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Detecting the effects of water regime on wetland plant communities: Which plant indicator groups perform best?

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ABSTRACT

Water regime is a primary driver of patterns in wetland vegetation composition. Differences in composition can be used as indicators of differences in water regime. We used vegetation point intercept data collected from 51 wetland monitoring plots in the Blue Mountains, south-eastern Australia, to determine which of three indicator group classifications, growth forms, water plant functional groups (WPFGs) or wetland indicator categories (WICs), demonstrated the most consistent differences between vegetation communities from plot sample groups differing in location (wetland edge or core) and surface water availability (typically inundated or damp). PERMANOVA tests showed significant differences between core and edge plot communities analysed by growth form or WIC relative frequencies, but only when tree canopy data (higher in edge plots, which were abutting woodland) was included. Significant differences in communities (PERMANOVA, $p \leq 0.02$) were detected between inundation categories for all classification methods when tree data were included, but not for WIC data when tree data were excluded. Overall, ordination plots and ANOSIM R values showed the most consistent community-level differences (least overlap in sample groups) between inundation categories when data were classified by WPFGs, followed by growth forms. ANOVA tests on individual indicator group relative frequencies showed that WPFG classification provided the most indicator groups differing significantly in relative frequency between inundation categories, with these groups also collectively comprising a much higher proportion of the total vegetation recorded per plot than the growth forms or WICs that differed between categories.

1. Introduction

Water regime is a primary driver of vegetation zonation and succession in wetlands and the effects of changes in water regime on wetland plant communities can be determined by monitoring changes in species distribution, composition and relative abundance (Downes et al., 2002; Cole and Kentula, 2011). However, in monitoring programmes involving multiple wetlands, variability in species pools can make it difficult to identify differences based on hydrology that are applicable across all sites, especially for wetlands distributed over large geographic areas (Tiner, 1999; Alexander et al., 2008; Casanova, 2011; Campbell et al., 2014). Differences in species pools between wetlands and regions can also prevent application of knowledge gained from individual wetland monitoring programmes to management of wetlands elsewhere, when data are interpreted at the species level only (Tiner, 1999; Casanova, 2011; Campbell et al., 2014). These issues can be overcome by assessing the relative abundance of key vegetation types or functional groups rather than species, provided these groups occur across the region of interest and respond to the relevant driver (such as changing water availability) in predictable ways (Noble and Gitay, 1996; Brock and Casanova, 1997; Campbell et al., 2014).

A variety of classification methods have been used to describe differences in wetland vegetation composition related to hydrology (as summarised by Mountford and Chapman, 1993; Brock and Casanova, 1997; Runhaar et al., 1997; Toner and Keddy, 1997). However, few studies have compared the effectiveness of different vegetation classification methods for summarising differences between sites based on water regime (though see Runhaar et al., 1997). This makes it difficult to determine which classification methods and indicator groups are likely to show the clearest and most broadly-applicable trends; important considerations when selecting target variables for monitoring programmes or other ecological studies comparing wetland or riparian sites distributed over broad spatial scales (Casanova, 2011; Campbell et al., 2014). Another consideration for method selection is how readily classification methods can be applied to new species based on the extent and types of data required, particularly for communities with species that have not been classified previously.

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In this paper, we compare three common vegetation classification methods (classification by growth forms, wetland indicator categories and water plant functional groups) to determine which reveals the most consistent differences in community composition and individual indicator group abundances based on differences in water availability. While alternative indicator group classifications exist, we chose to focus on these three for several reasons. Firstly, the data required for all three classification methods were readily available for species in the selected study system. Secondly, growth form, wetland indicator category and water plant functional group composition and relative abundance have each been specifically correlated with differences in water regime and used to demonstrate broad trends that were applicable across multiple wetland plant communities and regions (Tiner, 1999; Keddy, 2010; Campbell et al., 2014). Finally, these classification methods differ in ease of application based on the types of data required, allowing us to compare the relative merits of indicator groups defined using basic morphology alone (growth forms), field habitat affiliation data only (wetland indicator categories), or data on species growth and survival under different hydrological conditions, derived from controlled experiments and/or field observations (water plant functional groups).

At the growth form level, encroachment of woody species (trees and shrubs) and reductions in sedge, rush and/or aquatic (i.e. floating and submerged) macrophyte abundance due to drying have been demonstrated in a variety of wetland and riparian habitats (Toner and Keddy, 1997; Limpens et al., 2014). Wetland indicator categories defined by frequency of occurrence in wetland vs non-wetland habitats are well established and used to help delineate wetlands at a national scale by government agencies responsible for wetland mapping and management in the United States (Table 1; Reed, 1997; Tiner, 2012), with dominance by hydrophytes, including species in the OBL (obligate wetland habitat), FACW (facultative wetland habitat) and FAC (facultative habitat) wetland indicator categories, considered a defining attribute of wetland vegetation (Reed, 1997; Tiner, 2012). The water plant functional group classification scheme devised by Brock and Casanova (1997) places species into sub-groups within the broader categories 'aquatic', 'amphibious' and 'terrestrial', based on experimental and/or field data that demonstrate how successfully species grow, survive and reproduce under different water regimes. Water plant functional groups have been used in a number of studies, particularly in Australia, to describe differences in wetland or floodplain plant communities correlated with water regime variables (e.g. Reid and Quinn, 2004; Casanova, 2011; Campbell et al., 2014).

We set out to identify indicator species or groups that could be used to detect the effects of drying on plant communities in 51 plots distributed across 23 wetlands on the Newnes Plateau, south-eastern Australia. Specifically, we aimed to determine: (1) how widespread species and indicator groups were amongst the monitoring plots; (2) which classification methods resulted in the largest and most consistent differences (i.e. highest Bray–Curtis dissimilarity and least overlap) between communities based on plot location (wetland edge or core) and surface water availability (typically inundated or damp); and (3) which individual species or indicator groups differed most in relative frequency based on these factors. Based on previous findings we expected that at the individual plant group level, woody growth forms (i.e. trees and shrubs), non-hydrophytic wetland indicator categories and terrestrial water plant functional groups would be more abundant in drier habitats (e.g. typically-damp plots) and at wetland edges, and that sedge, rush and aquatic macrophyte growth forms, hydrophytic wetland indicator categories, and aquatic and/or amphibious water plant functional groups would dominate in typically-inundated habitats and towards the middle of wetlands.

2. Methods

2.1. Study area

The Newnes Plateau is located in the western Blue Mountains, Australia (33°23′S, 150°12′E) and covers an area of approximately 400 km^2, with elevations ranging from approximately 950 to 1200 m above sea level. The climate of the area is mild and temperate with average monthly temperature minima ranging from 1 °C (July) to 13 °C (January/February) and maxima of 11 °C (June/July) to 26 °C (January) (Bureau of Meteorology, 2014). Annual rainfall is approximately 815 mm with average monthly precipitation between 40 and 124 mm and highest rainfall occurring in summer (Bureau of Meteorology, 2014).

The wetland vegetation communities on the plateau, known as Newnes Plateau Shrub and Hanging Swamps (NPSS and NPHS, respectively), have been classified as Endangered Ecological Communities under both State and Commonwealth government legislation (Threatened Species Scientific Committee, 2005). NPSS and NPHS share many species, primarily differing in landscape position and extent of tree cover (DEC, 2006). NPSS occur on valley floors and drainage lines and typically lack tree cover, while NPHS occur on hill slopes in groundwater seepage areas and often contain trees (DEC, 2006). Both communities contain waterlogging-tolerant shrub species (from the families Myrtaceae, Ericaceae and Proteaceae), with an understorey typically dominated by sedges and rushes (DEC, 2006; Benson and Baird, 2012). Species composition and vegetation structure vary both within and between NPSS and NPHS vegetation communities (Benson and Baird, 2012; Brownstein et al., 2015). Soils in these wetlands consist of permanently to periodically saturated peat and humic loams overlying sandstone substrates (DEC, 2006; Benson and Baird, 2012). Water regimes in these swamps are driven by a combination of groundwater and rainfall flows, with water depth and stability varying with catchment size and the extent of groundwater input. Some swamps are characterised by constant waterlogging and/or shallow surface inundation, with high water tables maintained by groundwater inflows, while in others water tables fluctuate more extensively, tracking recent rainfall (Benson and Baird, 2012; Centennial Coal, 2014c).

A number of factors may affect the water regimes in Newnes Plateau swamps, including climatic drought; modifications to drainage due to roads and infrastructure; sedimentation and erosion due to neighbouring land uses; mine water discharges into headwater streams and swamp systems; or landform deformation and/or cracking of aquitards, due to subsidence from underground long-wall mines (Benson and Baird, 2012). Piezometer, flora and site condition data have been collected from a number of wetlands across the plateau over the last decade for environmental monitoring of underground coal mines in the area (Benson and Baird, 2012,c; Centennial Coal, 2014a,b,c,c). Monitoring to assess the extent of changes in hydrology over time is primarily based on piezometer data, collected before and after undermining in each swamp. Vegetation monitoring is used to determine if any changes in hydrology that occur have an effect on the endangered wetland plant communities and is conducted both before and after mining in undermined swamps and at corresponding times in non-undermined reference swamps.

2.2. Sampling design

We used a point intercept method (Elzinga et al., 1998) to collect species composition and frequency data from within 51 established vegetation monitoring plots across 23 Newnes Plateau swamps in spring 2012. For individual plot locations, refer to Table S1 in