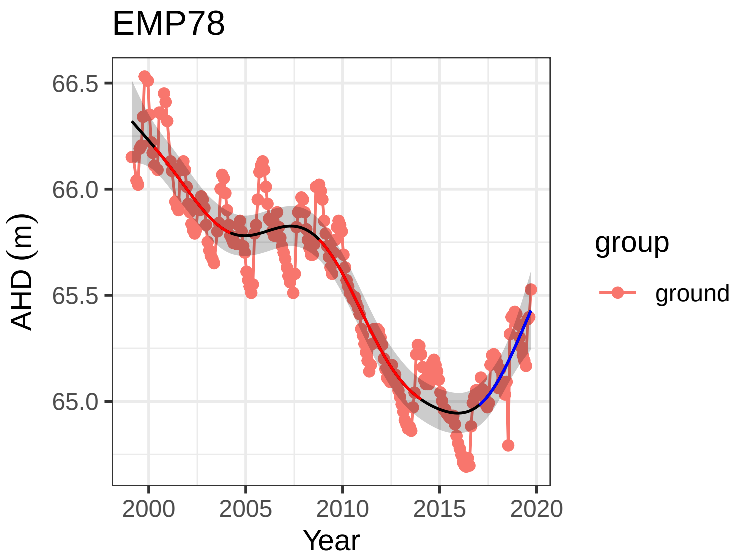

Figure 5: Ground water levels recorded at bore 61613231 in the vicinity of the Melaleuca Park 78 wetland. Red segments on fitted line represent statistically significant periods of decline and blue represent statistically significant periods of increasing water levels.

Table 3: Five year summaries of ground water level data at Maleleuca Park 78 recorded at 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

M. preissiana. Trajectories of compositional change provide further evidence for post-fire recovery as recent plot assemblages are becoming more similar to those recorded before the fire (Figure 7).

Bayesian regression modelling revealed a number of species associated with low ground water levels (Figure 8). In particular, some natives, including *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 withd declining ground waters. It is also likely that the richness of exotic species will increase with ground water decline as the site is invaded by exotics not currently recorded at the site.

Aquatic invertebrates

Revised water level threshold effects

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

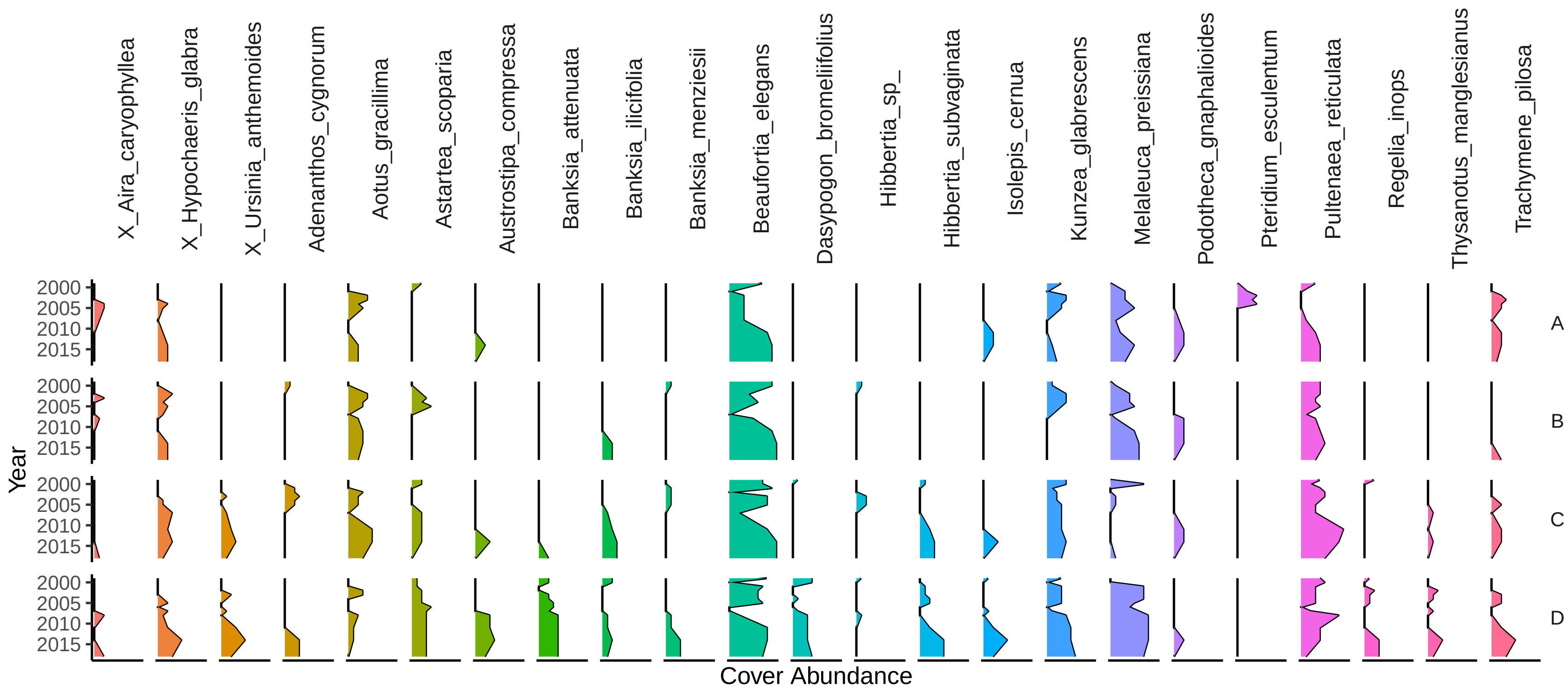

Figure 6: Cover abundances for each species across the four plots (A, B, C, D) at the Melaleuca Park 78 transect. Invasive species are denoted by 'X'. Only the most common species are included.

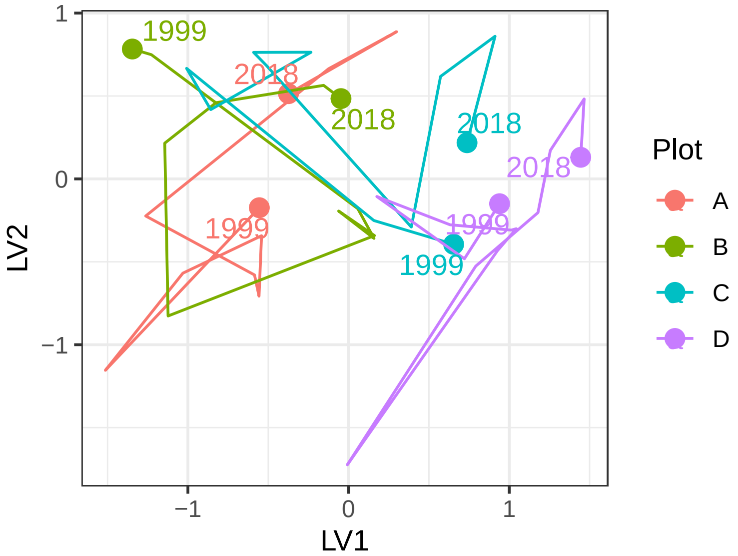

Figure 7: Unconstrained ordination based on the latent variable model for each surveyed year for Melaleuca Park 78. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

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 Complia
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		

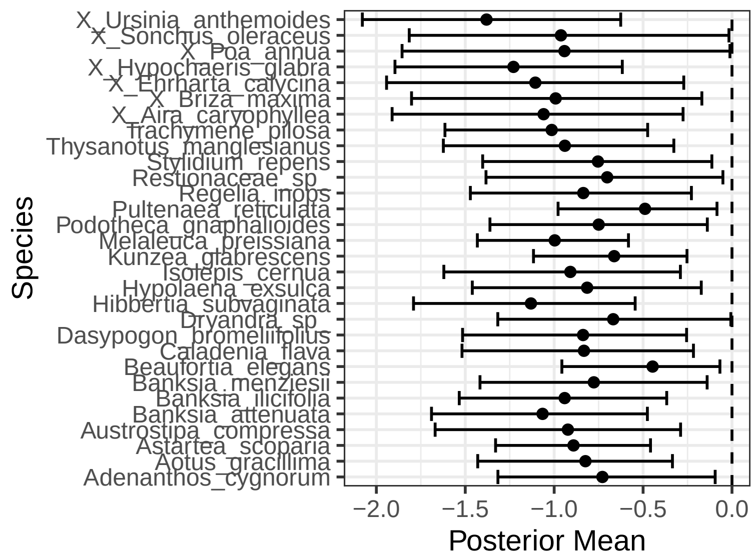

Figure 8: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Melaleuca Park 78 on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline. Only those species with coefficients significanlty different to zero are shown.

Table 5: Five year summaries of ground 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. [WHAT IS THIS SITE? A DAMPLAND< SUPALND LAKE ETC? THERE MUST BE SOME MORE INFORMATION I CAN INCLUDE]

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 occurring earlier in the year than in between 1994 and 1999 (Table 5).

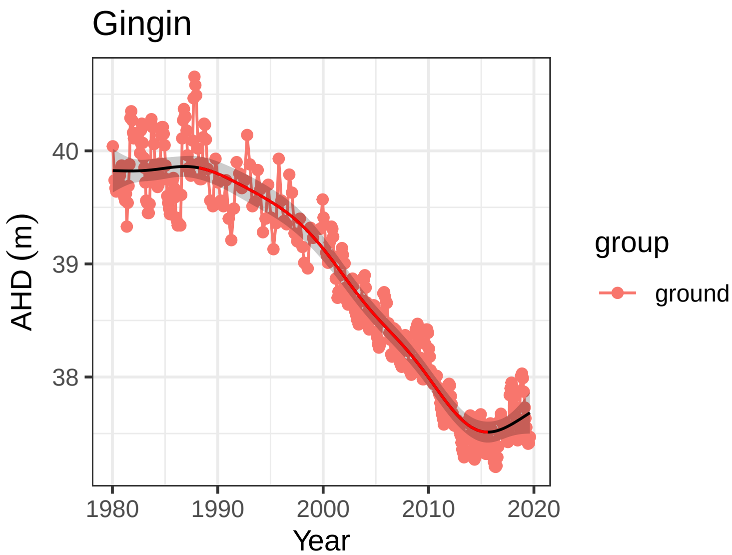

Figure 9: Ground water levels recorded at bore 61710078 that represent fluctuations in ground waters at Gingin Brook. Red segments on fitted line represent statistically significant periods of declining ground water levels.

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. [COMMENT ON SURROUNDING URBANISATION?]

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 acidification of waters in 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 along an established transect [I NEED TO READ THE 2014 VEG REPORT]. Plot A represents fringing *Melaleuca rhaphiophylla*/*Eucalyptus rudis* vegetation 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).

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

Ordination reveals that Plot A has a distinct assemblage to the other plots but has displayed similar shifts in vegetation composition during the monitoring period (Figure 12). 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. Bayesian regression analysis predicts many species to increase in cover abundance with declining surface water levels, while *B. articulata* is predicted to decrease significantly in cover abundance (Figure 13). Native species thought to increase in cover abundance 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 only increase slightly. Many exotic species are likely to increases in cover abundance under a scenario of declining surface waters, including *Briza maxima*, *Fumaria capreolata*, *Setaria palmifolia* and *Sparaxis bulbifera*.

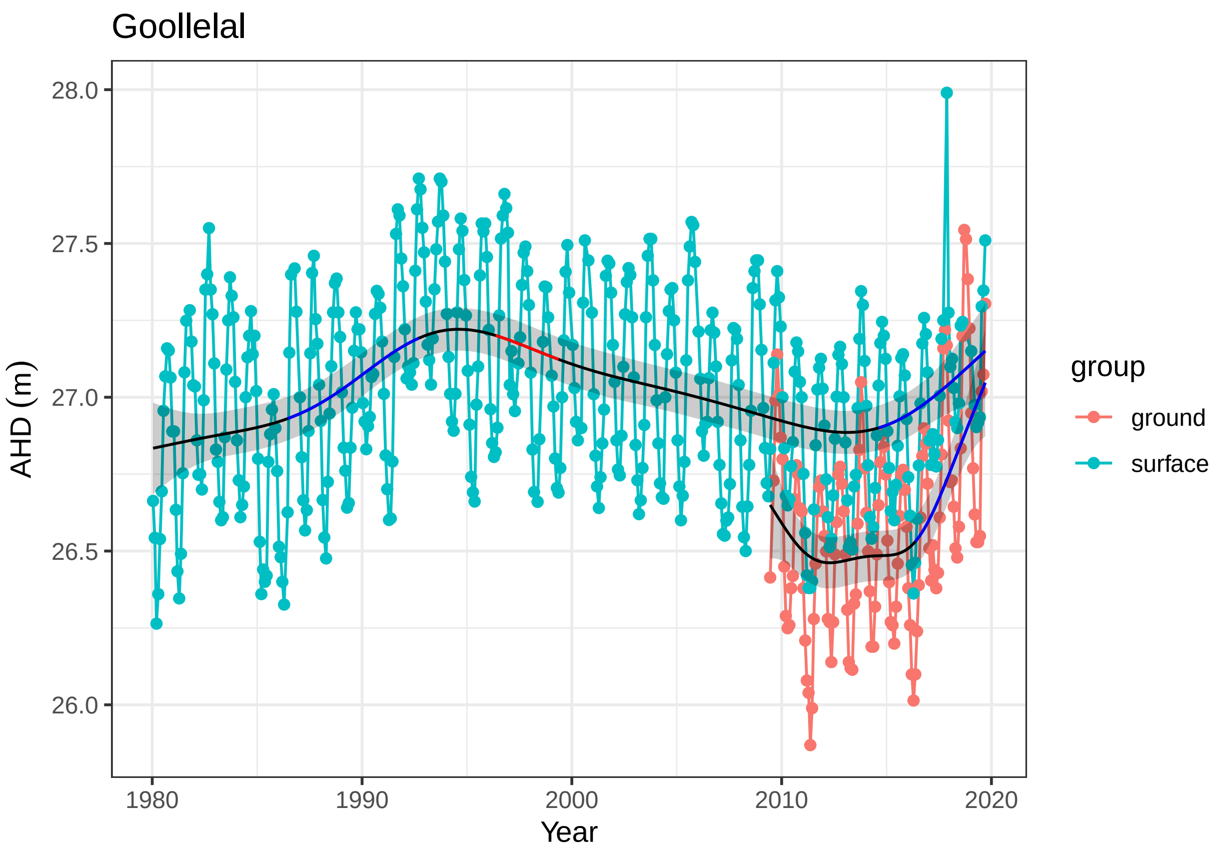

Figure 10: Ground and surface water levels recorded at bore 61611870 (red) and staff 6162517 (blue) for Lake Goollelal. Red segments on fitted line represent statistically significant periods of declining water levels and blue segments represent statistically significant periods of increasing water levels.

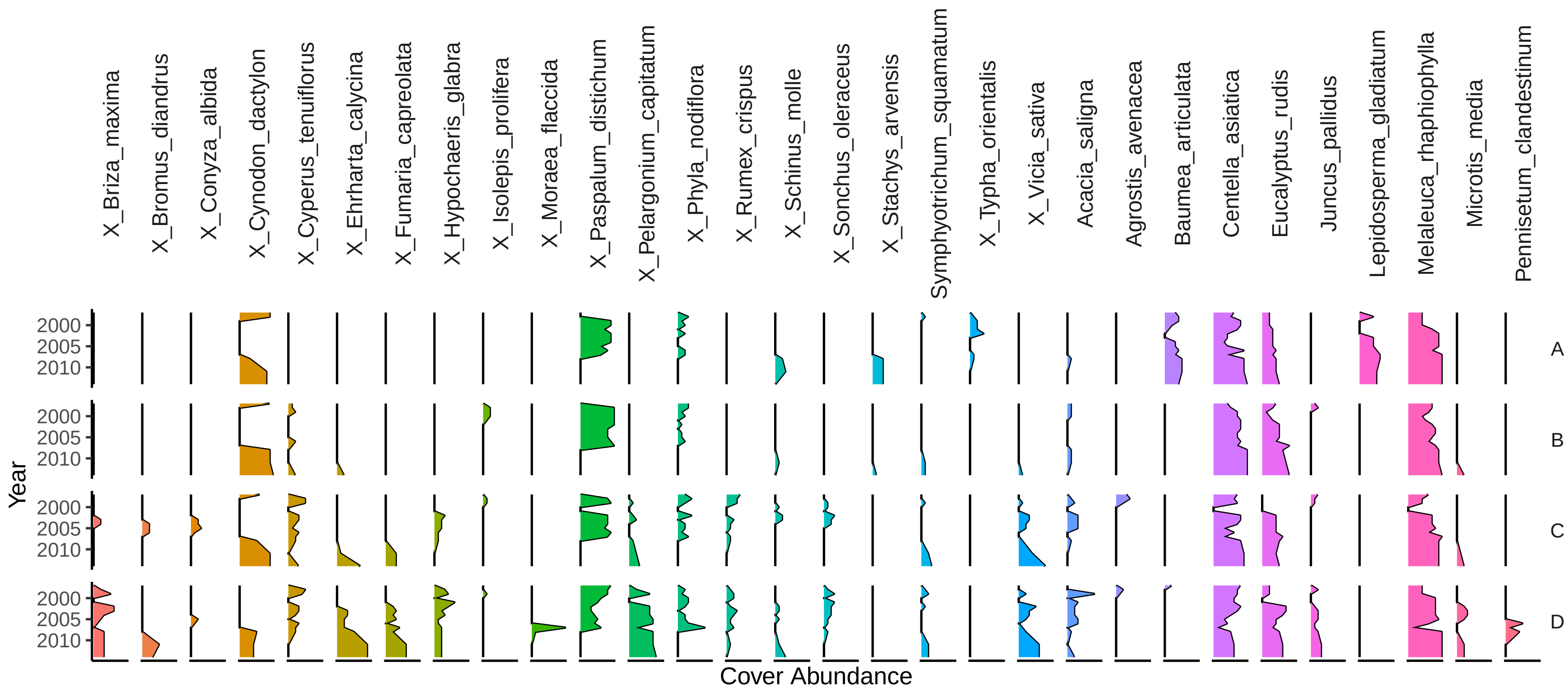

Figure 11: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Goollelal transect. Invasive species are denoted by 'X'. Only the most common species are included.

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		

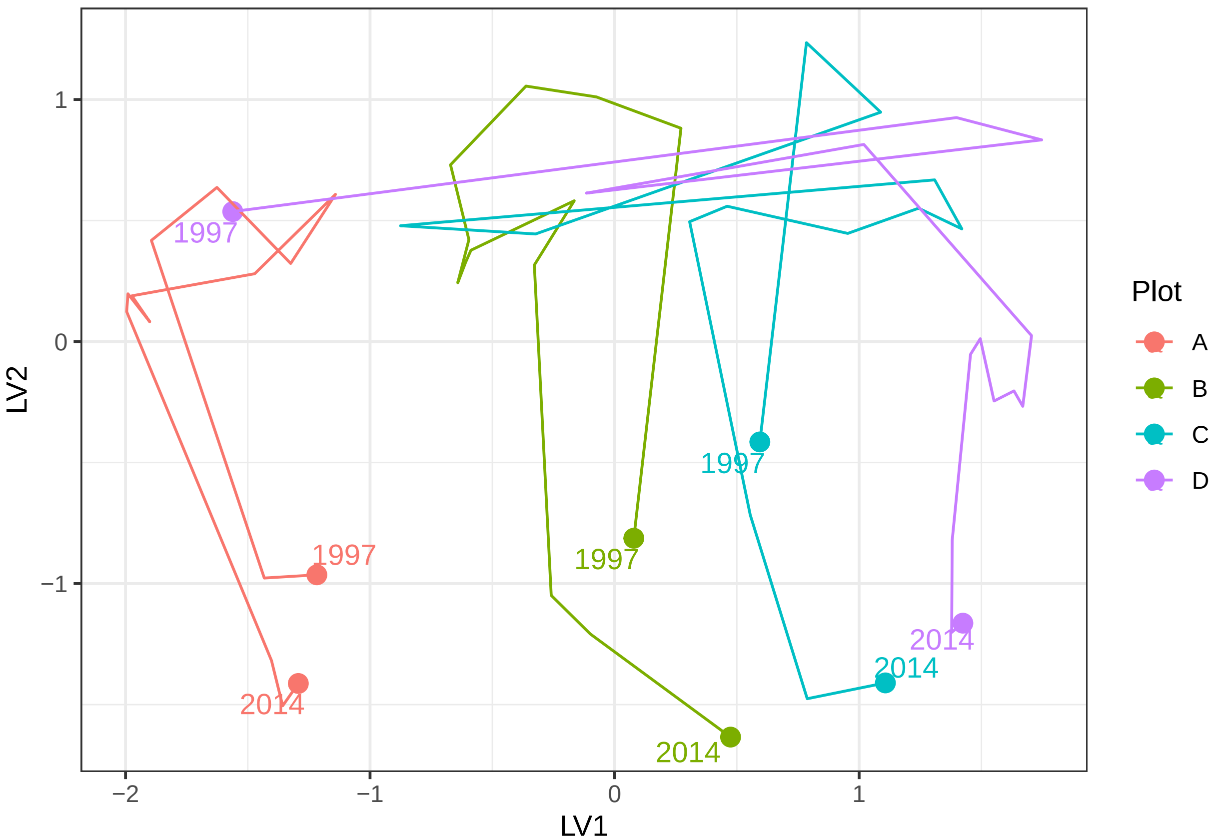

Figure 12: Unconstrained ordination based on the latent variable model for each surveyed year for Lake Goollelal. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

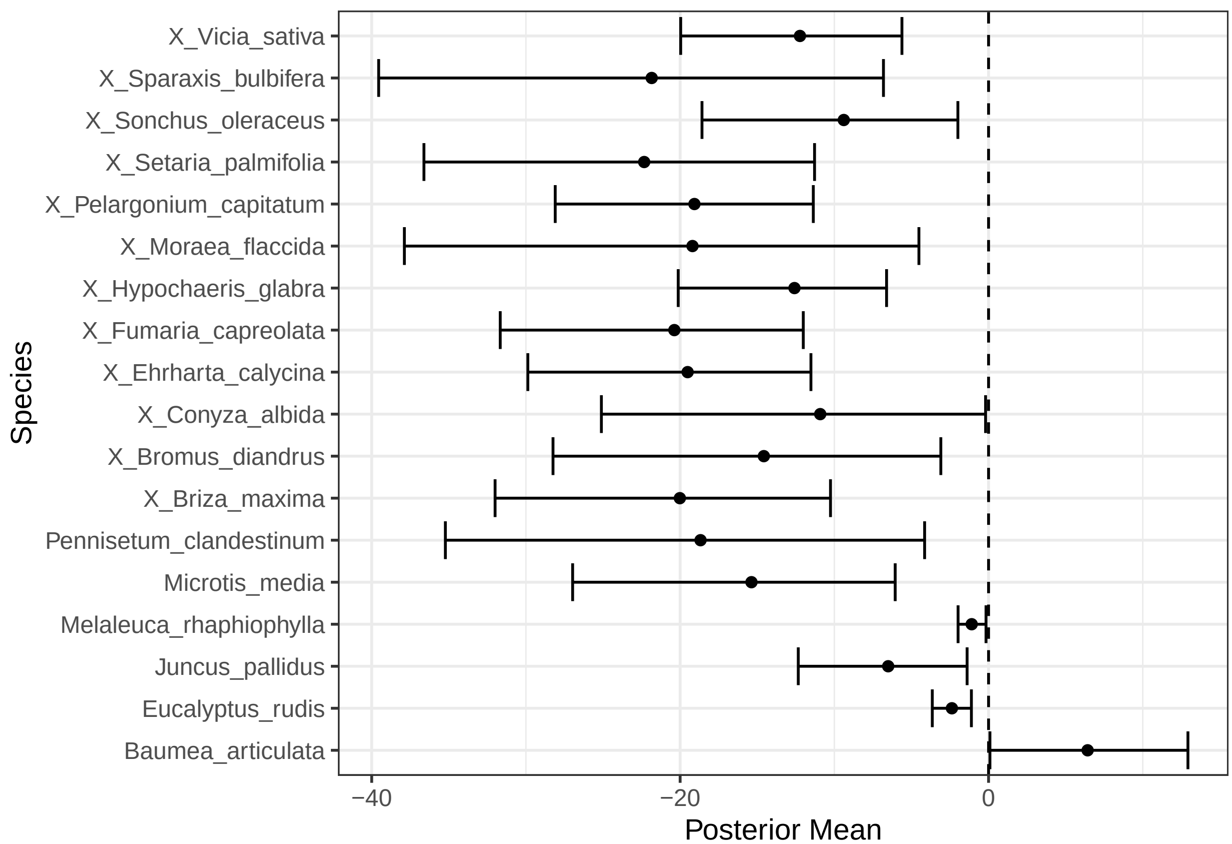

Figure 13: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Melaleuca Park 78 on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline while species with positive posterior values are likely to increase in cover abundance with increasing water levels. Only those species with coefficients significanlty different to zero are shown.

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

Lake Gwelup

Lake Gwelup is a shallow groundwater system located in the highly urbanised area of Gwelup/Karrinyup. The lake is permanently inundated and provides important habitat to a variety of fauna and fringing vegetation. The wetland is not currently a Ministerial criteria site.

Hydrology

Lake water levels were first monitored in 1960, but regular monitoring has occurred between 1967 and 1988, and from 1999 until the present. Lake levels in the 1970s and 1980s were 1m to 2m higher than in the 2000s (Figure 14). They have risen again since 2013 following a reduction in nearby public water supply abstraction, and levels are currently similar to levels in the 1980s and 1990's (Table 8). Nearby bore 61610032 has been monitored since 1972. Water levels at the bore have declined by around 4 meters since the start of monitoring. Levels have been reasonably stable since the early 2000s and have trended slightly upwards since 2011.

Vegetation dynamics

Vegetation monitoring at Lake Gwelup began in 2013 and was last conducted in 2017. The start of the transect was inundated by approximately 0.7 m of surface water during the 2017 survey. The wetland is dominated by exotic species such as *Cynodon dactylon* and *Ehrharta calycina* despite exotic cover abundance declining in the later surveys (Figure 15). The overstorey is dominated by the natives *Eucalyptus rudis* and *Maleleuca rhaphiophyla* which is in good health (BULLER REPORT 2017). There was a dramatic shift in community composition between 2014 and 2017 due to inundation of the plots (Figure 16). Bayesian regression analysis reveals that a number of exotic species will continue to decrease in cover abundances with the higher water levels (Figure **??**).

Revised water level threshold effects

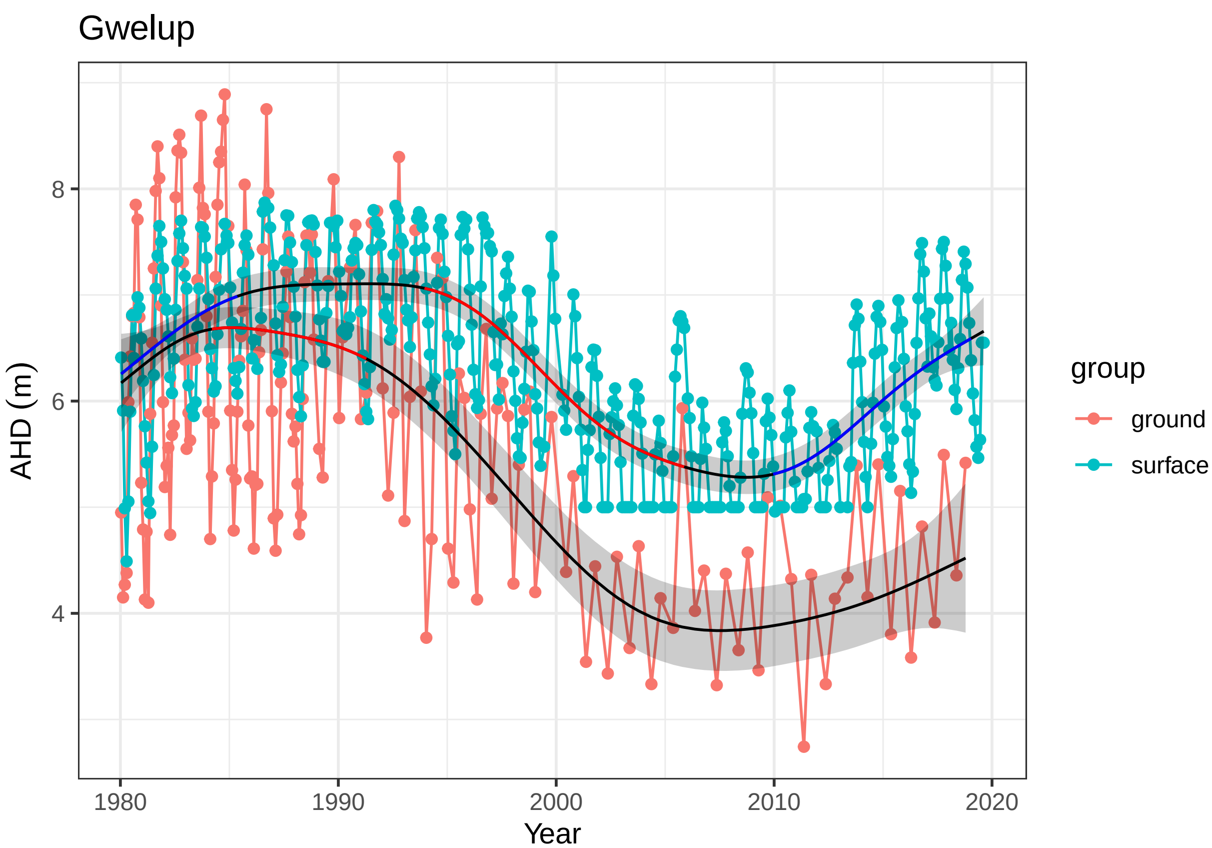

Figure 14: Ground and surface water levels for Lake Gwelup recorded at bore 61610032 (red) and staff 6162504 (blue). The minimum recordable water level for the staff gaugue is 5.0 mAHD. Blue dots at 5.0 mAHD represent water levels below the minimum level measurable by the staff. Red segments on fitted line represent statistically significant periods of decline and blue represent statistically significant periods of increasing water levels.

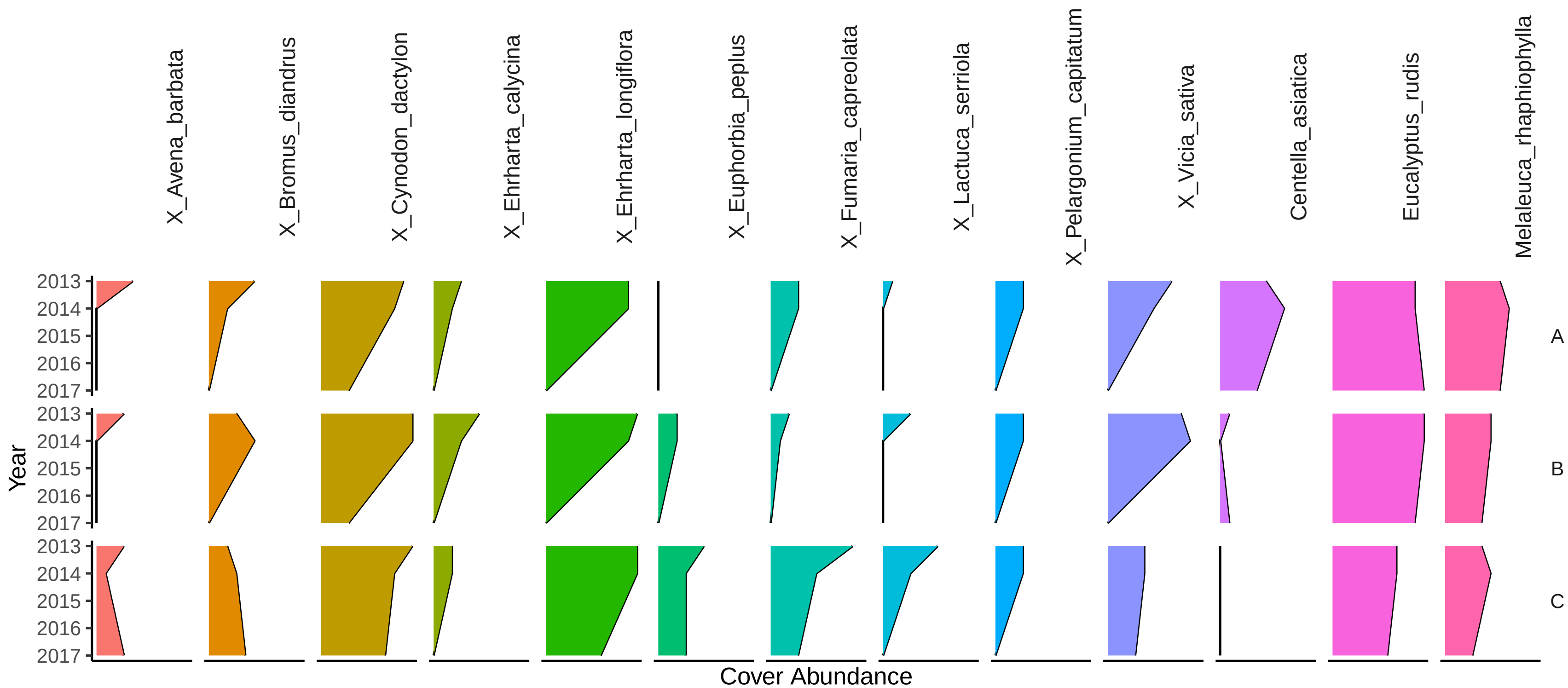

Figure 15: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Gwelup transect. Invasive species are denoted by 'X'. Only the most common species are included.

Table 9: 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 management objectives * To maintain permanent water for fauna habitat and for visual amenity, to maintain fringing vegetation.		

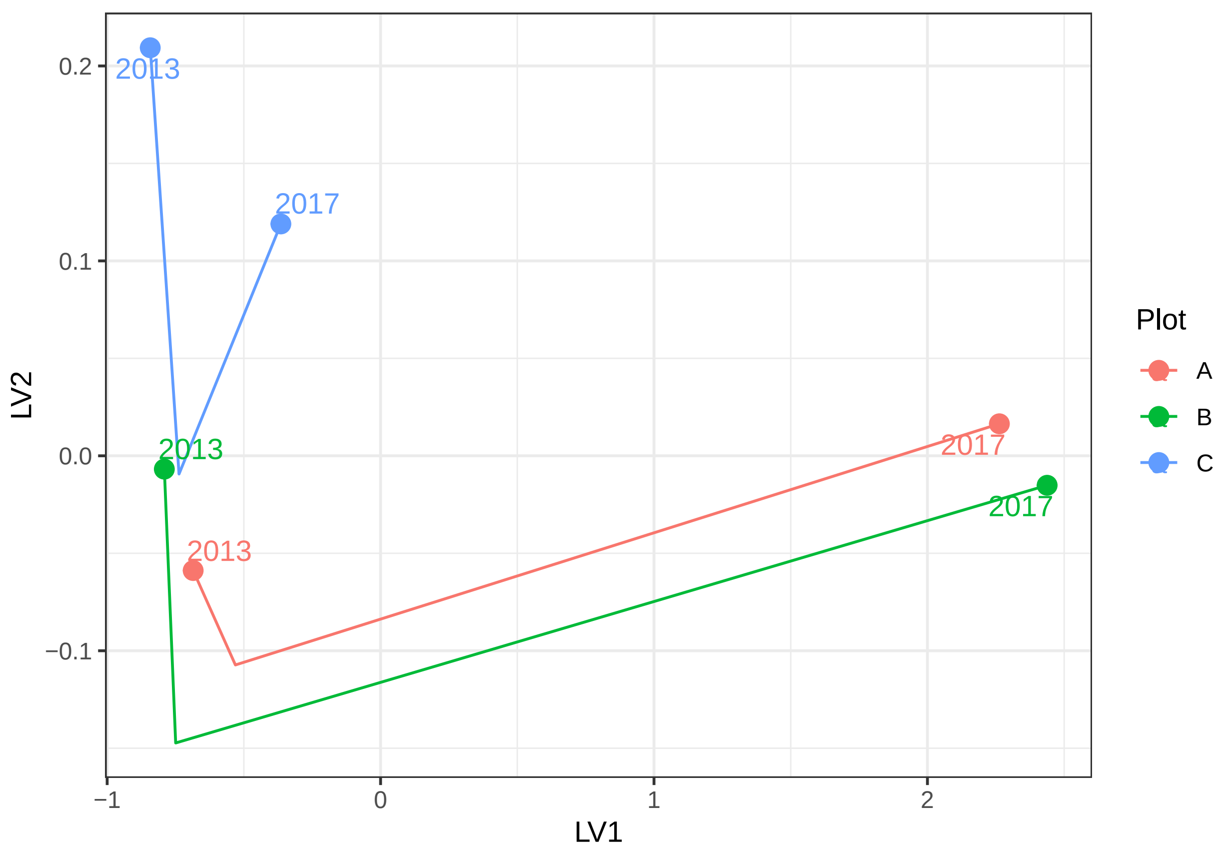

Figure 16: Unconstrained ordination based on the latent variable model for each surveyed year for Lake Gwelup. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

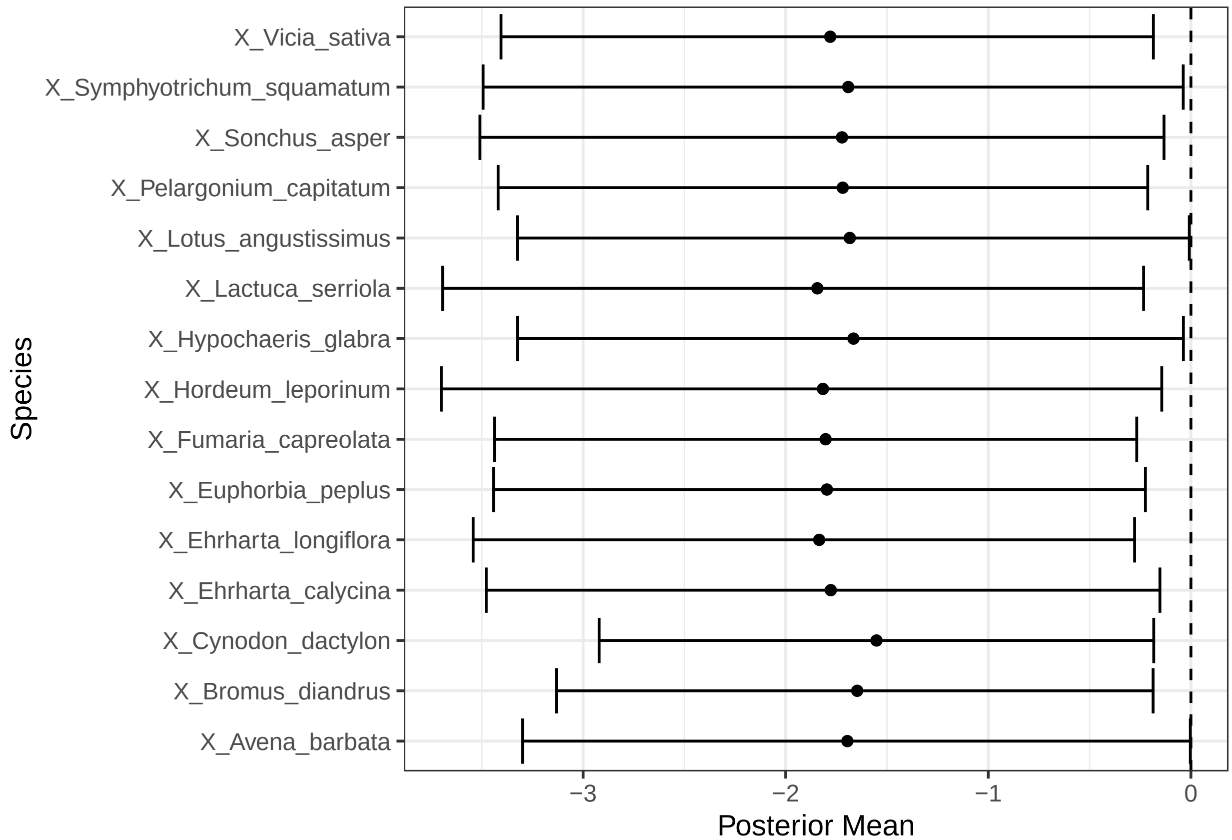

Figure 17: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Lake Gwelup on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline. Only those species with coefficients significanlty different to zero are shown.

Table 10: Five year summaries of surface water level data at Lake 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

Lake Jandabup

Lake Jandabup is an artificially watered wetland that supports the most diverse sedge and macrophyte vegetation communities in the Bassendean Dune wetlands (FROEND 2004). Low rainfall and groundwater abstraction impacts are thought to have caused an acidification event in 1998 and 1999 but restoration of water levels as returned the pH to normal levels (GMEMP 2019). Lake Jandabup has a high conservation value as it is one of the few 'eastern circular wetlands' to not be be permanently acidic. The waters usually have low levels of nutrients which and clear waters that supports a diverse aquatic invertebrate community. The abundance of invertebrates and fringing vegetation habitats also allow the wetland to support high numbers of resident and visiting water birds (BAMFORD AND BAMFORD 2003 - See chap 5).

Hydrology

Surface water levels of Lake Jandabup have only declined slightly since 1980 (Figure 18). Mean maximum seasonal water levels are now 0.2m lower than in 1994-1999 but mean minimum seasonal water levels are 0.1m higher than 1994-1999 levels and since 2009, the period of annual maximum to minimum water levels has increased (Table 10).

Vegetation dynamics

The Lake Jandabup wetland consists of a diverse community of native vegetation. In the 2017-2018 season, 43 native species were recorded with only 14% of the total cover abundance belonging to exotic species (BULLER 2018 VEG REPORT). There are four overstorey species present at the wetland, including *Banksia attenuata*, *Banksia ilicifolia*, *Banksia menziesii*, *Eucalyptus rudis* and *Maleleuca preissiana* (Figure 19), all of which have been increasing in health. A dense understorey of *A. scoparia*, *B. elegans* and *H. angustifolium* exists at plots A and B.

There has been a continual shift in community composition of Lake Jandabup throughout the monitoring period that reflects changes in invasive species cover abundances (Figure 20). A number of species are predicted to increase in cover abundance with increasing water levels, particularly *Euchilopsis linearis* which is present in the lower parts of the basin (Figure 21).

Aquatic invertebrates

Revised water level threshold effects

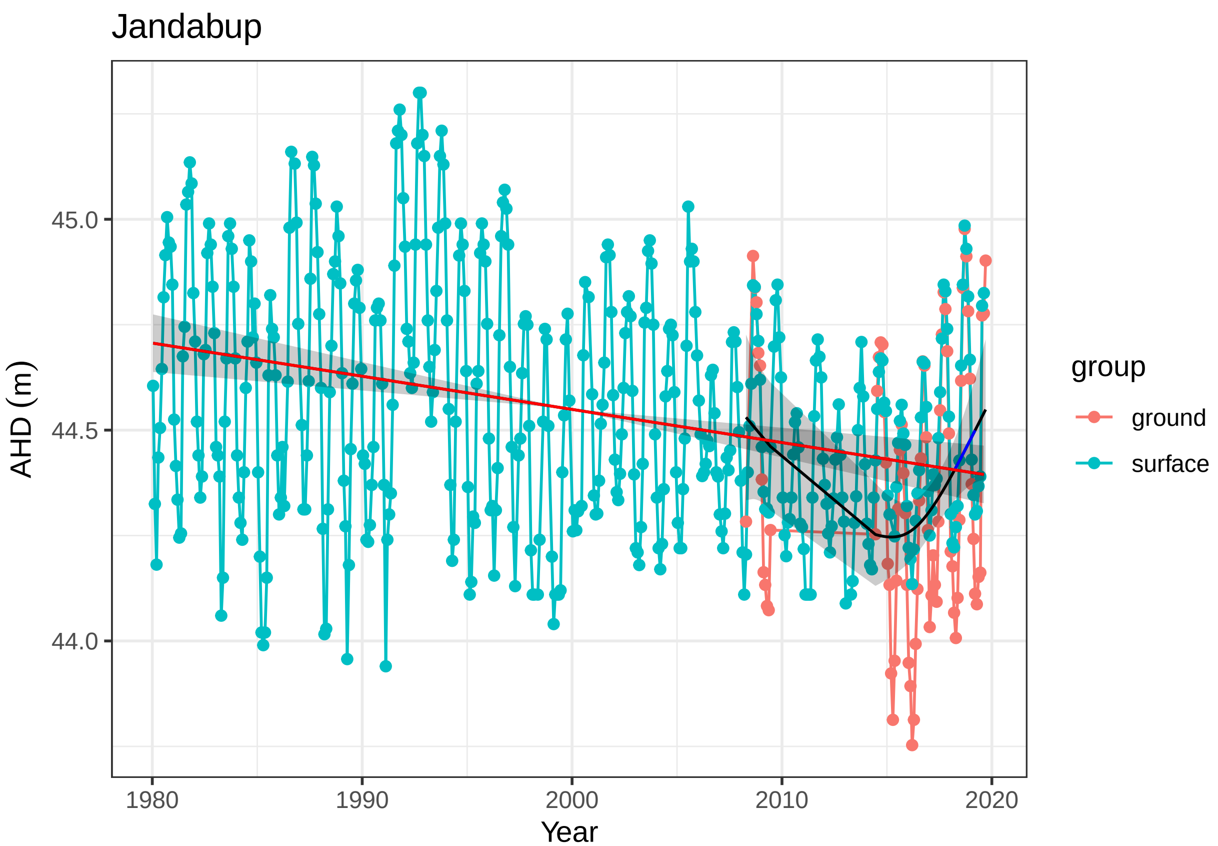

Figure 18: Ground and surface water levels for Lake Jandabup recorded at bore 61611850 (red) and staff 6162578 (blue). Red segments on fitted line represent statistically significant periods of declining water levels and blue segments represent periods of increasing water levels.

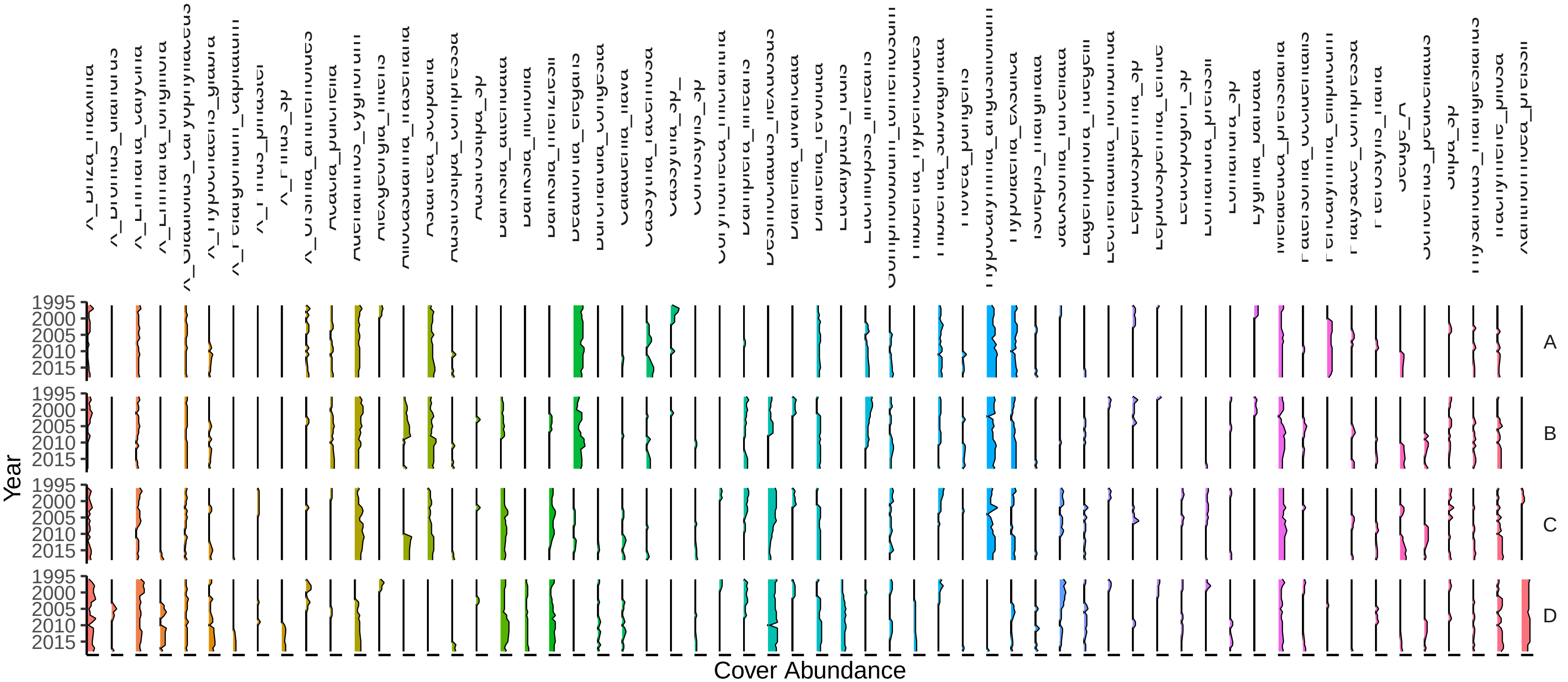

Figure 19: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Jandabup transect. Invasive species are denoted by 'X'. Only the most common species are included.

Table 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		
* Most diverse sedge and macrophyte vegetation of all Bassendean dune wetlands, including unusual species		
* Supports wide range of waterbirds, especially waders		
* Extremely good water quality with low nutrients		
Site management objectives		
* Conservation of flora and fauna		
* Maintenance of the current extent of wading bird habitat		
* No expansion in the areas of sedge vegetation, but maintenance of existing areas		
* Removal of mosquito fish from the lake		
* Maintenance of high species richness of aquatic macroinvertebrates, macrophytes and sedge vegetation		

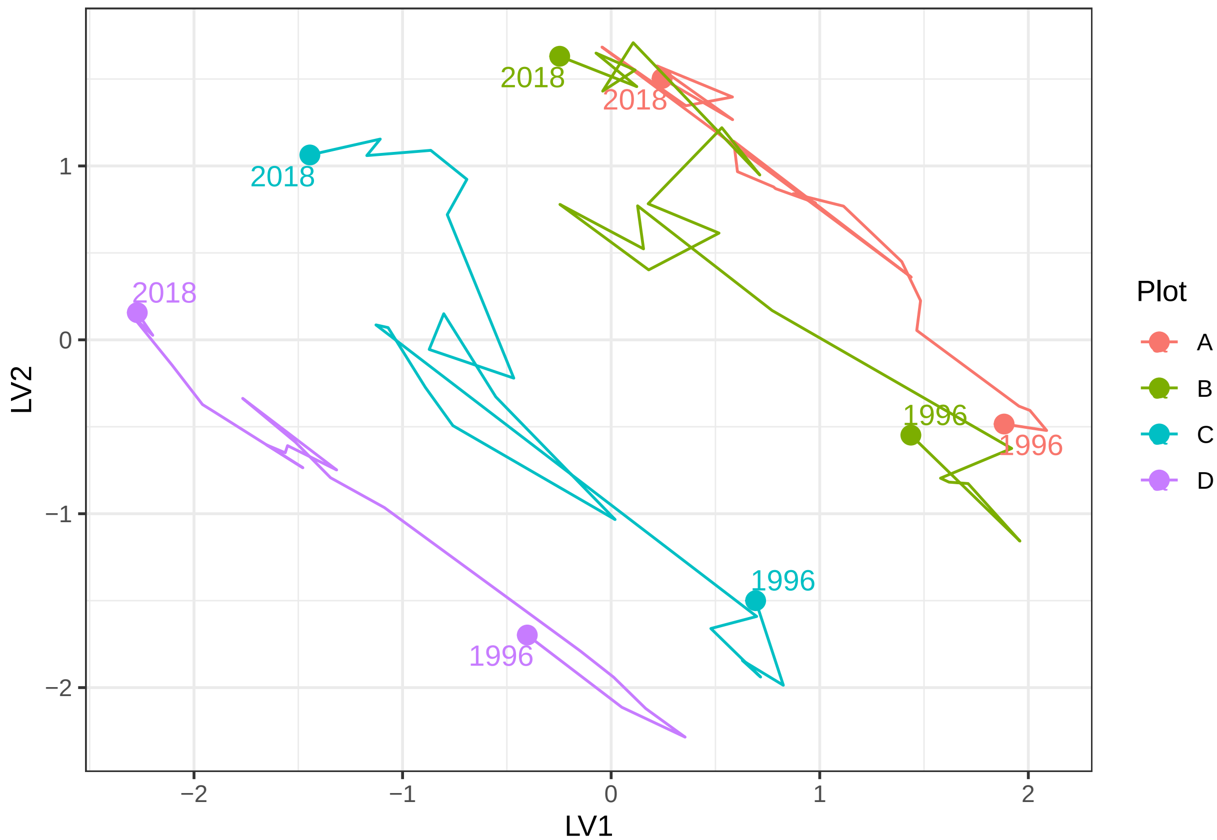

Figure 20: Unconstrained ordination based on the latent variable model for each surveyed year for Lake Jandabup. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

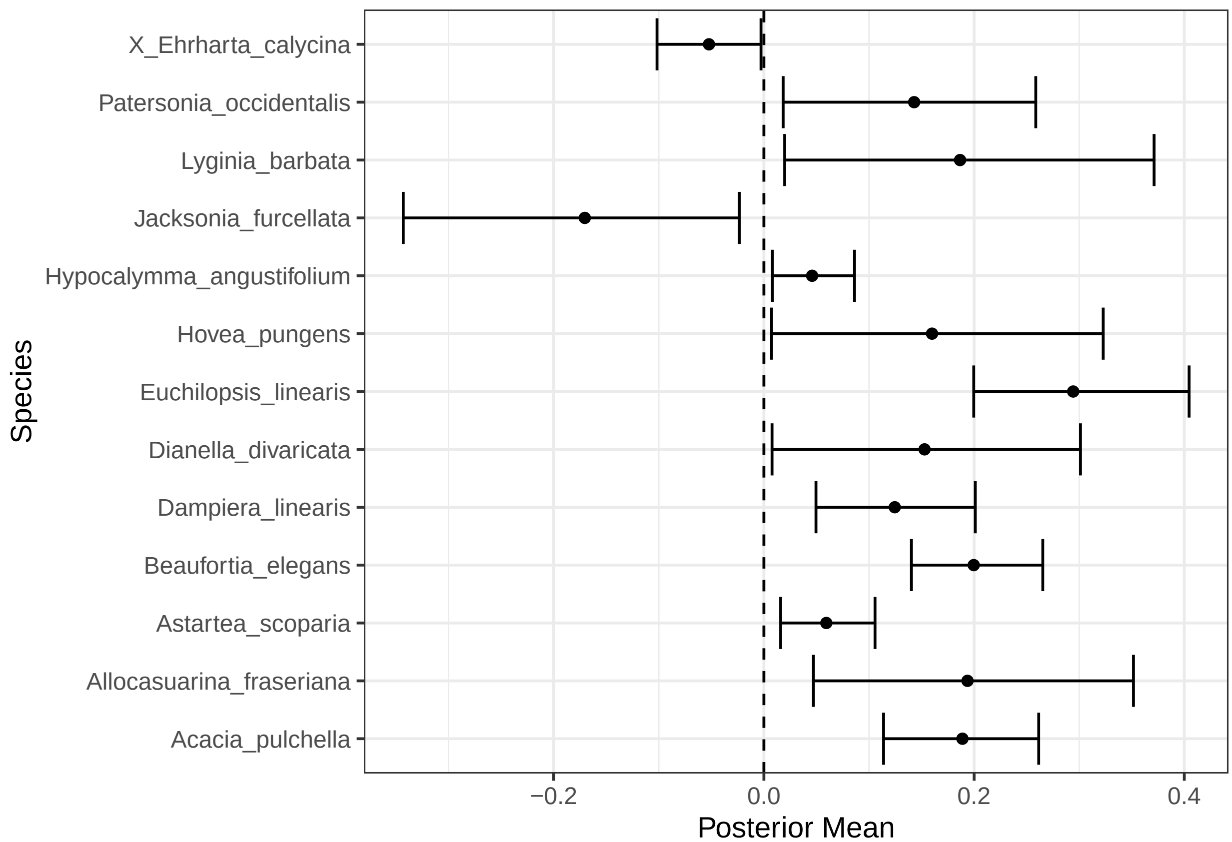

Figure 21: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Lake Jandabup on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline while species with positive values are likely to increase in cover abundance as water levels increase. Only those species with coefficients significanlty different to zero are shown.

Lake 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 22). 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 1990s. 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 12).

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 a northern (Figure 23) and southern (Figure 24) transect at Lake Joondalup. 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 periods (Figure 25). In the southern transect, latent model ordination reveals separation of the plots along the first axis, with a general temporal trend along the second axis, except for a period around 2003 - 2006 where there was a hiatus. This hiatus may be associated with the 2003 bushfire and represents a recovery period where species composition changed little. 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. Similar patterns have been observed in the northern transect despite the transect not being impacted by the 2003 fire event.

[DESCRIBE SPECIES ASSOCIATIONS WITH WATER LEVELS] (Figure 26)

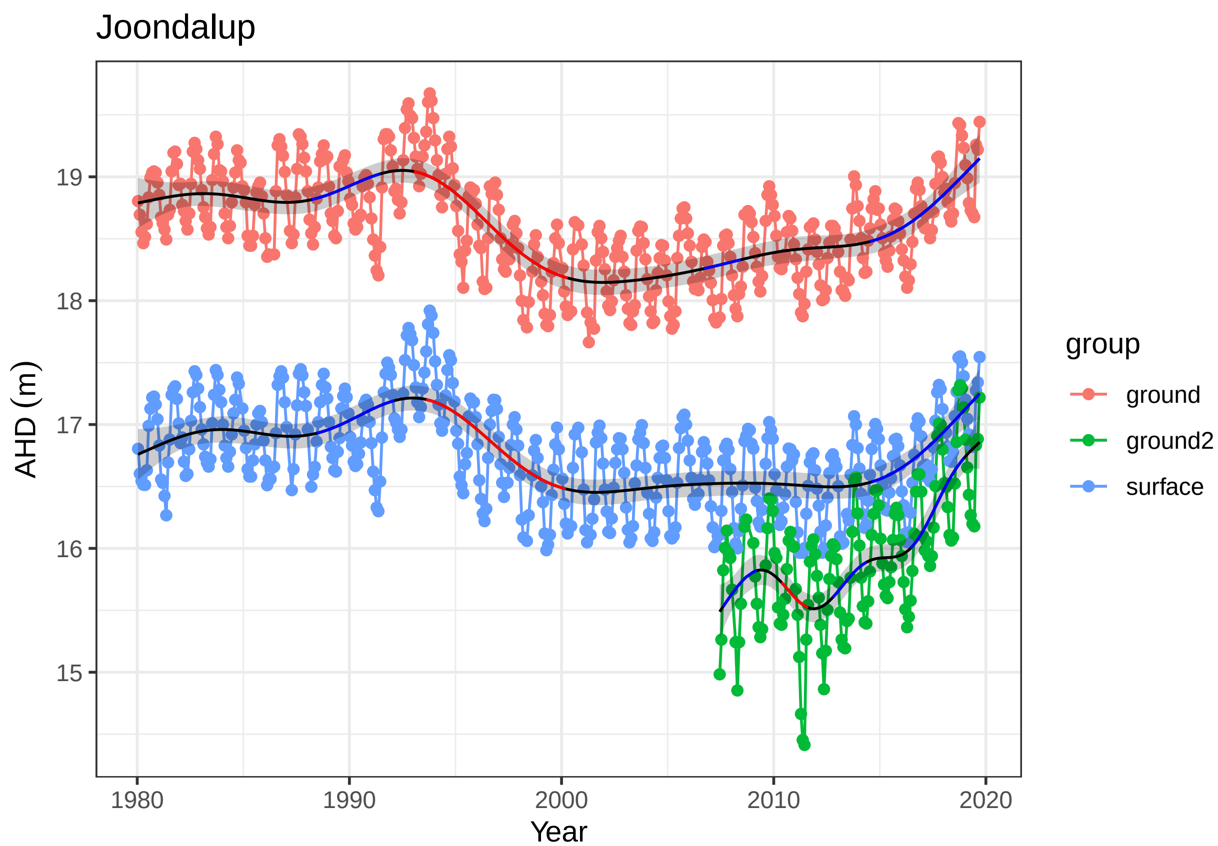

Figure 22: Ground and surface water levels recorded at bore 61610661 (red), bore 61611423 (green) and staff gauge 6162572 (blue) for Lake Joondalup.

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

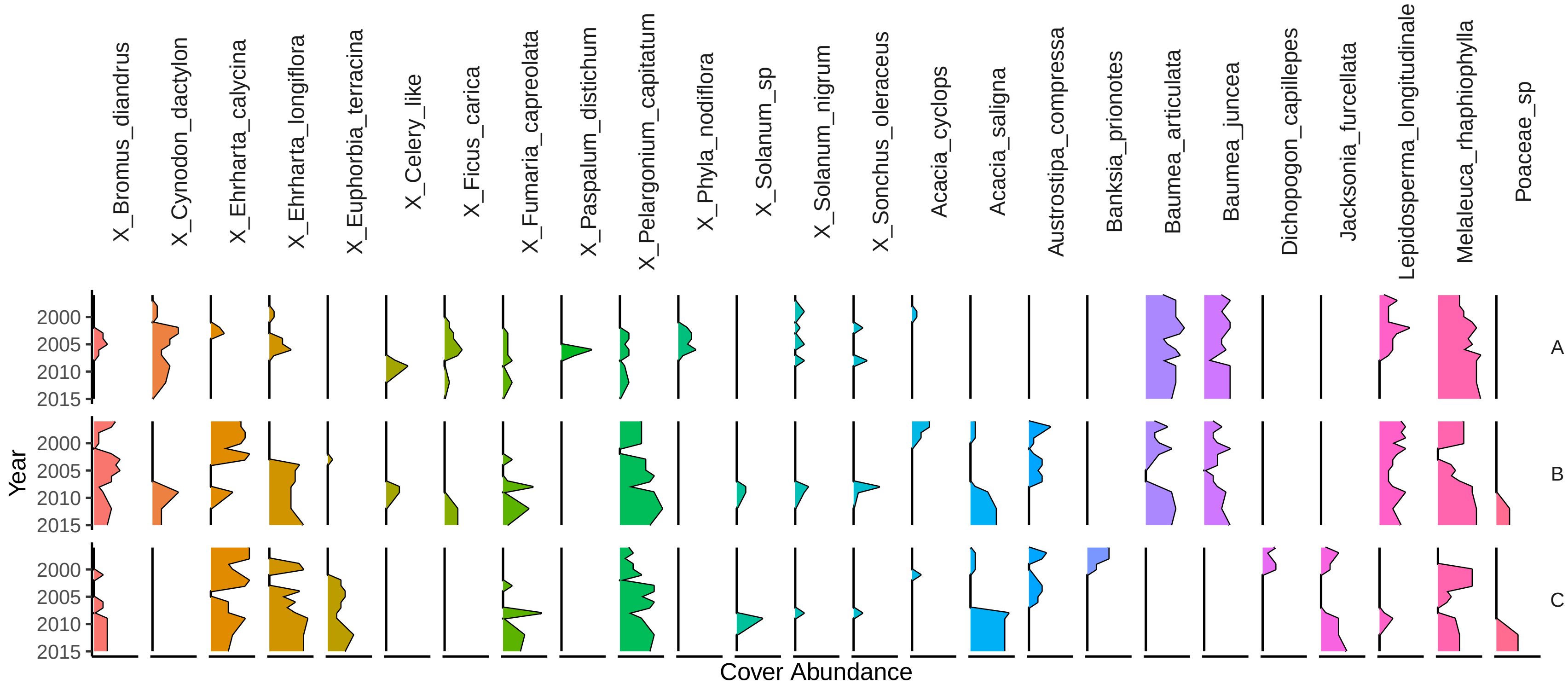

Figure 23: Cover abundances for each species across the four plots (A, B, C, D) at the northern Lake Joondalup transect. Invasive species are denoted by ‘X’. Only the most common species are included.

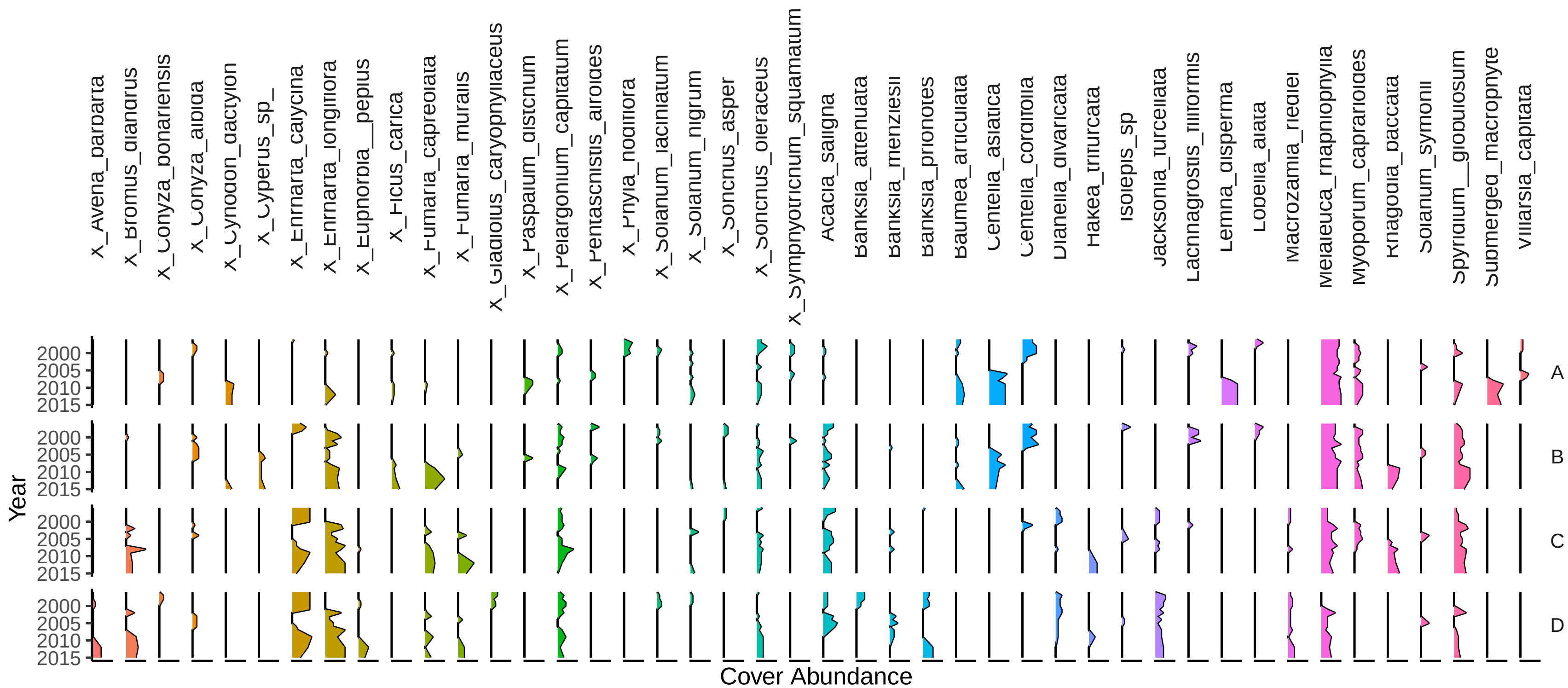

Figure 24: Cover abundances for each species across the four plots (A, B, C, D) at the southern Lake Joondalup transect. Invasive species are denoted by ‘X’. Only the most common species are included.

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 13: 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

	Likely effect of 2030 revised thresholds	Future Compliance
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

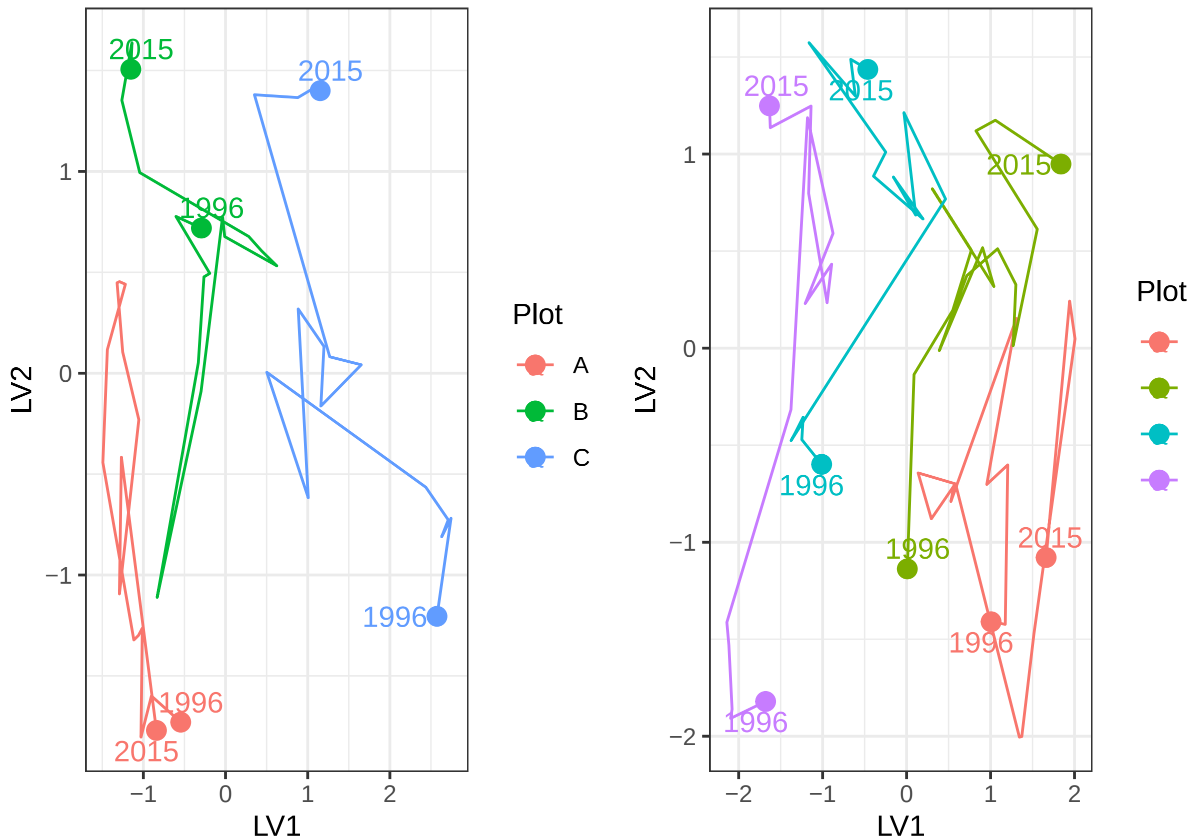

Figure 25: Unconstrained ordination based on the latent variable model for each surveyed year for the northern (left) and southern (right) Lake Joondalup transects. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

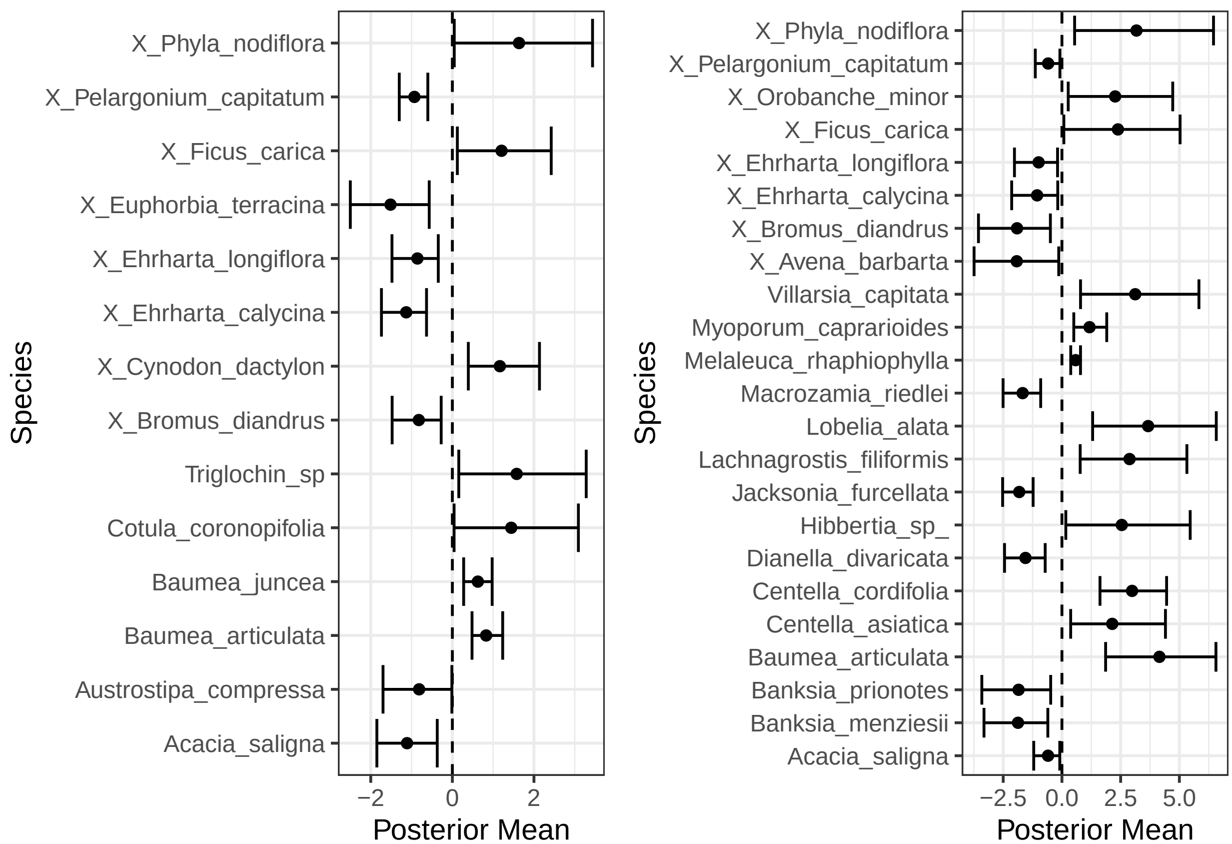

Figure 26: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at the northern (left) and southern (right) Lake Joondalup transects on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline and species with positive values are likely to increase in cover abundance when water levels increase. Only those species with coefficients significanlty different to zero are shown.

Table 14: Five year summaries of surface water level data at Lexia 186

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

The Lexia system of wetlands is composed of three separate wetlands, Lexia 86, Lexia 94 and Lexia 186. Lexia 186 was normally a seasonally waterlogged basin (Dampland), however, prolonged decline of ground water levels mean water levels are below the level of the basin all year. There has been dramatic shifts in fringing vegetation health and composition as the basin sediments dry and oxidise. The wetland is has a high conservation value (FROEND 2004).

Hydrology

There has almost been a continual decline in ground water levels at Lexia 186 from 1996 to 2015 by approximately 1 m and a significant increases in water levels since 2015 by 0.5 m (Figure 27). Nonetheless, current mean maximum and minimum water levels are 1.2 and 0.8 m below 1994-1999 levels and seasonally minimums are occurring earlier in the year (Table 14).

Vegetation dynamics

Vegetation monitoring has been occurring at Lexia 186 since 1997 with the last survey conducted in 2018 (Figure 28). Overall canopy health has remained stable with most *Melaleuca preissiana* in good or excellent condition and most *Banksia ilicifolia* with average condition (BULLER 2018 REPORT). Exotic richness is very low at Lexia 186 and natives account for approximately 90 % of total cover abundance at the transect. Ordination reveals similar trajectories in compositional change for each plot that reflect the continual changes in cover abundances of species (Figure 29). Regression analyses did not reveal significant effects of ground water levels on any of the species present at Lexia 186 (Figure 30). This result suggests that community composition is changing due to other factors that are independent of ground water. This is surprising given the significant declines in ground water at the site. (NOT SURE IF THERE IS ANY Baumea AT THE SITE AND WHETHER IT HAS DECLINED OR DISAPPEARED - PERHAPS WORTH A COMMENT) (ARE THERE ANY OTHER DRAMTIC CHANGES WITH THE DECLINING WL?).

Revised water level threshold effects

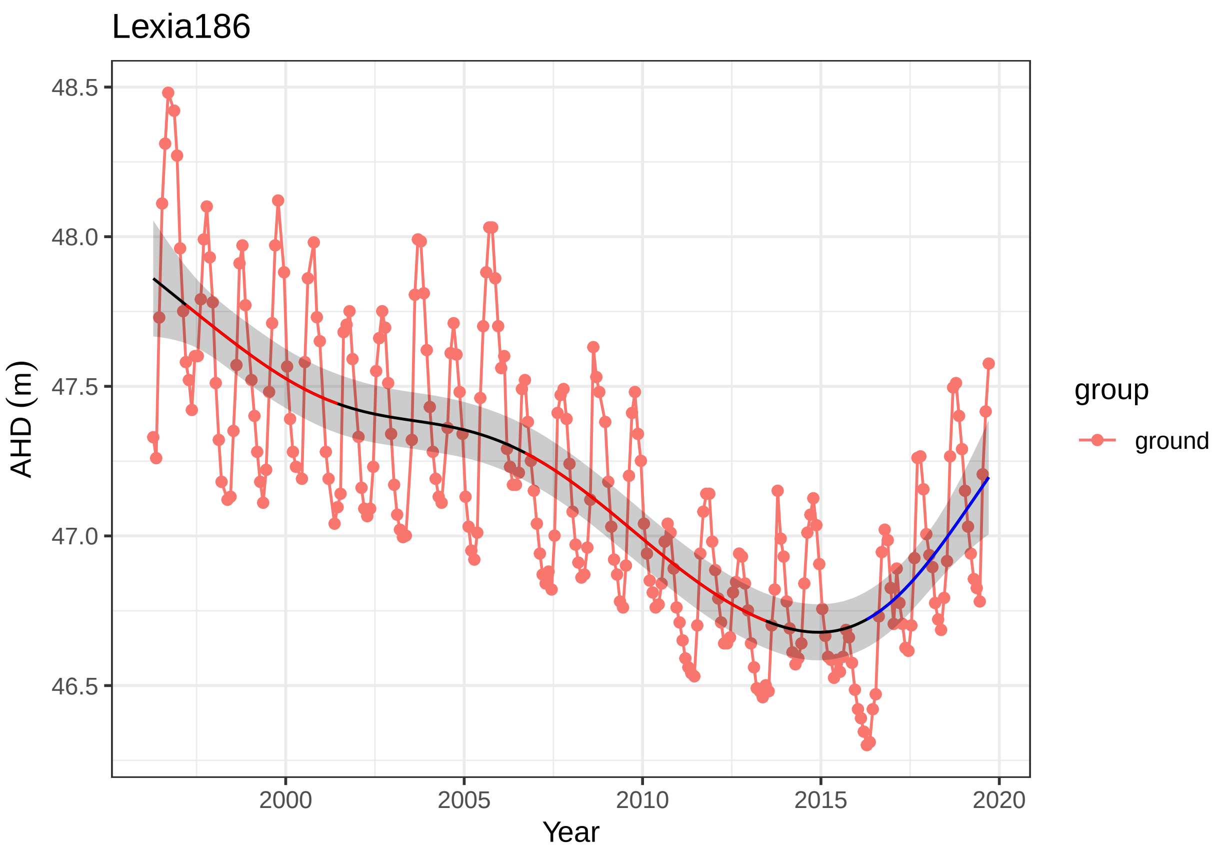

Figure 27: Ground water levels recorded at bore 61613214 that represent water level fluctuations at Lexia 186. Red segments represent periods of significant decline in water levels while blue segments represent periods of significant increase in water levels.

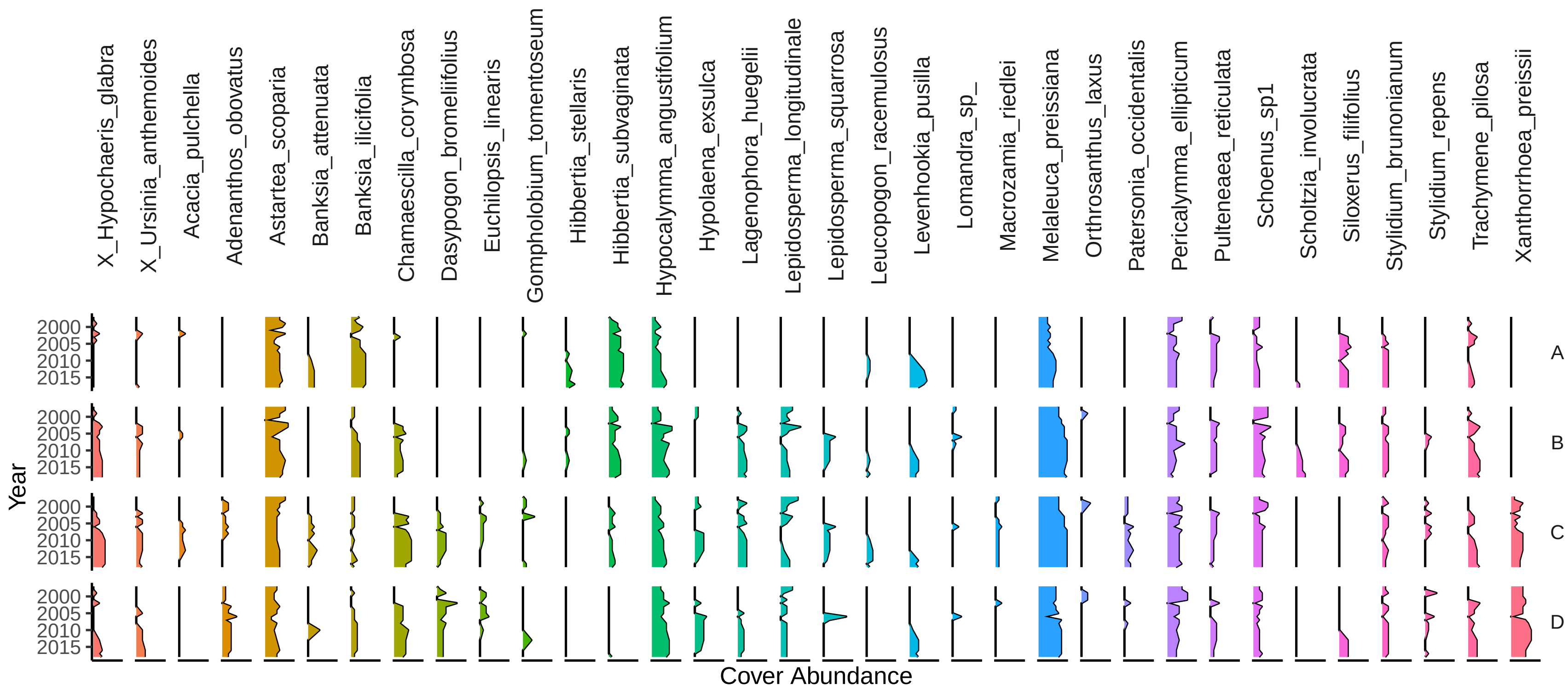

Figure 28: Cover abundances for each species across the four plots (A, B, C, D) at the Lexia 186 transect. Invasive species are denoted by ‘X’. Only the most common species are included.

Table 15: 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		
Undisturbed by typical impacts		
Supports diverse vegetation		
Significant fauna habitat		
Site management objectives		
Conserve ecological values		
Protect vegetation assemblages in and fringing the wetland		
Protect invertebrate communities dependent on the wetland		

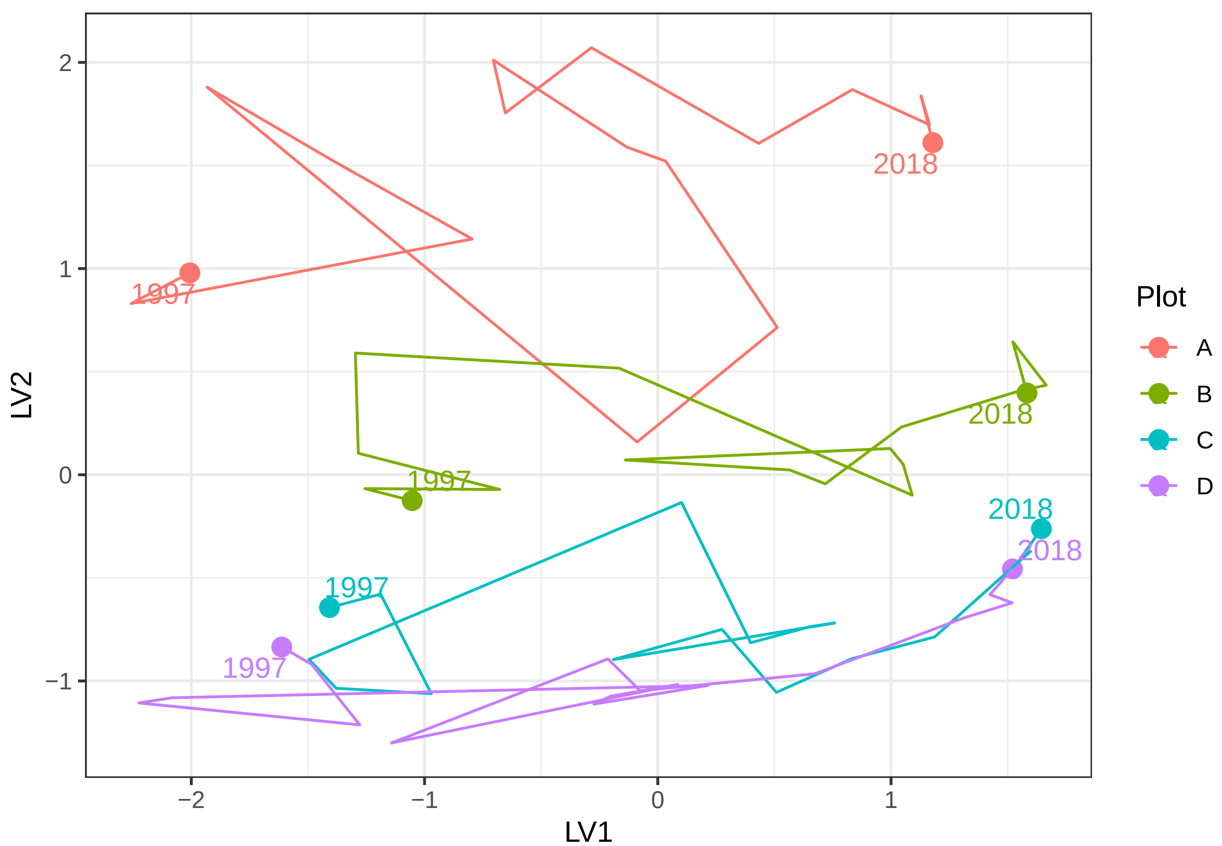

Figure 29: Unconstrained ordination based on the latent variable model for each surveyed year for Lexia 186. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

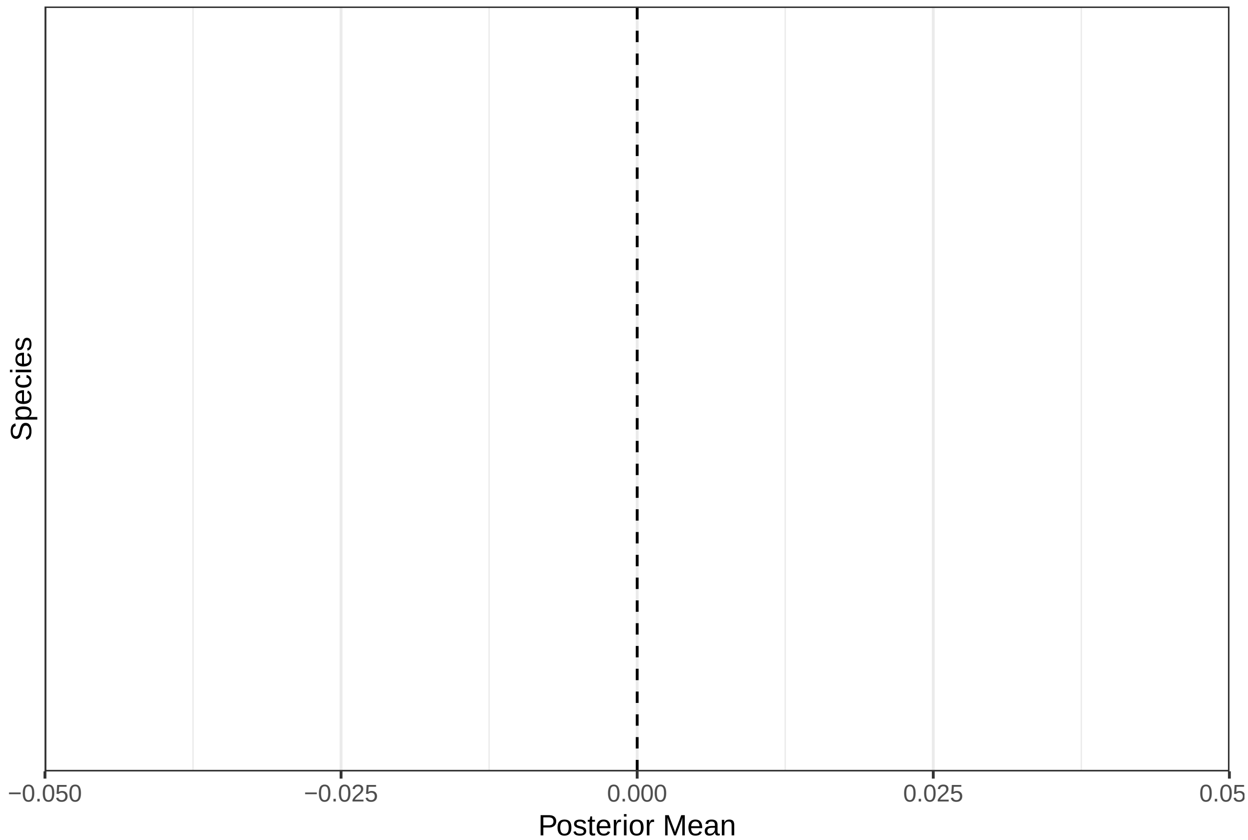

Figure 30: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Lexia 186 on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline. Only those species with coefficients significanlty different to zero are shown.

Table 16: 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

Loch McNess, located in Yanchep National Park, is a relatively undisturbed wetland with large areas of intact Herdsman Complex vegetation, relatively good water quality and important habitat for water birds and other aquatic fauna (FROEND 2004). Permanent water is required to support a local Rakali (*Hydromys chrysogaster*) population and resident and visiting populations of water birds and waders. Loch McNess is a wetland of high conservation value because of its intact vegetation, largely unaltered aquatic processes and important populations of fauna (FROEND 2004).]

Hydrology

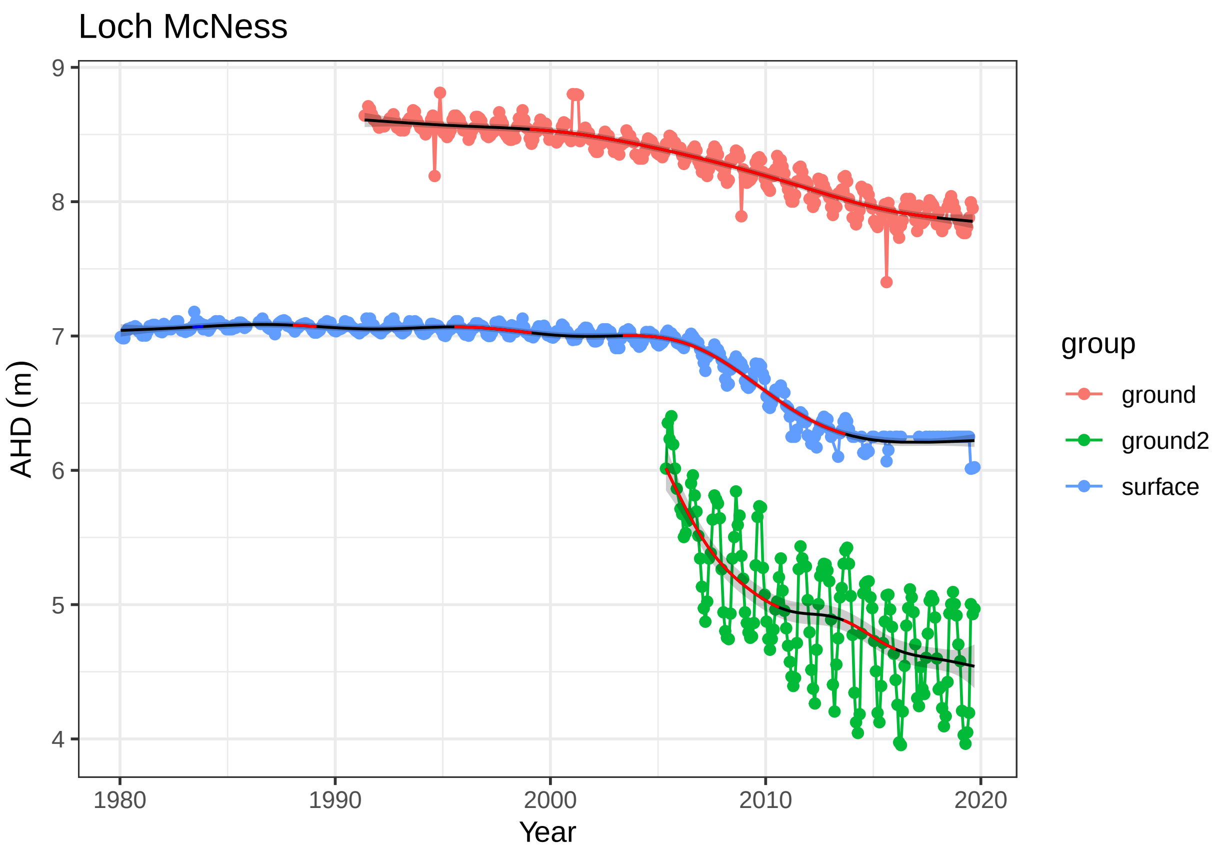

Figure 31: Ground and surface water levels recorded at bores 61612104 (red) and 61640108 (green) and staff gauge 6162564 (blue) that represent changes in water levels at Loch McNess. Segments in red represent periods of significant decline in water level.

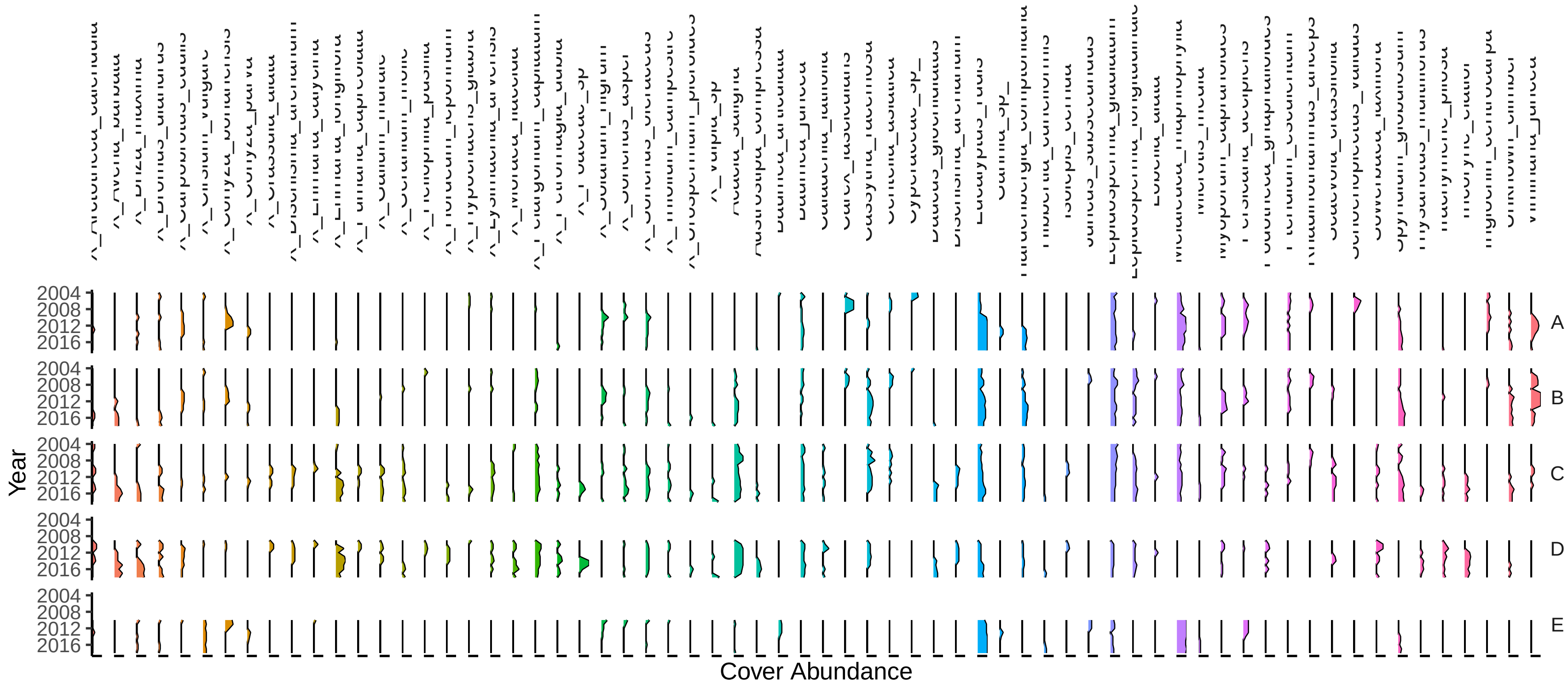

Figure 32: Cover abundances for each species across the four plots (A, B, C, D) at the Loch McNess transect. Invasive species are denoted by ‘X’. Only the most common species are included.

Table 17: 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		
* Undisturbed wetland		
* Unusual hydrologic regime		
* Rich aquatic fauna		
* Vegetation largely intact, provides a range of habitat types		
* Supports good populations of water birds and acts as a drought refuge		
* Excellent water quality		
Site management objectives		
* Maintain the environmental quality of the lake		
* Maintain North Loch NcNess' pristine state		
* Continue to use south Loch McNess for low key recreation		
* Maintain east Loch McNess in a natural state, to restore, where possible, natural flow		
* Maintain the existing hydrological regime		

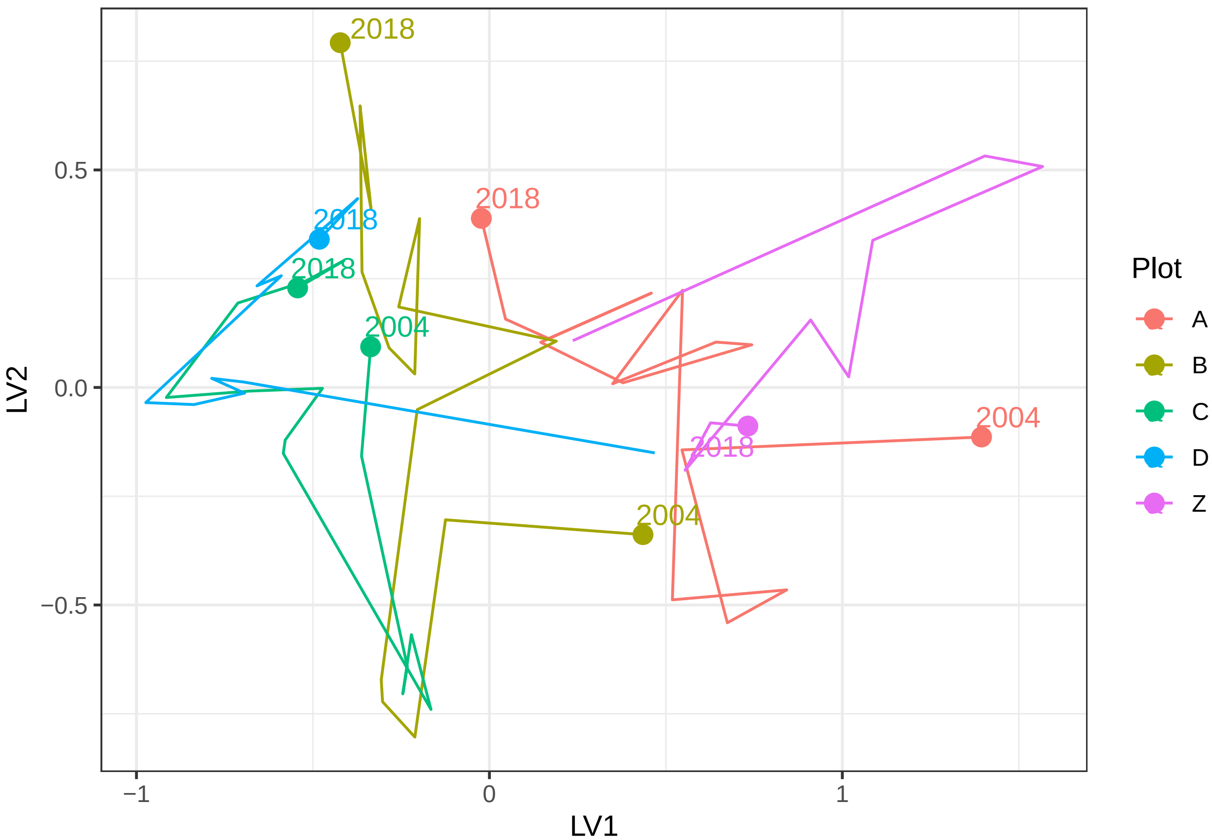

Figure 33: Unconstrained ordination based on the latent variable model for each surveyed year for Loch McNess. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

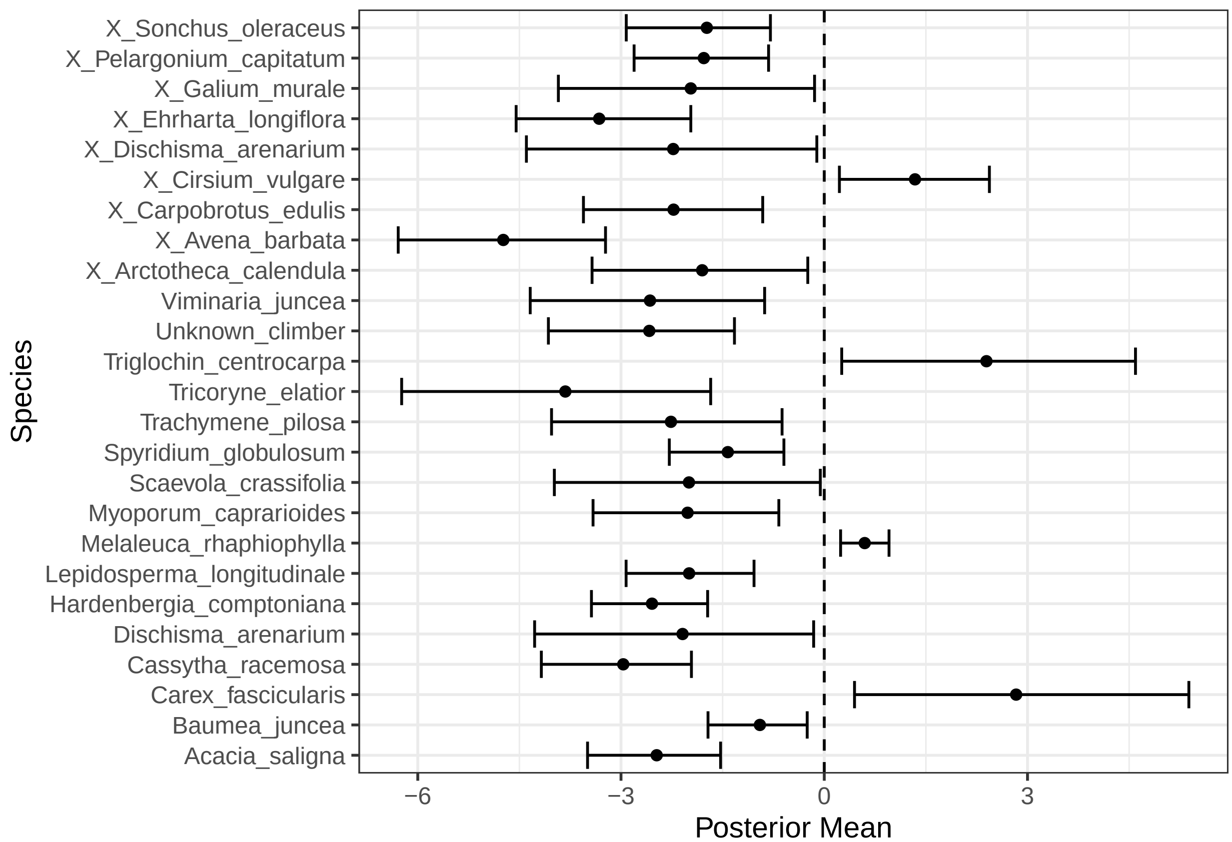

Figure 34: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Loch McNess on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline while species with positive values are predicted to increase in cover abundance with water increasing water levels. Only those species with coefficients significanlty different to zero are shown.

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

Lake Mariginiup

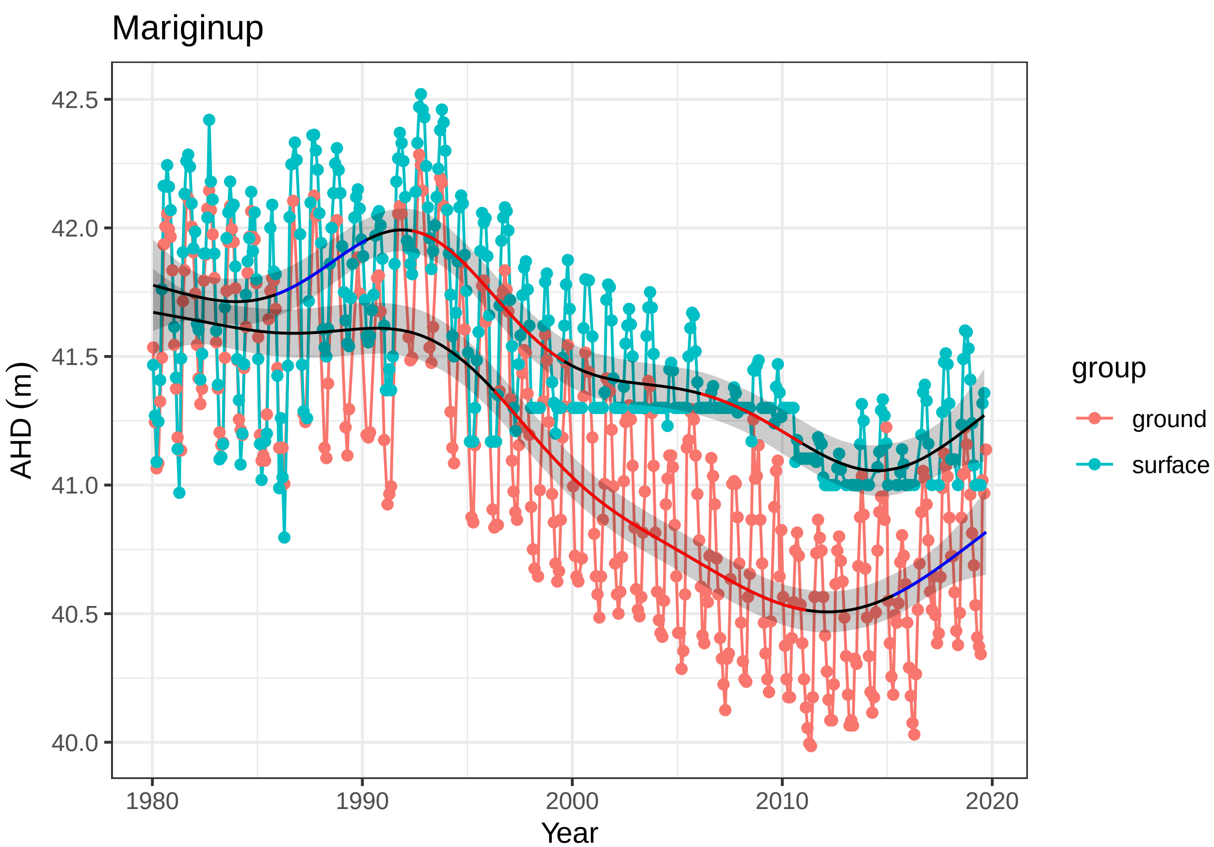

Figure 35: Ground and surface water levels recorded at bore 61610685 (red) and staff gauge 6162577 (blue) that represent changes in water levels at Lake Mariginiup.

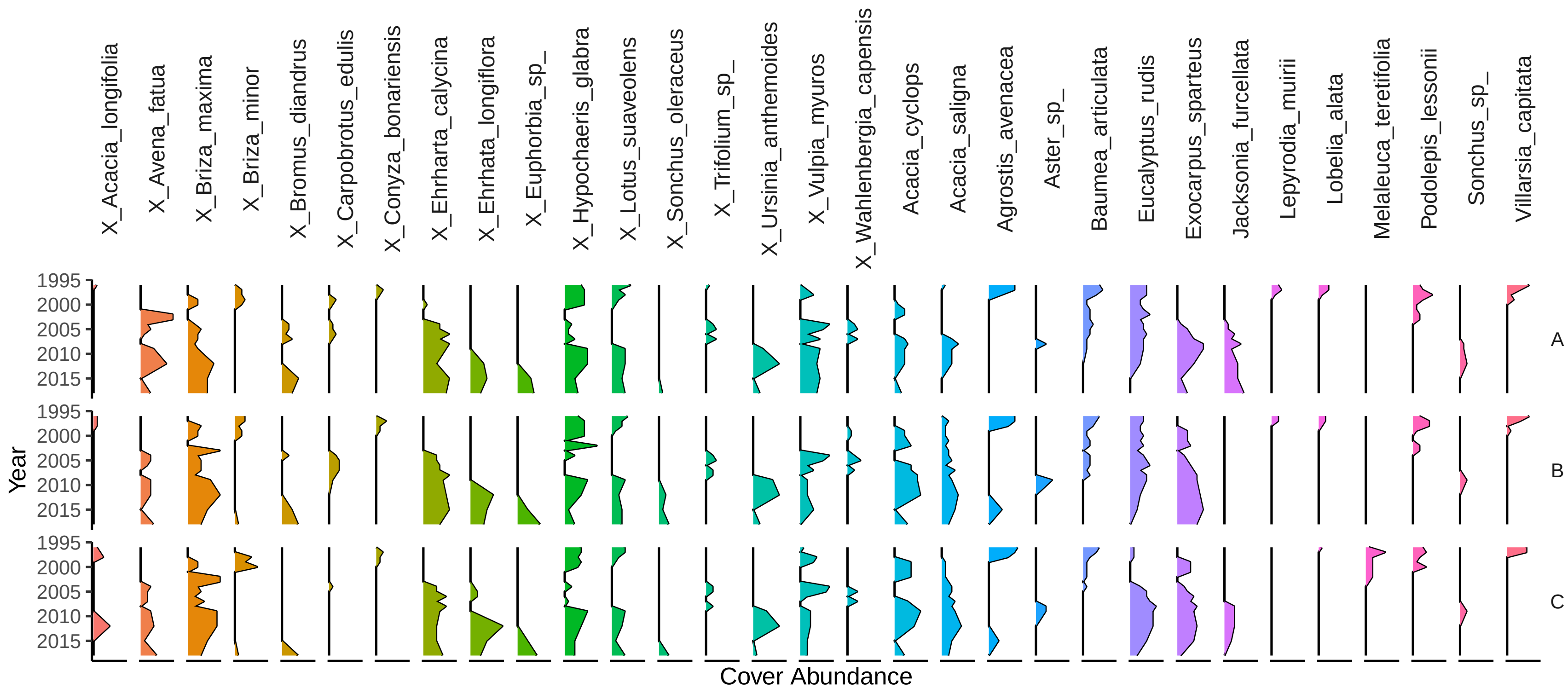

Figure 36: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Mariginiup transect. Invasive species are denoted by ‘X’. Only the most common species are included.

Table 19: 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 - Whiteman Park East

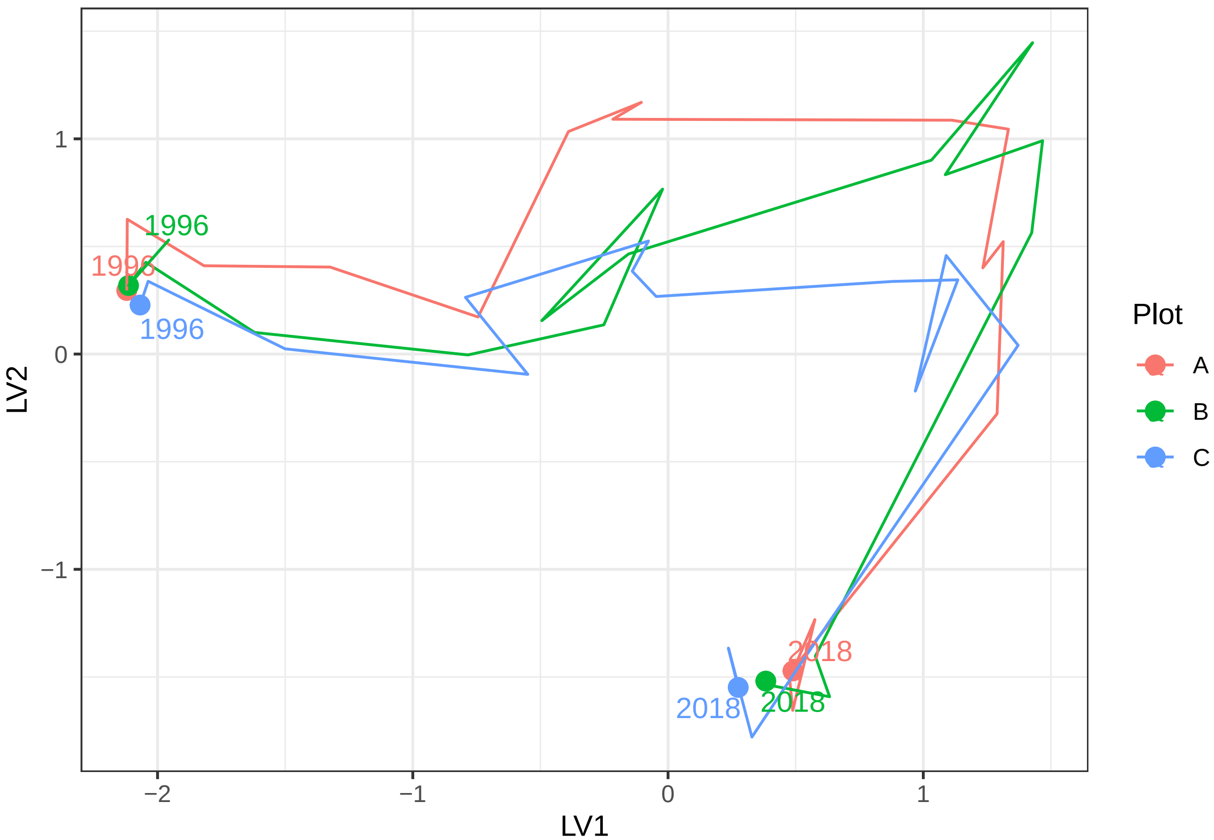

Figure 37: Unconstrained ordination based on the latent variable model for each surveyed year for Lake Mariginiup. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

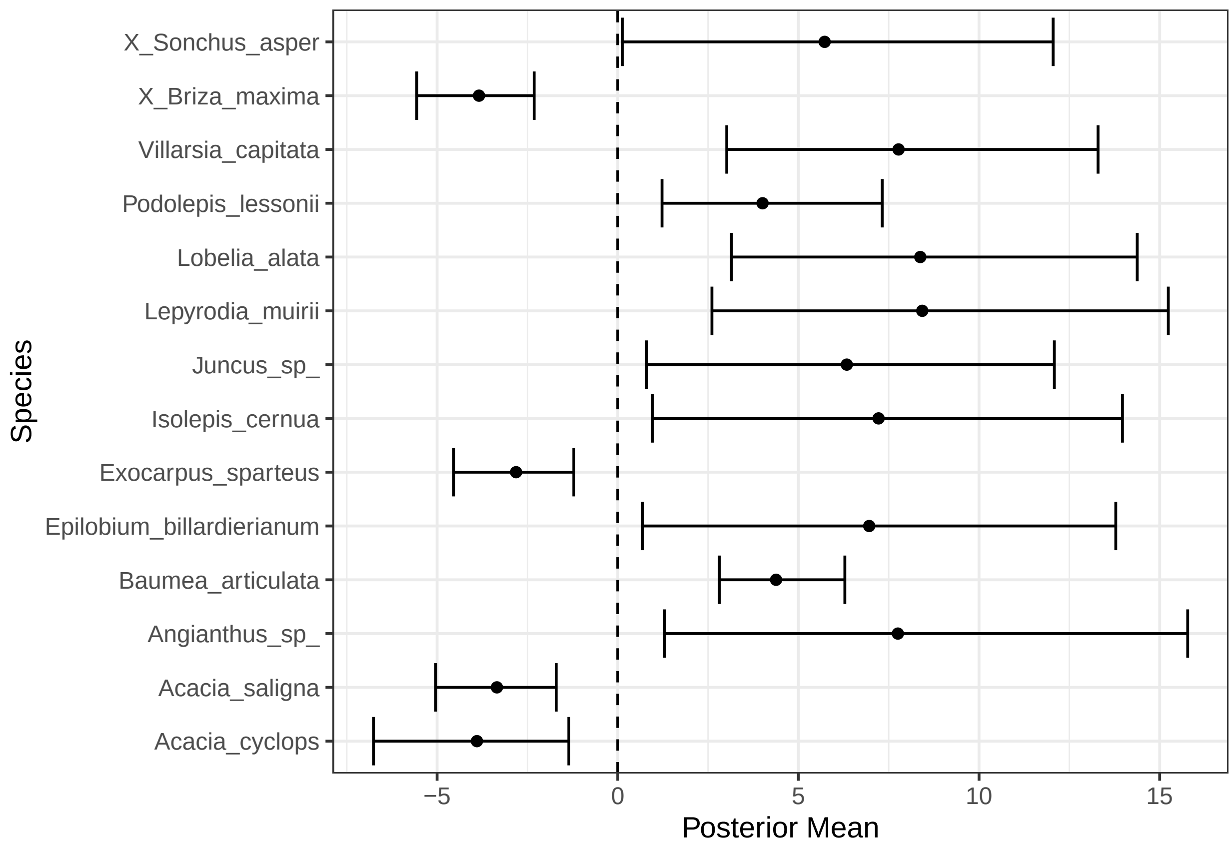

Figure 38: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Lake Mariginiup on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline and species with positive values are predicted to increae in cover abundance with increasing water levels. Only those species with coefficients significanlty different to zero are shown.

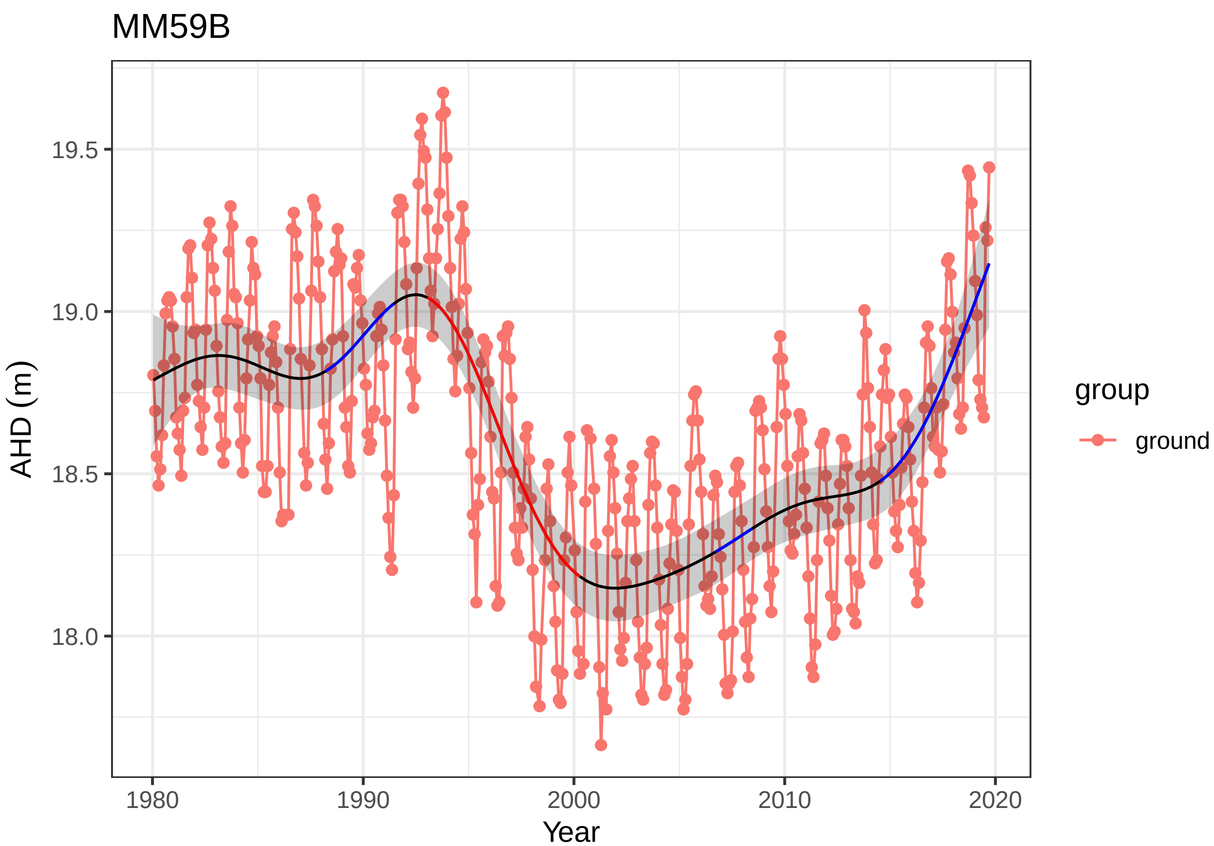

Figure 39: Ground water levels recorded at bore 61610661 in the vicinity of MM59B. Red segments represent periods of significant decline in ground water level while blue segments represent periods of significant increase in ground water level.

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

Lake Nowergup

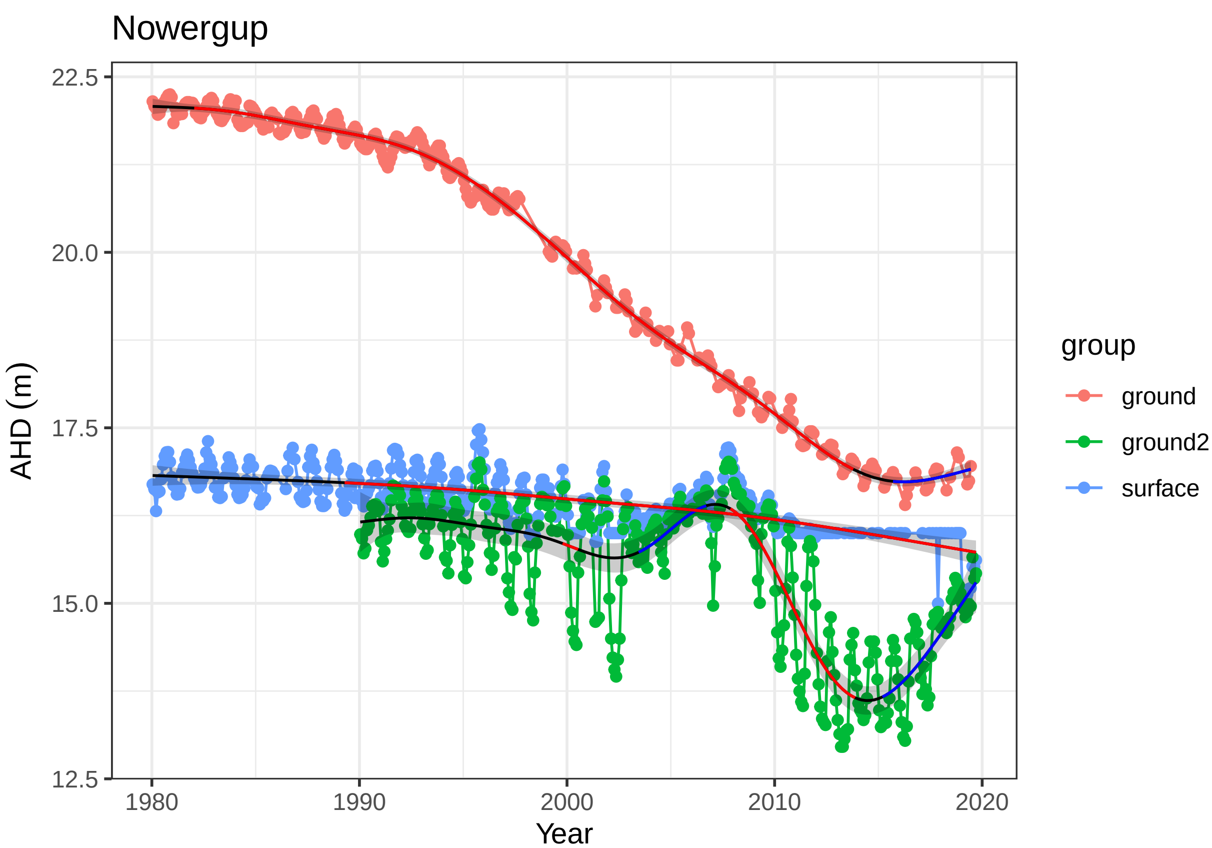

Figure 40: Ground and surface water levels for Lake Nowergup recorded at bores 61610601 (red) and 61611247 (green) and staff gauge 6162567 (blue). The minimum recordable water level for the staff gaugue is 16.0 mAHD. Blue dots at 16.0 mAHD represent water levels below the minimum level measurable at the staff gaufe. Red segments on fitted line represent statistically significant periods of declining water levels and blue segments represent periods of increasing water levels.

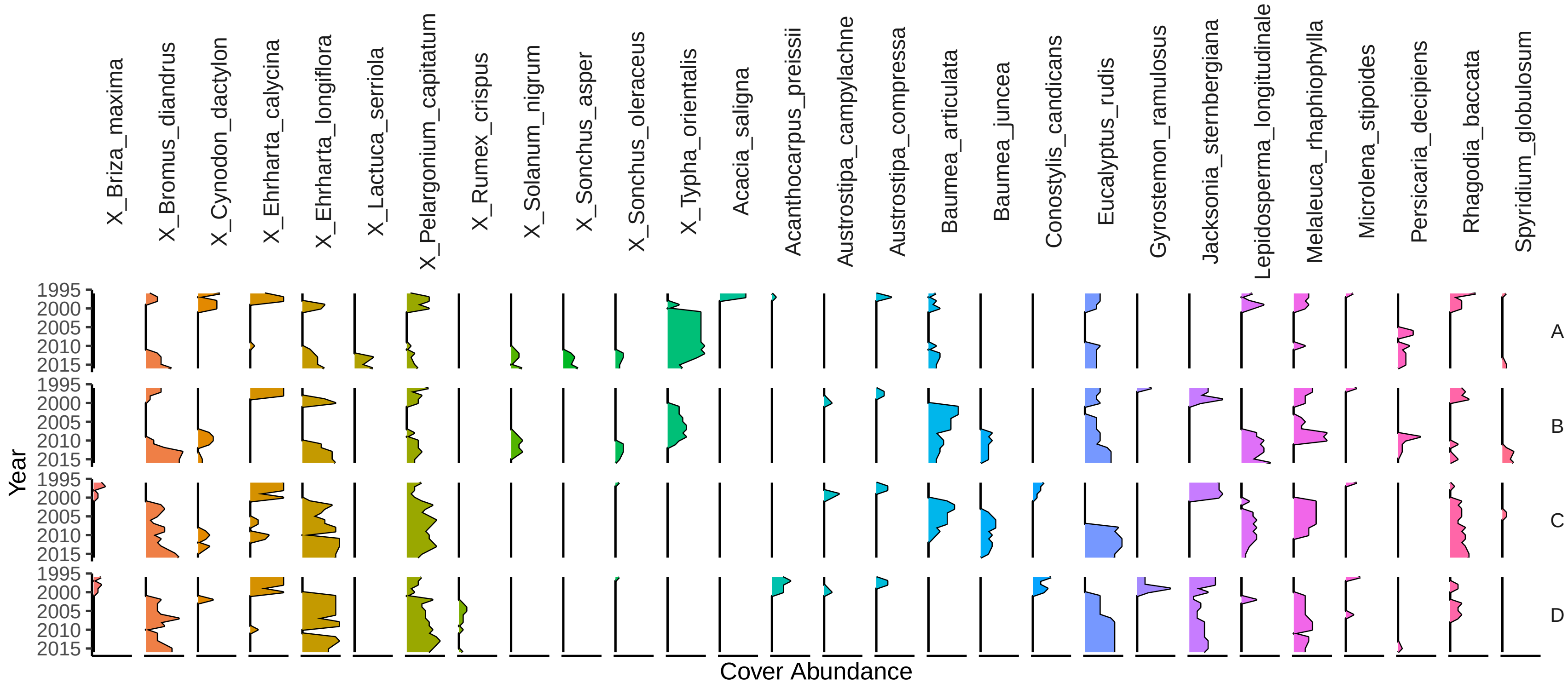

Figure 41: Cover abundances for each species across the four plots (A, B, C, D) at the northern Lake Nowergup transect. Invasive species are denoted by 'X'. Only the most common species are included.

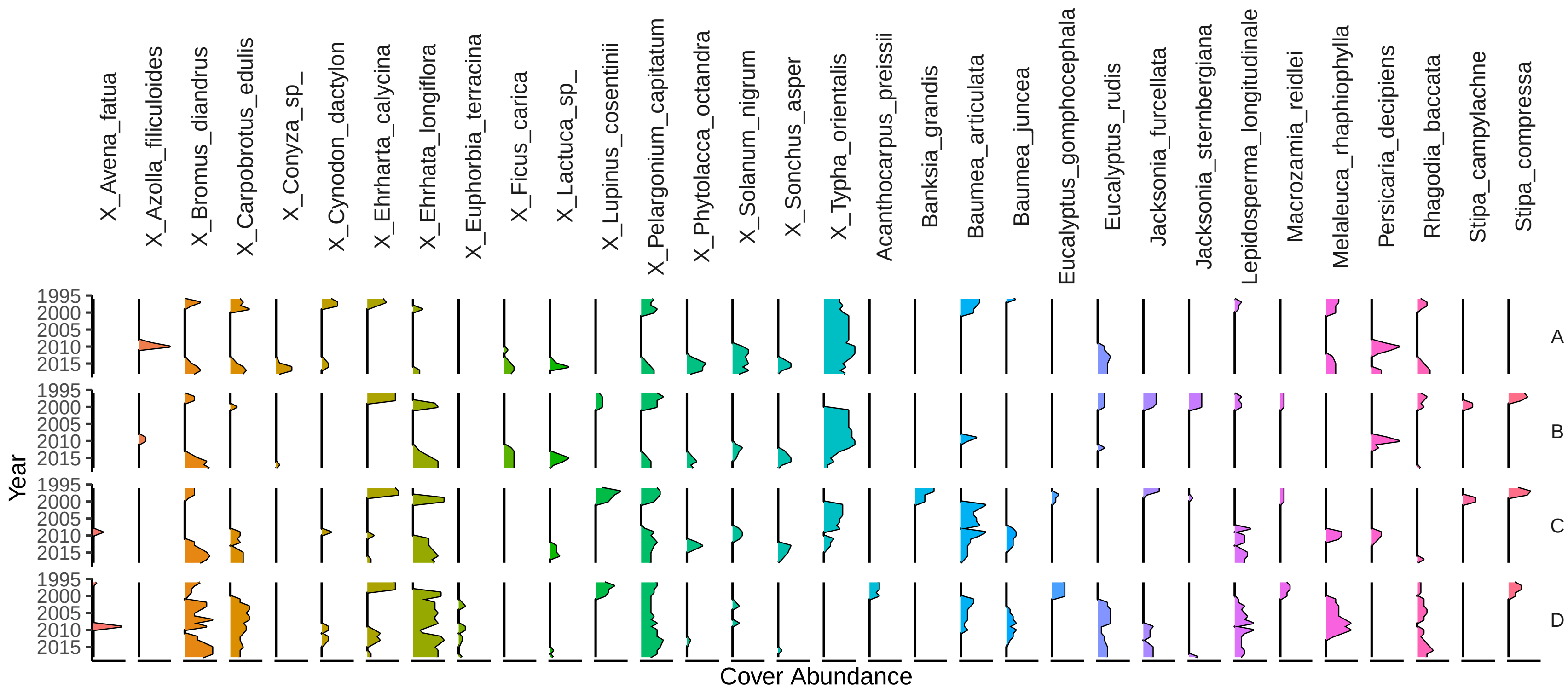

Figure 42: Cover abundances for each species across the four plots (A, B, C, D) at the souther Lake Nowergup transect. Invasive species are denoted by 'X'. Only the most common species are included.

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

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 Swamp

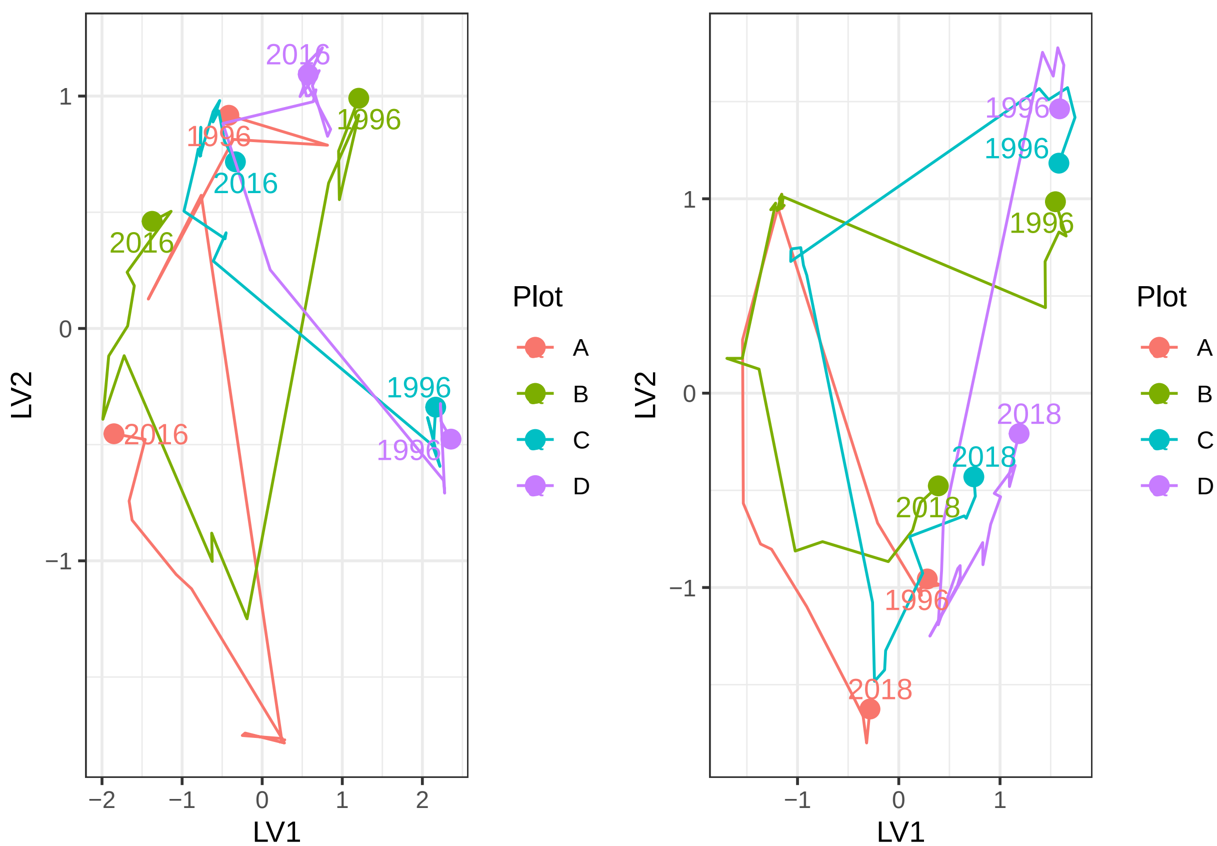

Figure 43: Unconstrained ordination based on the latent variable model for each surveyed year for the northern (left) and southern (right) Lake Nowergup transects. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

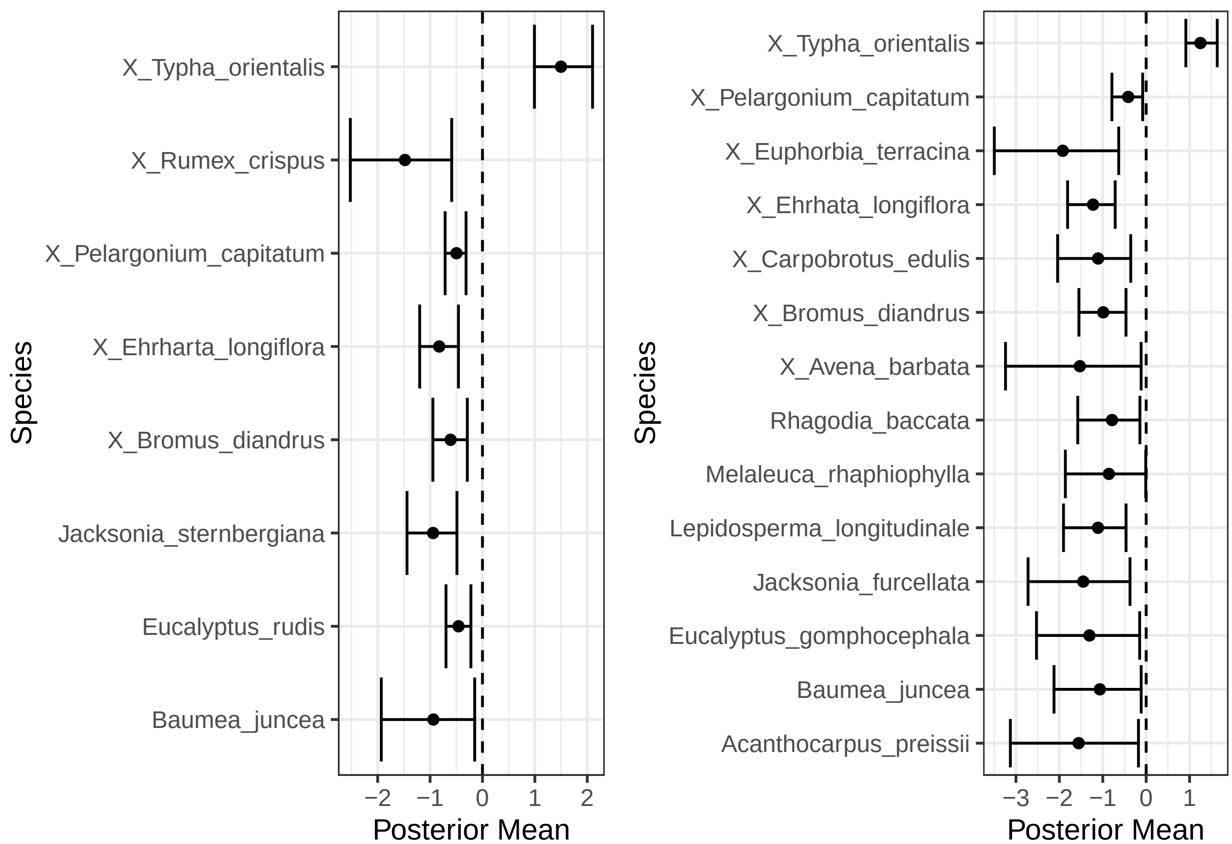

Figure 44: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at the northern (left) and southern (right) Lake Nowergup transects on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline and species with positive values are likely to increase in cover abundance when water levels increase. Only those species with coefficients significantly different to zero are shown.

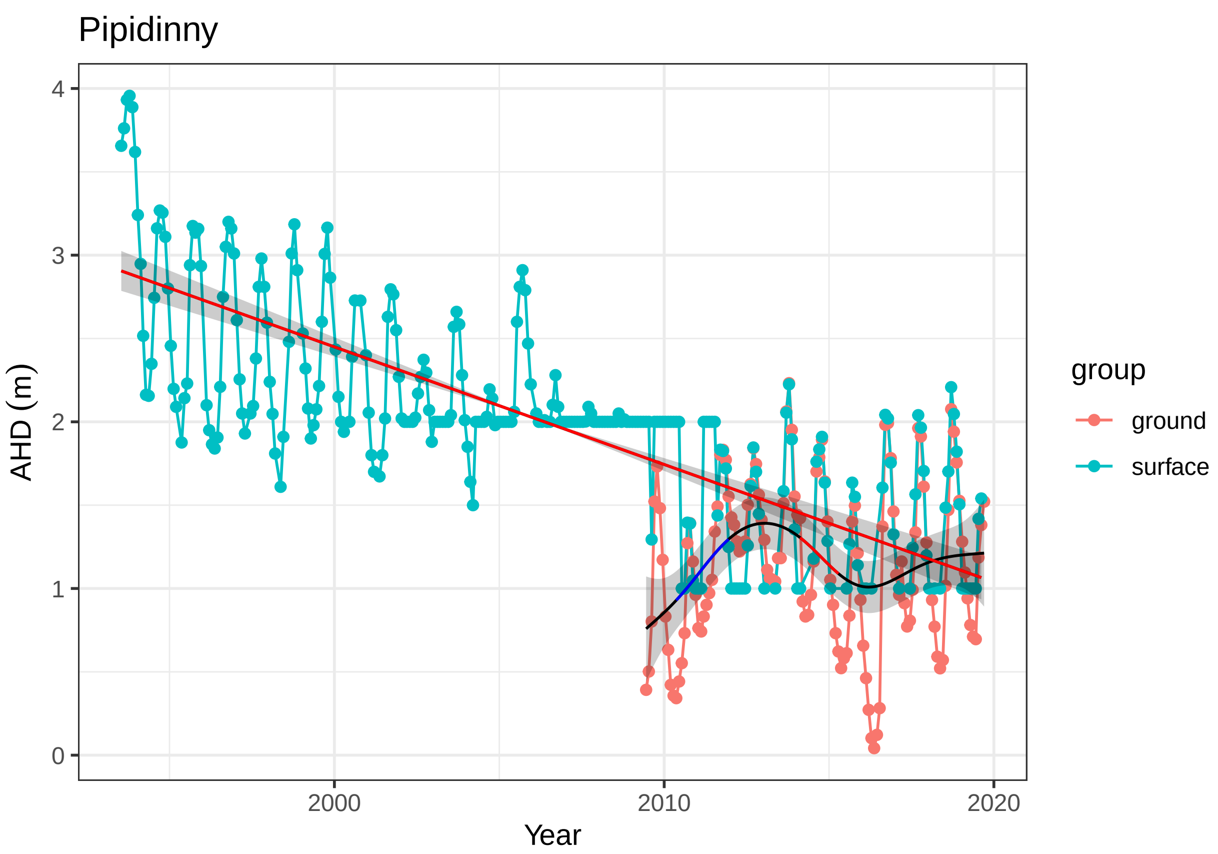

Figure 45: Ground and surface water levels recorded at bore 61611872 (red) and staff gauge 6162624 (blue) that represent fluctuations in water levels at Pipidinny Swamp. Surface water levels were initially only recordable above 2 mAHD and later above 1 mAHD. Red segments of trend line represent periods of significant decline in water levels while blue segments represent periods of significant increases in water levels.

Table 22: 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 - Pinjar North

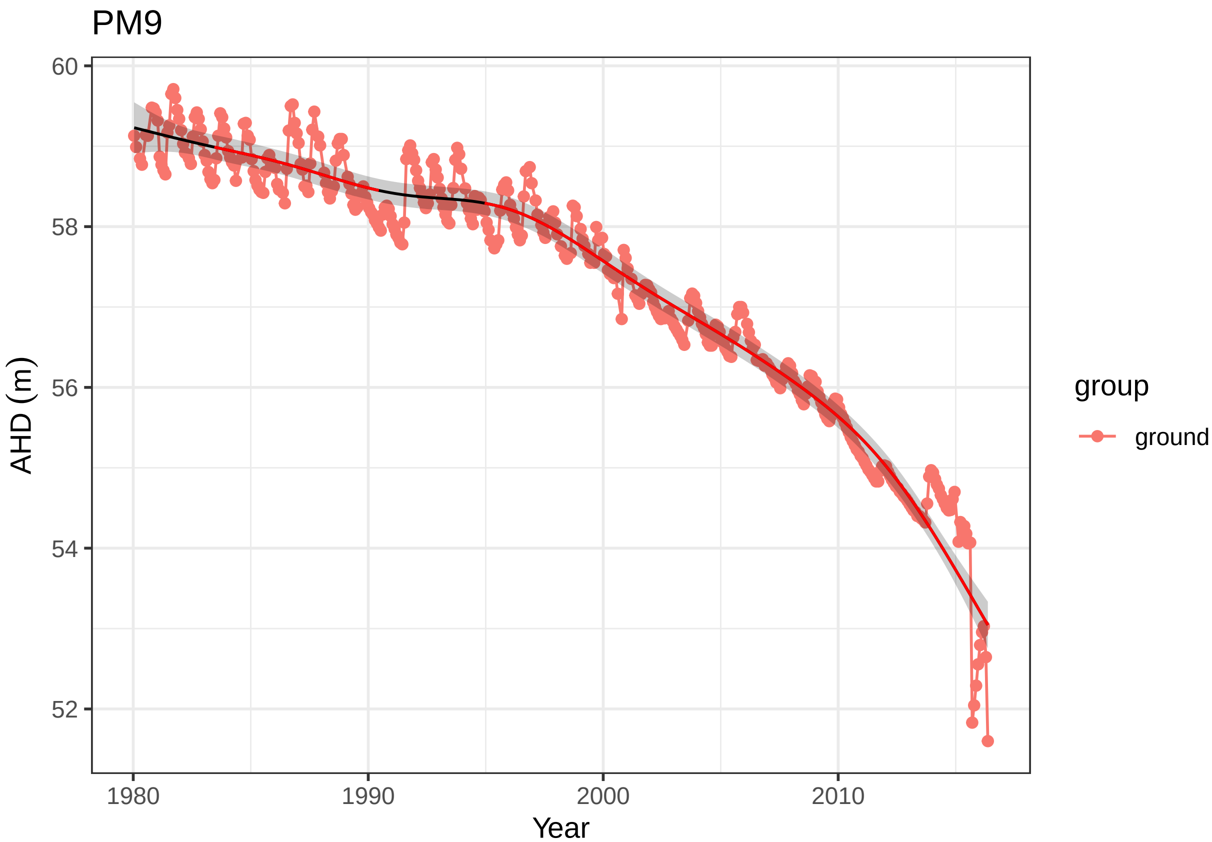

Figure 46: Ground water levels recorded at bore 61610804 in the vicinity of PM9. Red segments along trendline indicate preiods of significant decline in ground water levels.

Table 23: 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

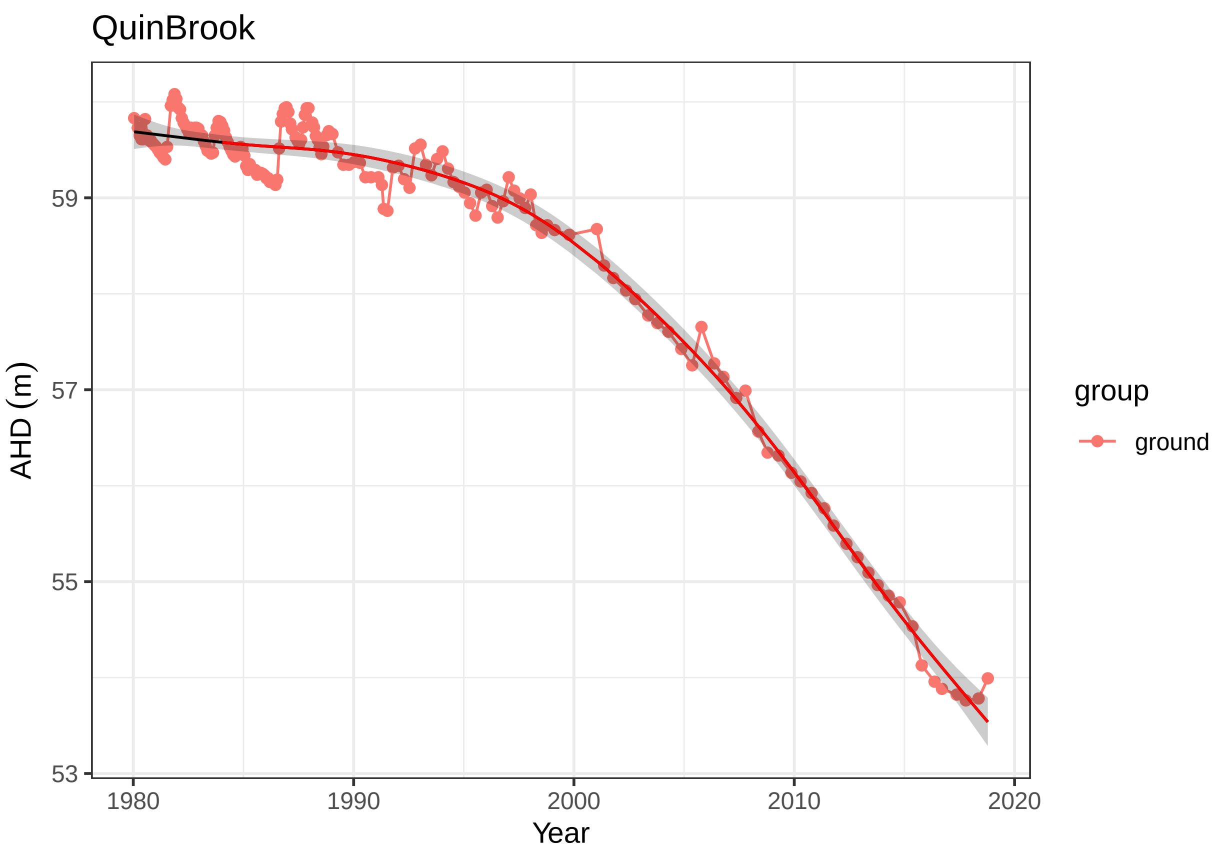

Figure 47: Ground water levels recorded at bore 61710060 in the vicinity of Quin Brook. Red segments along trendline indicate preiods of significant decline in ground water levels.

Table 24: Five year summaries of surface water level data at Lake 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

Lake Wilgarup

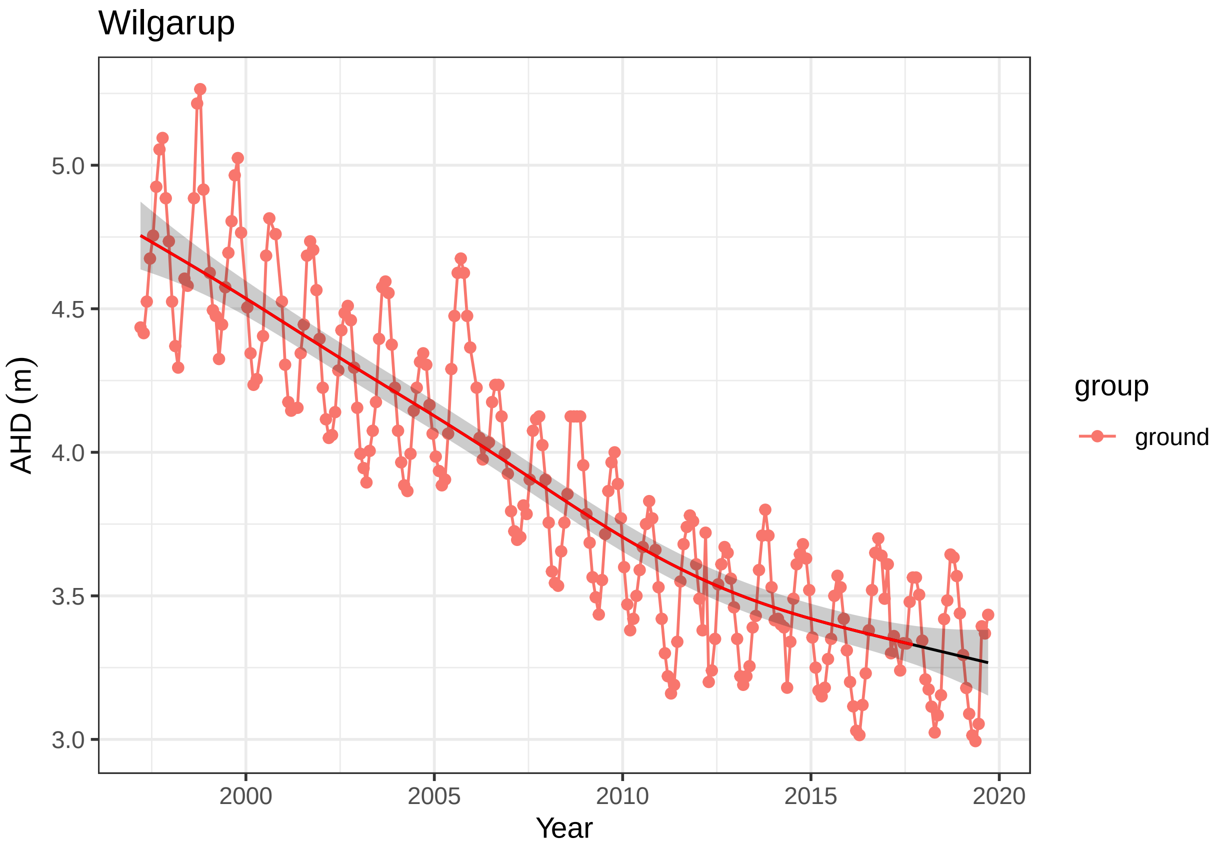

Figure 48: Ground water levels recorded at bore 61618500 in the vicinity of Lake Wilgarup. Red segments along trendline indicate preiods of significant decline in ground water levels.

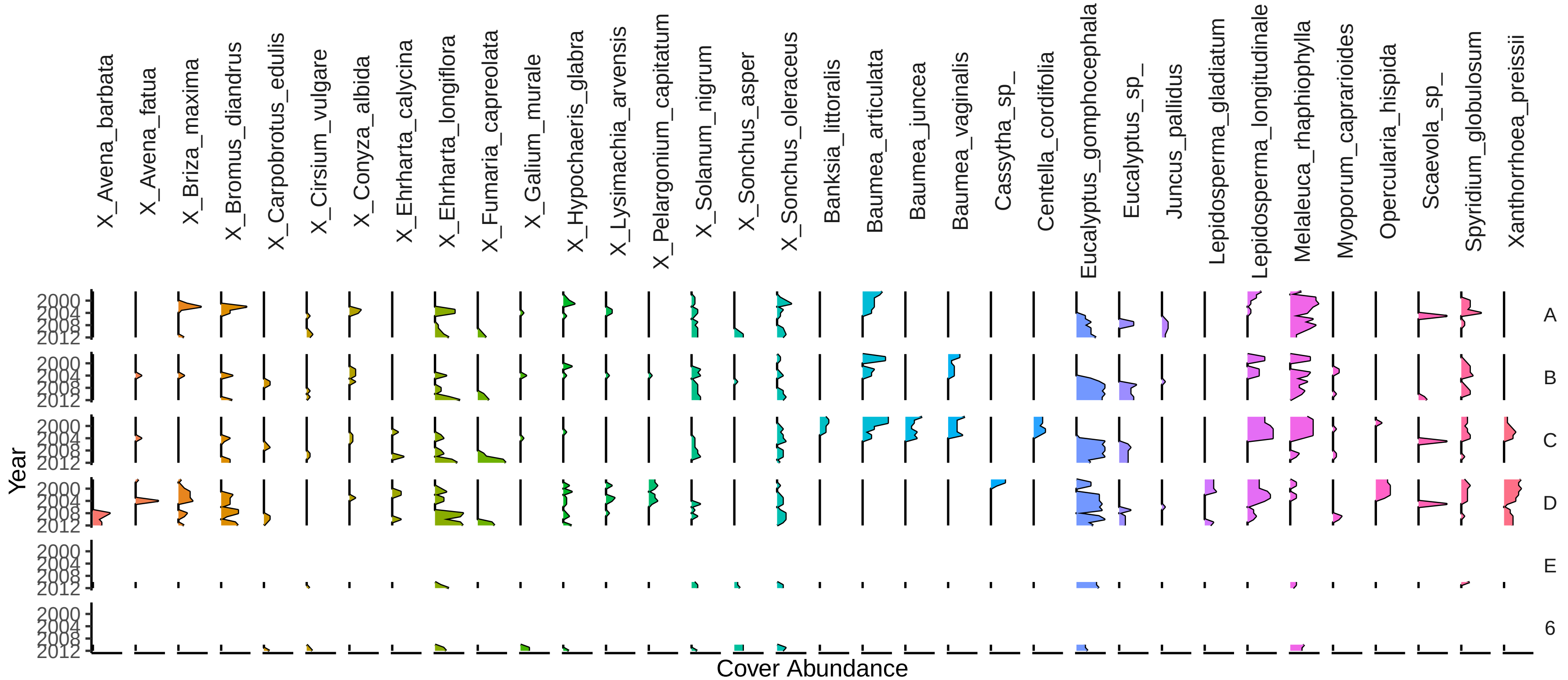

Figure 49: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Wilgarup transect. Invasive species are denoted by 'X'. Only the most common species are included.

Table 25: 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 - Pinjar

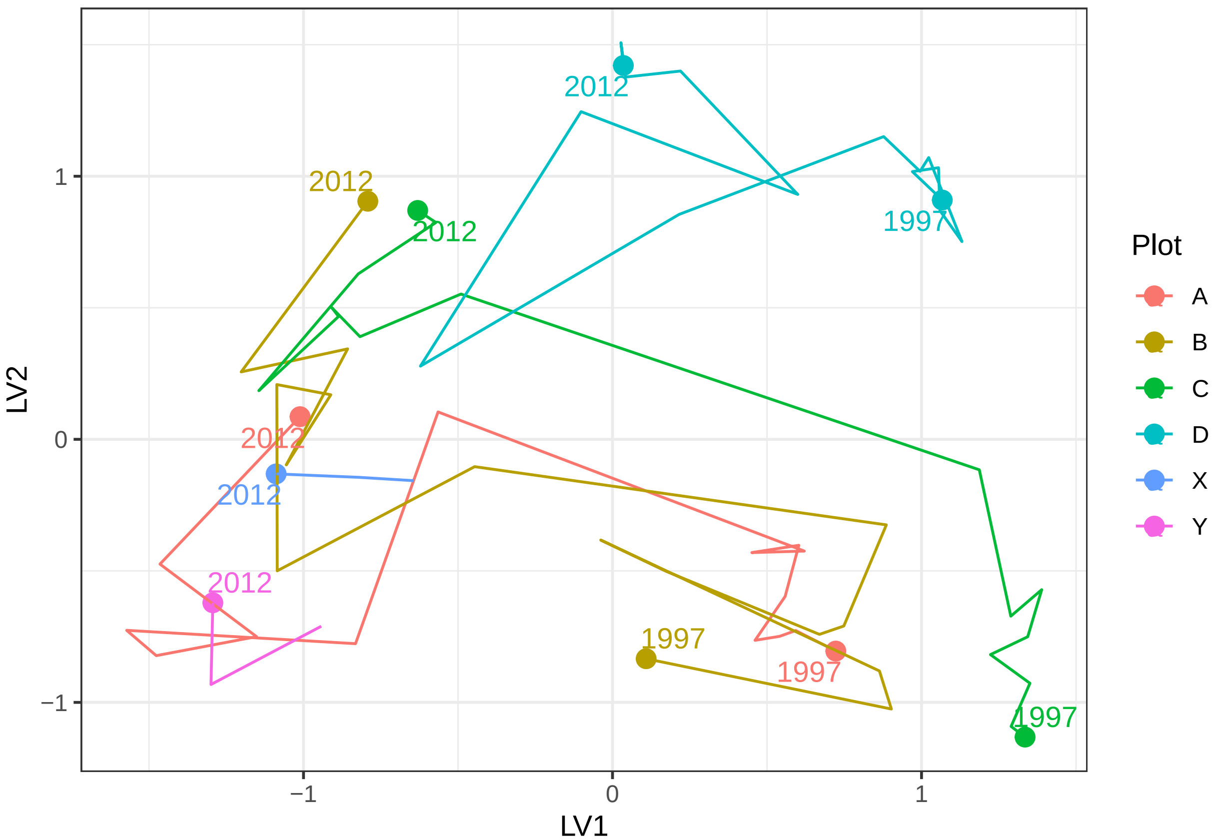

Figure 50: Unconstrained ordination based on the latent variable model for each surveyed year for Lake Wilgarup. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

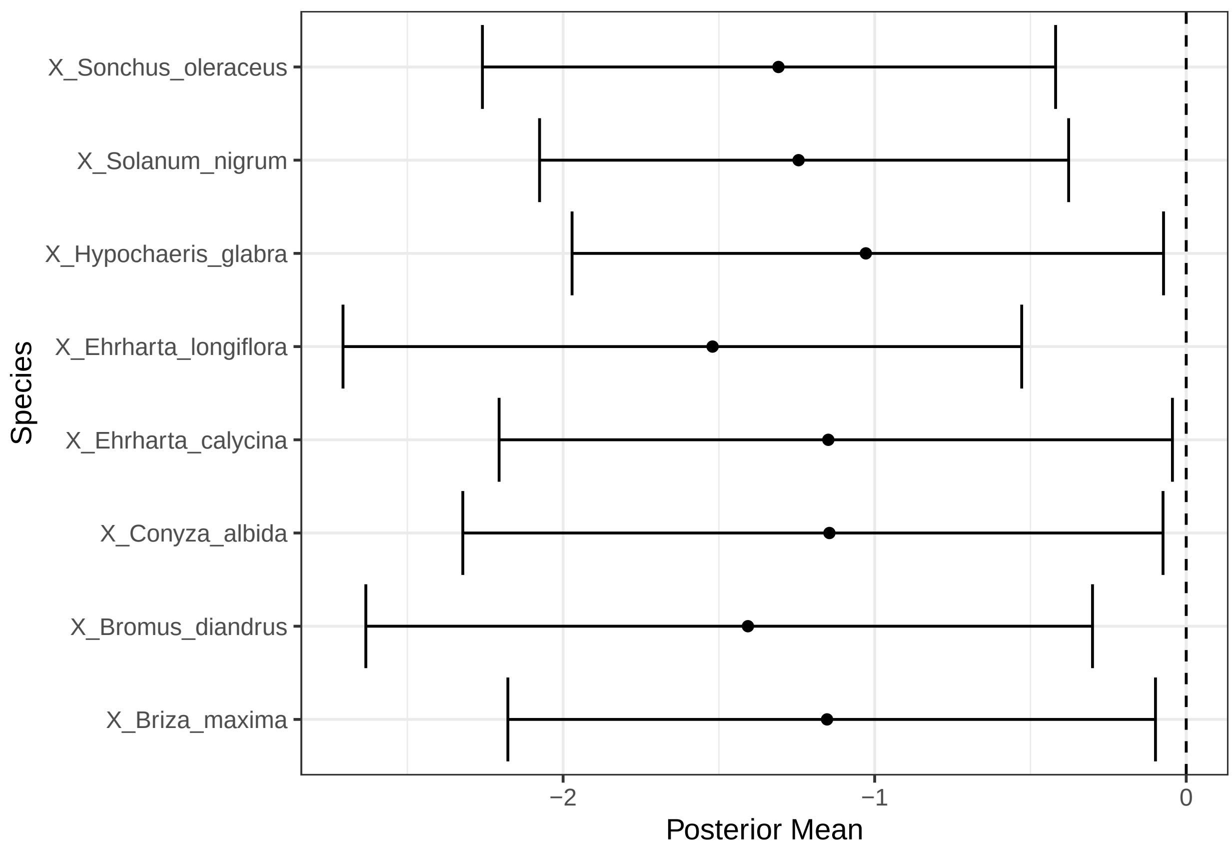

Figure 51: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Lake Wilgarup on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline. Only those species with coefficients significanlty different to zero are shown.

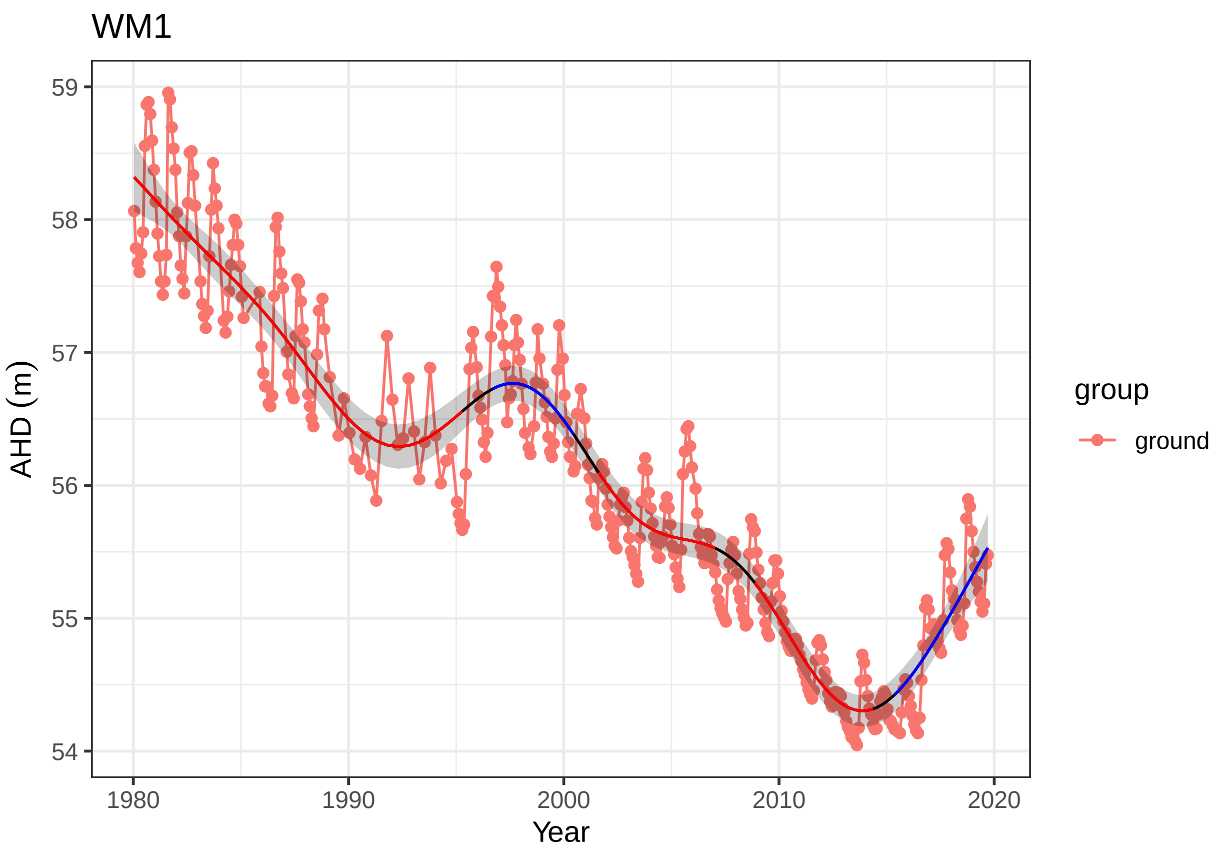

Figure 52: Ground water levels recorded at bore 61610833 in the vicinity of WM1. Red segments along trendline indicate preiods of significant decline in ground water levels and blue segments represent significant increases in ground water level.

Table 26: 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 - Melaleuca Park North

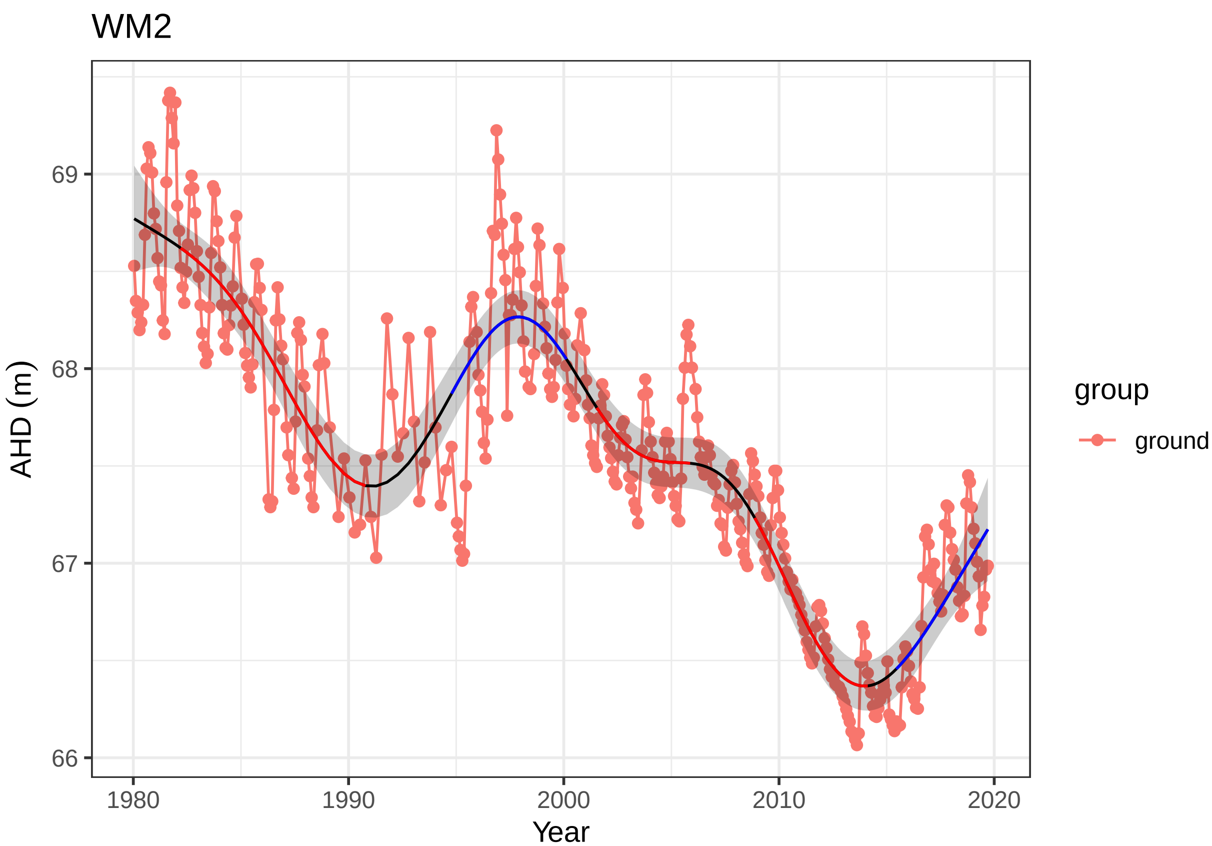

Figure 53: Ground water levels recorded at bore 61610908 in the vicinity of WM2. Red segments along trendline indicate preiods of significant decline in ground water levels and blue segments represent significant increases in ground water level.

Table 27: 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 - Melaleuca Park

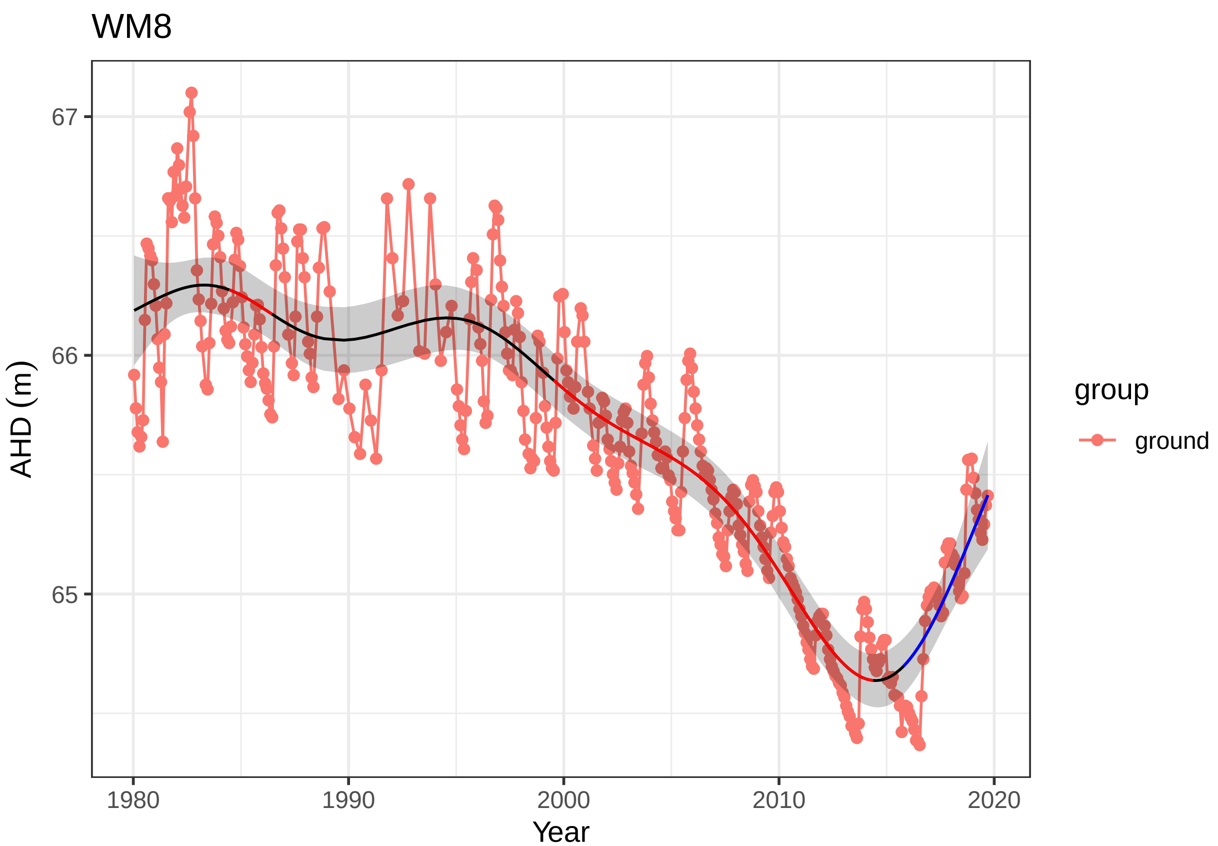

Figure 54: Ground water levels recorded at bore 61610983 in the vicinity of WM8. Red segments along trendline indicate preiods of significant decline in ground water levels and blue segments represent significant increases in ground water level.

Table 28: 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

Lake Yonderup

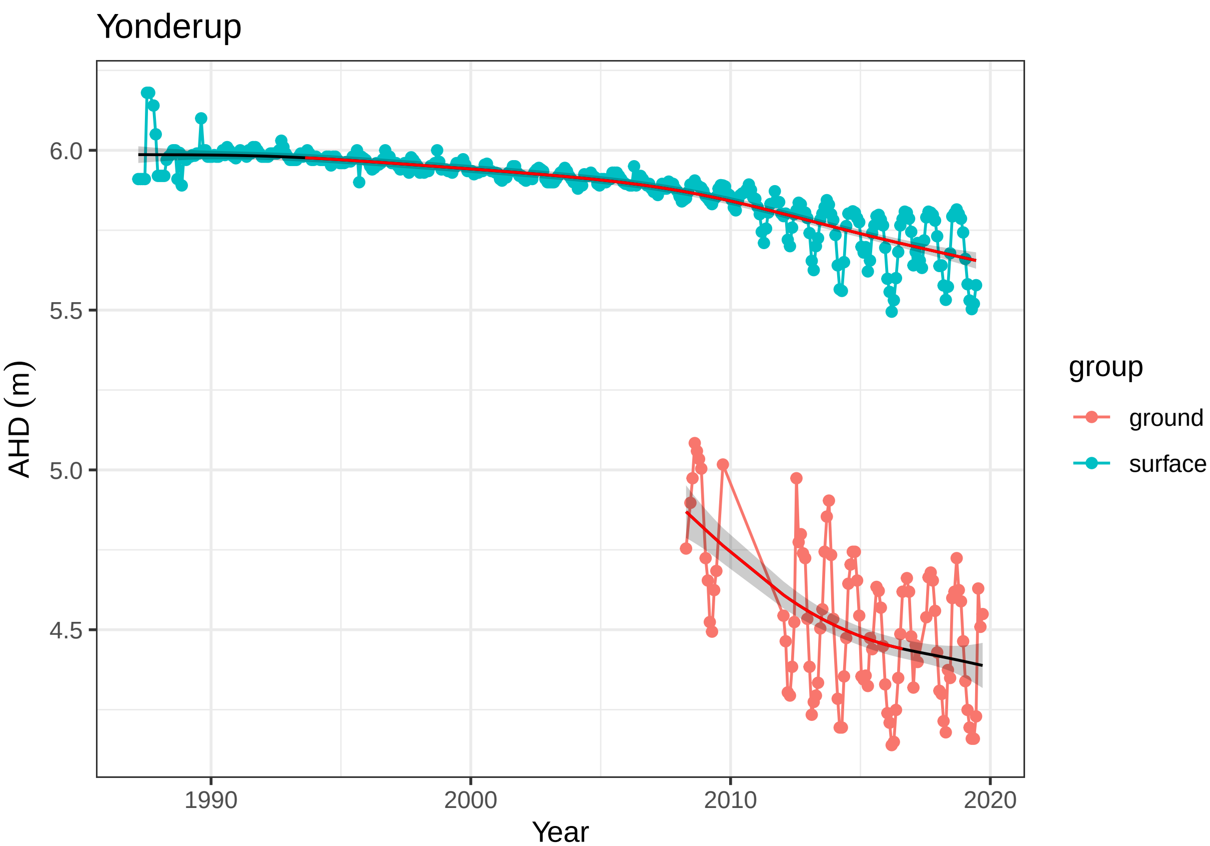

Figure 55: Ground water levels recorded at bore 61611840 (red) and staff gauge 6162565 (blue) in the vicinity of Lake Yonderup. Red segments along trendline indicate preiods of significant decline in ground water levels and blue segments represent significant increases in ground water level.

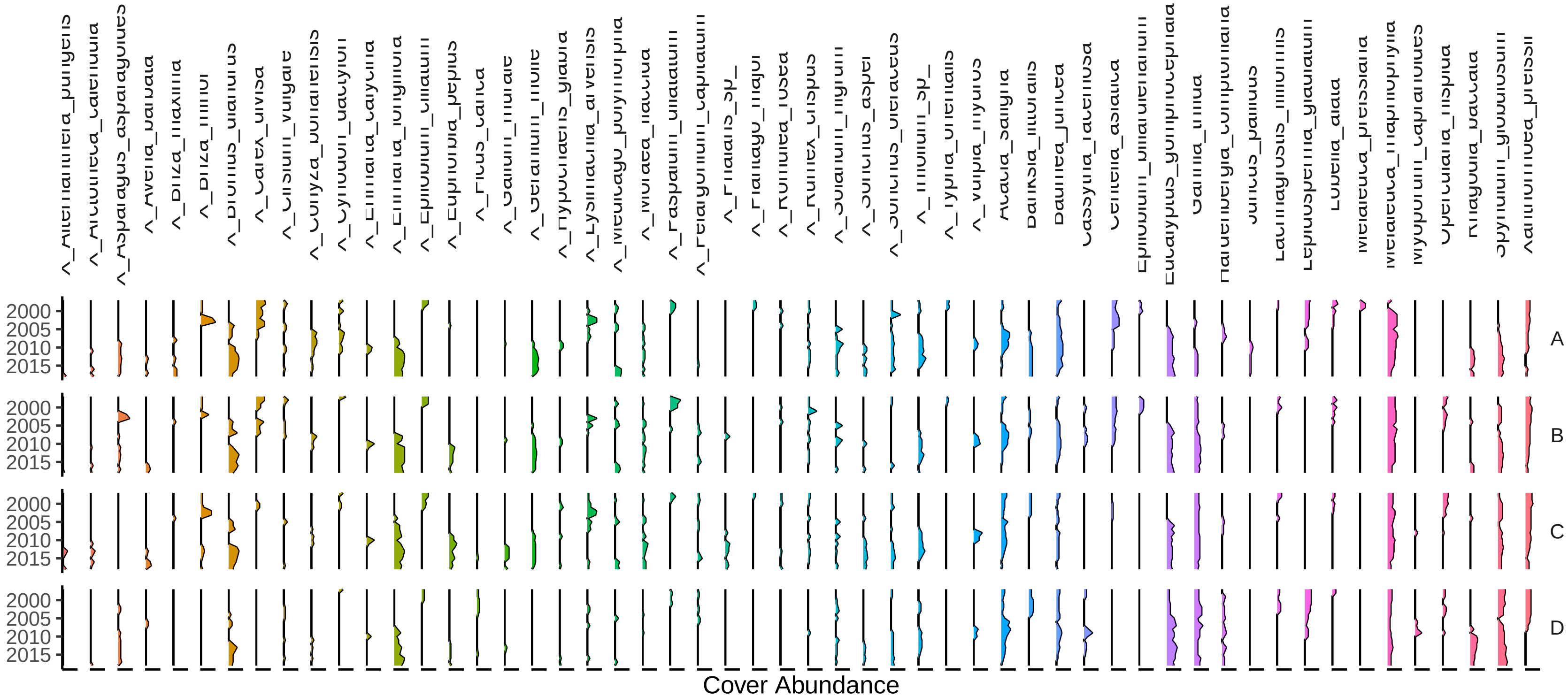

Figure 56: Cover abundances for each species across the four plots (A, B, C, D) at the Lake Yonderup transect. Invasive species are denoted by 'X'. Only the most common species are included.

Summary

Overview

Vegetation

Aquatic Invertebrates

Management objectives

Conclusions

References

#Appendix

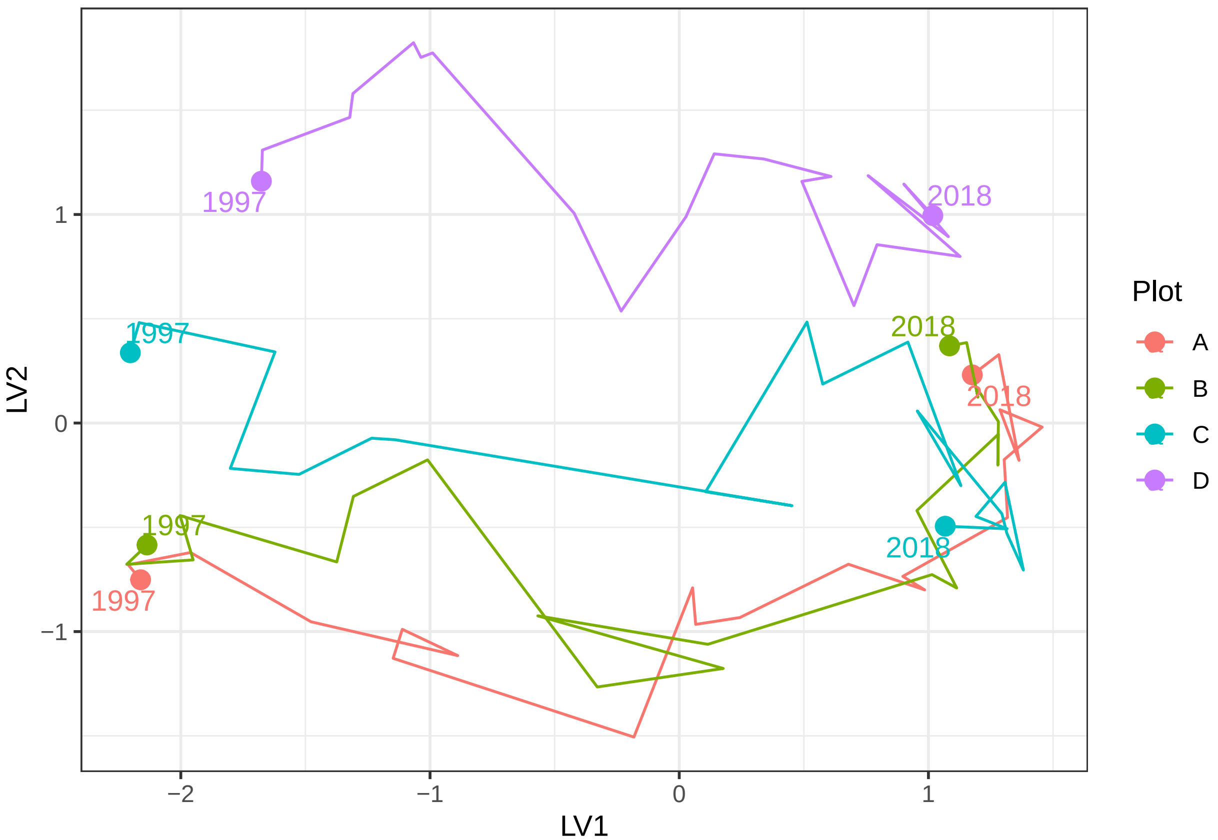

Figure 57: Unconstrained ordination based on the latent variable model for each surveyed year for Lake Yonderup. Plots are represented as different colours and consecutive years are joined by a line with first and last survey years labeled.

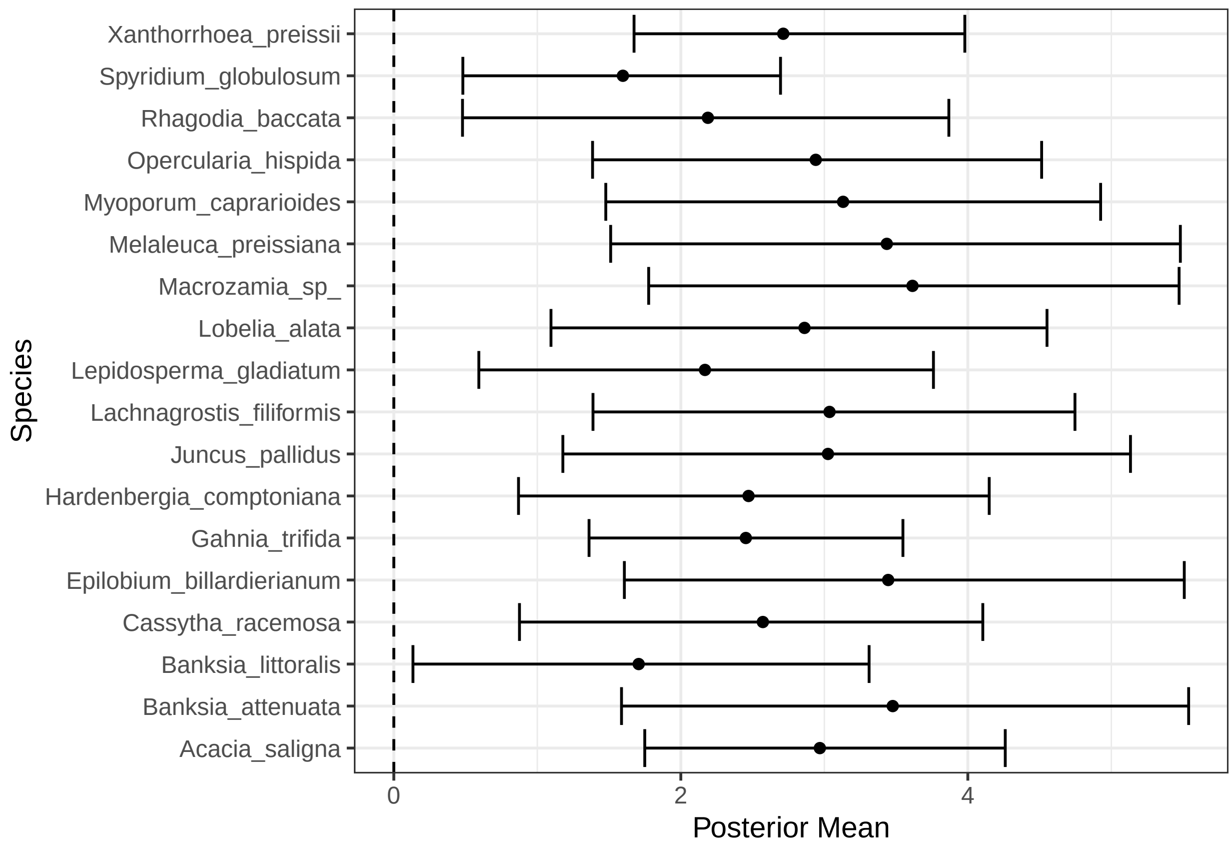

Figure 58: Estimated mean regression coefficients (dots) and 95% credible intervals (bars) for effect of ground water levels at Lake Yonderup on vegetation species cover abundances based on Bayesian Regression Analysis (HUI REF 2015). Species with a negative mean posterior value are likely to increase in cover abundance as water levels decline. Only those species with coefficients significanlty different to zero are shown.