Montane mire vegetation of the New England Tablelands Bioregion of Eastern Australia

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Abstract

Aims: To use unsupervised techniques to produce a hierarchical classification of montane mires of the study region. Study area: New England Tablelands Bioregion (NETB) of eastern Australia. Methods: A dataset of 280 vascular floristic survey plots placed across the variation in montane mires of the NETB was collated. Vegetation types were identified with the aid of a clustering method based on group averaging and tested using similarity profile analysis (SIMPROF) and through ordinations using Bray-Curtis similarity and non-metric multidimensional scaling (NMDS). A hierarchical schema was developed based on EcoVeg hierarchy and was circumscribed using positive and negative diagnostic taxa via similarity percentage analysis (SIMPER) and importance based on summed cover scores and frequency. Results: We defined one macrogroup to include all montane mire vegetation of the NETB and within these two groups and twelve alliances. Conclusions: Our study re-enforced the separation of bogs from other montane mire systems and confirmed the separation of fens and wet meadows, a distinction that previously had not been independently tested. Based on our results many existing montane mire communities of the NETB have been ill-defined at multiple hierarchical levels, leading to confusion in threat status and mapping. Additionally, nearly half of the alliances we recognise were found to have no correlates within current classification systems, which necessarily has implications for the effectiveness of current conservation planning.

Taxonomic reference: PlantNET (http://plantnet.rbgsyd.nsw.gov.au/, accessed June 2016).

Abbreviations: BC Act = Biodiversity Conservation Act; EPBC Act = Environmental Protection and Biodiversity Act; NETB = New England Tablelands Bioregion; NMDS = non-metric multidimensional scaling; PCT = plant community type; RE = regional ecosystem; SIMPER = similarity percentage analysis; SIMPROF = similarity profile analysis.

Keywords

Australia, bog, EcoVeg, fen, marsh, New England Tableland Bioregion, similarity percentage analysis (SIMPER), wet meadow, unsupervised classification

Introduction

The first step in understanding the distribution, rarity and interrelationships of vegetated systems is description and classification (Franklin et al. 2016; Jensen et al. 2016). This is particularly true for systems that are under greatest threat and impact from human activities and which provide significant ecosystem services. Unfortunately, vegetation within many areas of the globe have poor survey coverage and/or inconsistent survey protocols, leading to insufficient or poor data hampering classification (Gellie et al. 2017; De Cáceres et al. 2018). Even within areas considered relatively well surveyed, many highly restricted and/or ephemeral systems are likely to be poorly sampled and incompletely treated within current classification systems, leading to misunderstandings of their
placement, function, importance and rarity (Hunter and Hunter 2017; Hunter and Lechner 2017). Not all classification systems are hierarchical in nature, and many have no clear analytical proof of conceptual links (De Cáceres et al. 2018; Gellie et al. 2017). Ideally, hierarchical classification systems facilitate integrated understanding of relationships between vegetation assemblages and also allow conceptualisations at different ranks to match scales at which management and investigations may be applied, from local to global (Faber-Langendoen et al. 2018).

Australia is a dry continent, and thus, the more common and widely distributed wetlands are those that are impermanent in nature; that is, they may ‘wet-up’ once a year, multiple times a year or once within several decades, often not associated with seasonal patterns, but are dry more often than they are wet (Paijmans et al. 1985; Bell et al. 2008; Bell et al. 2012; Hunter and Lechner 2017). Such wetlands may contain shallow water less than 2 m depth, but more commonly only have saturated soils or seasonally standing water a few centimetres depth. Montane areas within Australia are limited and thus montane wetlands, in particular, are sparsely distributed and rare within the continent and poorly sampled across their range (Wahren et al. 1999; Whinam and Hope 2005).

The montane region bordering northern New South Wales and south east Queensland has been defined as the New England Tableland Bioregion (NETB) based on its unique biological and environmental elements (Thackwell and Creswell 1995). The Hunter Valley to the south of the NETB creates a break in the Great Dividing Range and separates the NETB from more southern montane environments in south eastern Australia. Within the NETB a number of semi-permanent and ephemeral mire systems locally known as bogs, fens, lagoons (marshes) and sod tussock grasslands (wet meadows) occur (Hunter and Bell 2007; 2009; Bell et al. 2008; Hunter and Hunter 2016a). Whinam and Chilcott (2002) showed through unsupervised analyses of floristic plots that the NETB bogs were dissimilar floristically from other montane bogs further south in eastern Australia. Hunter and Hunter (2016) also highlighted the distinct floristic differences between montane sod tussock grasslands (wet meadows) and those of other south eastern Australian montane districts. Lechner et al. (2016), in an analysis of environmental data associated with montane wetlands, found the NETB was largely encompassed by a unique montane wetland ecoregion.

Bogs of the NETB are characterised by altitudes above 850 m a.s.l, commonly on nutrient poor sites with low pH, saturation occurring seasonally or sporadically, and shallow standing water infrequent (Hunter and Bell 2007) (Suppl. material 1: Plate 1). Peat often forms but is largely created by sedge debris and at times Sphagnum (Hunter and Bell 2007; Hunter and Bell 2013; Hunter 2016a). Due to frequent fires, peat accumulation is often thin but can develop to depth where fires are excluded for long periods of time (Hunter and Bell 2007). These systems are largely dominated by cyperaceous taxa with a distinct component of woody shrubs species usually 0.5–1.5 m in height (Myrtaceae, Fabaceae, Proteaceae and Ericaceae) (Hunter and Bell 2007).

Fens within the NETB are found along watercourses and flat to concave valley floors generally associated with mineral rich substrates (Hunter and Bell 2009) (Suppl. material 1: Plate 1). Fens are dominated by softer leaved sedges, grasses and herbs and do not have a woody shrub component within the NETB (Hunter and Bell 2009). Peat accumulation can occur but is largely based on cyperaceous materials and soil pH is slightly acidic to neutral. Overall fens are far more common within the NETB but are much less common within the national reserve system (Hunter 2013).

Lagoons within the NETB may be best described as semi-permanent or ephemeral marshes (Bell et al. 2008) (Suppl. material 1: Plate 1). Unlike the other wetlands they are generally oval in shape and are distinguished by having a well-defined bank with a sandy lunette on their downwind shores formed under previous climatic conditions (Bell et al. 2008). Only 58 of these ephemeral marshes are known within the NETB and these are restricted to the top of the Great Dividing Range almost exclusively on basalt soils (Bell et al. 2008). Ephemeral marshes differ in depth and duration of inundation but water, when present, is less than 1.5 m deep and never persistent. The lagoons have very localised catchments often only a few hundred hectares in size or less and thus inundation is often unpredictable and reliant on very localised rainfall often unrelated to regional rainfall averages or season. Due to longer and deeper inundation, the ephemeral marshes, unlike the other wetland systems on the NETB, can support free floating and aquatic vegetation usually >20% vegetation cover (Bell et al. 2008; Hunter 2016a).

The sod tussock grasslands would likely be classed as spring fed and floodplain wet meadows within the mire classification (van Diggelen et al. 2006; Hunter and Hunter 2016) (Suppl. material 1: Plate 1). Wet meadows of the NETB occur within lower physiographic positions and frost hollows generally on higher nutrient soils which are seasonally damp or inundated with a few centimetres of water (Hunter and Hunter 2016).

Within the state of New South Wales, vegetation has been described into units called plant community types (PCTs), which are considered an equivalent to an association level of nomenclature (Benson et al. 2010) and used to assign conservation significance and threat. PCTs are based on a mixture of supervised and semi-supervised techniques (Gellie et al. 2017), and they have been subsequently placed within an independently derived hierarchical system of classes and formations (Keith 2004). As these classes and formations are circumscribed largely by supervised methods, and independently from PCTs, the interrelationships between the two systems and thus the placement of PCTs within formations and classes has been achieved by expert opinion without independent statistical testing (Gellie et al. 2017). The circumscription of associations within mires of the NETB have been either poor, misinterpreted, inconsistent or missed entirely.
within state-based vegetation classifications (Hunter and Bell 2007; 2009; Hunter and Hunter 2016). For instance, though Groves (1981) described a *Glyceria australis* wet grassland, no such PCT has been formally included in summaries of vegetation types for the NETB by Benson et al. (2010), nor wet meadows been included within state wide classes and formations (Keith 2004). Only four PCTs currently circumscribe the range of fens, bogs and lagoons found within the NETB (Benson et al. 2010).

Currently within certain Australian jurisdictions the development of vegetation community types is based almost solely on floristic classification techniques with little or no influence of environmental factors, although types may contain environmental terms as descriptors secondarily to floristics (Sivertsen 2009; Environmental Protection Authority 2016; Gillie et al. 2018). Although this has not always been the case due to poor plot data coverage within New South Wales, any new proposed associations need proof of floristic distinctiveness via unsupervised analyses. Floristic distinctiveness via unsupervised analysis is now a requirement that also applies for listings of threatened ecological communities on both the Federal *Environmental Protection and Biodiversity Act* and the New South Wales *Biodiversity Conservation Act*. Thus, currently for both general classification purposes and for endangered community listings floristic distinctiveness by analysis is removed from ecological distinctiveness and is generally the only method of recognition of types.

A concerted and comprehensive effort has been placed on plot-based sampling of the montane wetlands of the NETB in order to describe phytosociological units through unsupervised means (Bell et al. 2008; Hunter and Bell 2007; 2009; Hunter and Hunter 2016). Using the plot-based data and unsupervised floristic analyses, these studies describe 28 phytosociological assemblages equivalent to associations (Hunter and Bell 2007; Bell et al. 2008; Hunter and Bell 2009; Hunter and Hunter 2016). The majority of these associations are not encompassed within formal PCTs (Benson et al. 2010) and many are difficult to place within current published classes and formations (Keith 2004). However, these recent investigations into NETB mires have been conducted in isolation of each other and there is a need to provide an understanding of their interrelationships and to formally place them within an unsupervised hierarchy. Here we provide a plot-based analysis of mire assemblages within the NETB, to provide a formal understanding of the floristic relationships between the types and derive from analysis a hierarchical classification above that of association for the mires within the NETB.

**Methods**

**Study area**

The study region encompasses the New England Tablelands Bioregion (NETB; 30,000 km²; Figure 1) which lie on the Great Dividing Range in eastern Australia. The NETB is largely restricted to north-east New South Wales but extends into south eastern Queensland with altitudes ranging from 700 to 1500 m a.s.l. The region has a strong west-east rainfall gradient (600–2500 mm) with easterly airflows from the Pacific Ocean causing orographic influences in the east (Resource and Conservation Assessment Council 1996).

**Figure 1.** Location of the New England Tablelands Bioregion within Australia and location of 280 full vascular floristic survey plots.

**Field sampling**

Data from 280 full vascular floristic survey plots were collected from wetlands within the NETB. The plots were sampled on public lands, where possible first preference was to occurrences within state conservation reserves and secondarily within private reserves or travelling stock reserves. Conservation reserves are un-grazed by non-native animals while travelling stock reserves are only periodically grazed by state government authorities. Thus non-native animal grazing was absent or minimal and tightly controlled. Standard plot sizes were 20 m × 20 m. Species were scored using a six-point modified Braun-Blanquet system based on percentage foliage cover (Westhoff and van der Maarel 1980): 1 = 1–5% cover, uncommon; 2 = 1–5% cover, common; 3 = 6–25%; 4 = 26–50%; 5 = 51–75% and 6 = >75%. Plots where placed across the study area over a ten-year period between 2008 and 2018 within spring and summer. All plots were scored...
for general wetland type (bog, fen, sod grassland, lagoon), and location and altitude were based on global positioning system (GPS). All plot data has been submitted for hosting in version 3 of sPlot (Bruelheide et al. 2019; https://www.divi.de/?id=1768&L=0) and is listed on GIVD as AU-AU-003 (https://www.givd.info/databases.xhtml). No new data has been collected for this research with only existing data collected by the authors and previously published separately being used (see Hunter and Bell 2007; Bell et al. 2008; Hunter and Bell 2009; Hunter and Hunter 2016; Hunter 2018). Further details of the wetland types investigated, stratification and how data was collected for each survey is contained within these previous publications including information on species richness, elevation, vegetation cover and height, synoptic tables and photographs for each defined association.

Statistical analysis

Primer E (ver. 7.0.11; Quest Research Limited; Ivybridge, Devon, UK) was used for data exploration, whereby an initial triangular resemblance matrix using Bray-Curtis similarity co-efficient was created without transformation, as the Braun-Blanquet scoring was considered a pre-treatment. Non-metric multidimensional scaling (NMDS) in two and three dimensions was also created. Clustering was achieved through group averaging and the similarity profile tested using similarity profile analysis (SIMPROF) permutation tests (999 iterations). SIMPROF tests the statistical significance of every node within a dendrogram starting from the top of the dendrogram and (all points within a single group) and highlighting only those groups which show within group multivariate structure. The EcoVeg approach (Faber-Langendoen et al. 2014) was used to define hierarchical levels and guide the nomenclatural of the types. The type and density of data available allowed for the circumscription of vegetation types at the medial scales of group and alliance with associations derived from previous published analyses of the same data.

Similarity percentage analysis (SIMPER) identifies the species driving differences between selected types. SIMPER uses the Bray–Curtis similarity measure (Primer E ver. 7.0.11; Quest Research Limited; Ivybridge, Devon, UK) to identify positively and negatively diagnostic taxa across vegetation types. Taxa with combined high fidelity and cover were also identified and listed for diagnostic purposes and type delineation. Attempts to place current eastern Australian state based noncultural units was derived by comparing diagnostic and non-diagnostic taxa from SIMPER results.

The results of our analyses were used to define mid to lower level classification levels (macrogROUP, group and alliance) based on EcoVeg terminology. It should be noted that although EcoVeg uses the alliance and association as does the Braun-Blanquet approach, the nomenclatural and procedural roles are distinct. Previous unsupervised cluster analyses using Kulzynski similarity measure have been performed and published on subsets of these datasets defining vegetation units at approximately the association level (see Hunter and Bell 2007; Bell et al. 2008; Hunter and Bell 2009; Hunter and Hunter 2016; Hunter 2018). It is the intention of this analysis to define hierarchical levels above association using the combined datasets from these previous investigations.

Results

Collectively, all mires within the NETB were defined as NETB montane mires (Level 5 – macrogroup) (Table 1). Our analyses support the separation of bogs, fens and wet meadows as broadly distinct units (Figures 2–4). Plots sampled within ephemeral marshes did not form a consistent group in either 2 or 3 axis results and were distributed throughout the non-bog plots (Figures 2–4). Both SIMPROF cluster analysis and NMDS ordination highlight a clear separation of bogs from that of the other types of mires within the NETB (Figures 2, 3). Bogs are floristically and often structurally distinct, being the only mire type on the NETB with a prominent shrub layer (Figure 5, Table 1). This high-level separation is considered appropriate for delineating at Level 6 – Group and thus two groups have been delineated; Baeckea omissa – Lepidosperma limicola NETB montane bog mires and Glyceria australis – Carex gaudichaudiana NETB fen, wet meadow and ephemeral marsh mires (Table 1).

Splicing the dendrogram at a similarity of 16, we further defined 12 alliances all of which are delineated at a level which shows statistical evidence of multivariate structure via SIMPROF (Figure 2; Suppl. material 1), two within the Baeckea omissa – Lepidosperma limicola NETB montane bogs and 10 within the Glyceria australis – Carex gaudichaudiana NETB fen, wet meadow and ephemeral marsh mires (Table 2). General environmental data and average species richness is given in Table 3 while the percent frequency of occurrence synoptic results of the most frequent taxa are presented in Table 4 (full table in Suppl. material 2).

A comparison of the placement of NETB montane mires with the currently published classification systems (PCT, class, formation, RE) shows only some congruence with our results (Table 2). The NETB montane mires would be placed within two formations and at least three class categories with some types unable to be clearly assigned. Seven of our 12 Alliances are not adequately circumscribed by current PCTs within New South Wales. Only one Queensland Regional Ecosystem (RE) describes montane mires within the NETB and this unit may cover three of our alliances, leaving three that are known to occur in this jurisdiction but uncategorized.

Discussion

We have successfully applied a consistent classification section to montane mire vegetation within the NETB using unsupervised techniques which have highlighted a number of differences with the current classifications used within eastern Australia. Although the EcoVeg approach
Table 1. Circumscription of mires of the New England Tableland Bioregion (NETB) of eastern Australia. Descriptions include positive and negative diagnostic and negatively associated species, common dominant taxa (based on cumulative frequency and cover) and notes for each unit. Positive diagnostic species are listed in order of decreasing contribution to group identity. Common taxa are listed in decreasing order of cumulative frequency and cover within each identified group.

| Hierarchy | Positive diagnostic (SIMPER) | Negative diagnostic (SIMPER) | Common taxa | Notes and distribution |
|-----------|------------------------------|-----------------------------|-------------|------------------------|
| Macrogroup: | Baeckea omissa, Glyceria australis, Leptospermum gregarium, Carex gaudichaudiana | NA | NA | Restricted to the NETB commonly at altitudes above 800 m and rainfall above 700 mm per annum |
| | Scientific Name: Baeckea - Carex – Glyceria mires. | | | |
| | Colloquial: New England Tableland montane mires | | | |
| Group 1: | Baeckea omissa, Epacris microphylla, Leptospermum gregarium, Gonocarpus micranthus, Goodenia bellidifolia, Baloskion stenocoleum, Lepidosperma limicola, Callistemon ptyoidae, Hakea microcarpa, Entalasia stricta | Glyceria australis, Carex gaudichaudiana, Carex appressa, Poa sieberiana, Pennisetum alopecuroides, Epilobium bilardierianum, Stellaria angustifolia | Baeckea omissa, Epacris microphylla, Baloskion stenocoleum, Lepidosperma limicola, Goodenia bellidifolia, Leptospermum gregarium, Gonocarpus micranthus, Lepadodia scariosa, Leptospermum arachnoideas, Callistemon ptyoidae | Commonly found on nutrient poor soils with low pH. Often with a prominent shrub layer and forming a peat layer. Often on granite, acid volcanic and metasedimentary rock types |
| | Scientific Name: Baeckea omissa – Lepidosperma limicola New England Tableland montane bog mires | | | |
| Alliance 1-1: | Baeckea omissa, Epacris microphylla, Leptospermum gregarium, Gonocarpus micranthus, Goodenia bellidifolia, Baloskion stenocoleum, Lepidosperma limicola, Callistemon ptyoidae, Hakea microcarpa, Entalasia stricta | Aristida juncea, Carex appressa, Schoenus bullatus, Caustis flexuosa, Tristemma flexuosum, Tristemma pedunculatum, Melichrus proculum | Lepidosperma limicola, Baeckea omissa, Thelionema caespitosa, Drosera binata, Caustis flexuosa, Tristemma parviflora, Schoenus brevisculus, Geranium solandri | Commonly found along the entire eastern half of NETB in higher rainfall areas. Structurally a shrubby sedgeland or sedgeland |
| | Scientific Name: Baeckea omissa – Epacris microphylla shrubby bog | | | |
| Alliance 1-2: | Lepidosperma gunnii, Carex gaudichaudiana, Schoenus distichum, Lepidosperma limicola, Schoenus strictus, Thelionema caespitosa, Austrostipa pubescens | Callistemon ptyoidae, Baloskion stenocoleum, Hakea microcarpa, Entalasia stricta | Lepidosperma limicola, Xyris operculata, Epilobium scarisoa, Drosera binata, Drosera spatulata, Baloskion clinostomum, Amphipogon strictus, Thelionema caespitosa, Caustis flexuosa | Generally restricted to the higher rainfall extreme north east of the NETB. Sometimes with a dominant shrub layer. Structurally a sedgeland or shrubby sedgeland |
| | Scientific Name: Lepidosperma gunnii – Lepidosperma limicola/herbaceous bog | | | |
| Group 2: | Glyceria australis, Carex gaudichaudiana, Juncus australis, Carex appressa, Poa sieberiana, Geranium solandri, Pennisetum alopecuroides | Baeckea omissa, Lepidosperma limicola, Leptospermum gregarium, Gonocarpus micranthus, Goodenia bellidifolia, Leptadodia scariosa, Callistemon ptyoidae, Entalasia stricta, Xyris complanata, Bignonia spinulosa, Epacris obtusifolia, Xyris operculata | Glyceria australis, Carex gaudichaudiana, Carex appressa, Poa sieberiana, Geranium solandri, Pennisetum alopecuroides, Juncus australis, Carex disticha, Epilobium bilardierianum, Isachne globosa, Stellaria angustifolia, Themeda triandra | Commonly found nutrient rich sites with moderate to high pH. Shrubs rarely present and dominated by sedges, grasses and forbs. Usually restricted to basalt or higher nutrient metasedimentary rock types. Often forming a peat layer |
| | Scientific Name: Glyceria australis – Carex gaudichaudiana New England Tableland fen, wet meadow and ephemeral marsh mires | | | |
| Alliance 2-1: | Carex appressa | Carex appressa | Carex appressa, Poa sieberiana, Geranium solandri, Pennisetum alopecuroides, Juncus australis, Carex disticha, Epilobium bilardierianum, Isachne globosa, Stellaria angustifolia, Themeda triandra | Carex appressa, Carex gaudichaudiana, Eleocharias acuta, Geranium solandri, Stellaria angustifolia, Pennisetum alopecuroides, Juncus australis, Haloragis heterophylla, Epilobium bilardierianum | Commonly found on medial to lower rainfall areas of the NETB within central and western areas. A sedgeland |
| | Scientific Name: Carex appressa herbaceous fen | | | |
| Alliance 2-2: | Carex gaudichaudiana, Isachne globosa, Epilobium bilardierianum, Stellaria angustifolia, Geranium solandri, Cyperus spheroideus | Isachne globosa, Scirpus polytachyus, Viola caleyana, Lycopus australis, Baloskion stenocoleum, Lythrum salicaria | Carex gaudichaudiana, Isachne globosa, Epilobium bilardierianum, Stellaria angustifolia, Geranium solandri, Carex appressa, Scirpus polytachyus, Carex disticha, Lythrum salicaria, Cyperus spheroideus, Baumea planifolia | More commonly found within higher rainfall areas of the NETB, particularly in the eastern half. A sedgeland |
| | Scientific Name: Carex gaudichaudiana – Isachne globosa herbaceous fen | | | |
| Hierarchy | Positive diagnostic (SIMPER) | Negative diagnostic (SIMPER) | Common taxa | Notes and distribution |
|-----------|-----------------------------|-------------------------------|-------------|-----------------------|
| **Alliance 2-3:** | **Scientific Name:** Phylirum lanuginosum – Potamogeton tricarinatus | **Phylidium lanuginosum – Potamogeton tricarinatus, Gymnoz areal, Carex areal, Lythrum salicaria** | Elytrichia pusilla, Gymnoz areal, Phylidium lanuginosum, Potamogeton tricarinatus, Lythrum salicaria | Found on wet mud and retreat lagoon margins and around the margins of ephemeral marshes and fen |
| **Alliance 2-4:** | **Scientific Name:** Lachnagrostis filiformis | **Lachnagrostis filiformis** | Myriophyllum variifolium, Eleocharis acuta | Found on wet mud and retreat lagoon margins and around the margins of ephemeral marshes and fen |
| **Alliance 2-5:** | **Scientific Name:** Myriophyllum variifolium – Eleocharis acuta | **Myriophyllum variifolium, Eleocharis acuta, Lachnagrostis filiformis** | Myriophyllum variifolium, Eleocharis acuta, Lachnagrostis filiformis | Almost exclusively found on basalt substrates at the top of the Great Dividing Range within the central areas of the NETB. Primarily restricted to ephemeral lagoons. A herbfield or sedgeland |
| **Alliance 2-6:** | **Scientific Name:** Glyceria australis | **Glyceria australis** | Glyceria australis, Pennisetum alpicepulae | Found throughout but more common within central areas of the NETB. A wet tussock grassland |
| **Alliance 2-7:** | **Scientific Name:** Juncus areal – Cyperus papyrus | **Juncus areal** | Juncus areal, Carex areal | Found in open cold air drainage areas on the margins of damper wet meadows and on the upper margins of lagoons as a tussock grassland or fen |
| **Alliance 2-8:** | **Scientific Name:** Carex tereticaulis – Asperula conferta | **Asperula conferta, Carex tereticaulis, Hydrocotyle laxiflora** | Carex tereticaulis, Asperula conferta, Glyceria australis | Found on sandy soils sometimes associated with the drier margins of ephemeral lagoons or around drier margins of wet meadows. A wet tussock grassland or fen |
| **Alliance 2-9:** | **Scientific Name:** Poa sieberiana – Themeda triandra | **Poa sieberiana, Themeda triandra** | Carex gaudichaudiana, Cyperus gramineus | Found in cold frost drainage valley floors that are periodically damp and around the margins of wetter meadows such as Alliance 2-6 and lagoon margins. A wet tussock grassland or fen |
| **Alliance 2-10:** | **Scientific Name:** Leptorrhynchos squamatus – Schoenus apogon | **Leptorrhynchos squamatus, Schoenus apogon** | Carex tereticaulis, Asperula conferta, Glyceria australis | Found restricted to lagoons that are largely dry for extended periods and often only become damp rather than inundated. A herbfield or wet tussock grassland |
Table 2. Comparison with existing hierarchical classifications within eastern Australia. Plant Community Types (PCT), class and formation are part of the current New South Wales vegetation classification schema and Regional Ecosystems are what are the Queensland equivalent of association.

| Hierarchy | PCT (Benson et al. 2010) | Class (Keith 2004) | Formation (Keith 2004) | Regional Ecosystem (Sattler and Williams (1999)) |
|-----------|-------------------------|--------------------|------------------------|-----------------------------------------------|
| Macrogroup: New England Tableland montane mires | | | | |
| **Group 1**: Baeckea omissa – Lepidosperma limicola New England Tableland montane bog mires | | | | |
| **Alliance 1**: Baeckea omissa – Epacris microphylla shrubby bog | PCT 607: Montane bogs (in part); 518: Heath swamps wetland on leucogranite and granite (not in Benson et al. 2010) | Montane Bags & Fens | Freshwater Wetlands | Regional ecosystem ‘13.12.7’ – Sedgeland along small drainage lines and soaks at high altitude |
| **Alliance 1**: Lepidosperma gunnii – Lepidosperma limicola herbaceous bog | PCT 582: Sedgeland fens wetland of impeded drainage | Montane Bags and Fens | Freshwater Wetlands | NA |
| **Group 2**: Glyceria australis – Carex gaudichaudiana NETB fen, wet meadow and ephemeral marsh mires | | No equivalent | Temperate Montane Grasslands | No equivalent |
| **Alliance 2**: Carex appressa herbaceous fen | PCT: 574 Tea-tree riparian shrubland/heathland wetland | Montane Bags and Fens | Freshwater Wetlands | Regional ecosystem ‘13.12.7’ Sedgeland along small drainage lines and soaks at high altitude |
| **Alliance 2**: Carex gaudichaudiana – Isachne glabella herbaceous fen | PCT 582: Sedgeland fens wetland of impeded drainage | Montane Bags and Fens | Freshwater Wetlands | NA |
| **Alliance 2**: Phyllocladus lanuginosus – Potamogeton tricarinatus herbaceous ephemeral marsh and fen | | No equivalent | Montane Lakes | Freshwater Wetlands | NA |
| **Alliance 2**: Lachnanthes filiformis herbaceous wet meadow or marsh | | No equivalent | Montane Lakes | Freshwater Wetlands | NA |
| **Alliance 2**: Myriophyllum varifolium – Eleocharis acuta herbaceous ephemeral marsh | PCT 500. Upland wetlands | Montane Lakes | Freshwater Wetlands | NA |
| **Alliance 2**: Glyceria australis grassy wet meadow | | No equivalent | Temperate Montane Grassland | No equivalent |
| **Alliance 2**: Juncus australis – Carex tereticaulis – Asperula conferta fen and wet meadow | | No equivalent | No equivalent | NA |
| **Alliance 2**: Carex tereticaulis – Asperula conferta fen and wet meadow | | No equivalent | No equivalent | No equivalent |
| **Alliance 2**: Poo sieberiana – Themeda triandra grassy wet meadow | PCT 586: Snow Grass – Swamp Foxtail tussock grassland sedgeland | Temperate Montane Grassland | Grassland | No equivalent |
| **Alliance 2**: Leptorrhynchus squamatus – Schoenus apogon herbfield | | No equivalent | No equivalent | No equivalent |

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typically considers ecological criteria, this is currently not the accepted general practice used in defining vegetation types within New South Wales or for state and federal listings of threatened communities. We believe our classification allows a better and more consistent understanding of the floristic relationships between these montane wetland types that co-occur within the NETB. The current New South Wales classification schema includes bogs and fens within the same class separate from wet meadows (Keith 2004). Our results and those of Hunter (2016a) show
Figure 4. NMDS ordination Segmented bubble plot of the six species with a Pearson correlation greater than 0.5. Segment sizes are proportional to the Braun-Blanquet score given to each species within plots (0–6).

Figure 5. Broad wetland types found within the New England Tablelands Bioregion. A) Bog, B) Fen, C) Lagoon in its more common dry phase, D) Sod Tussock Grasslands.

a clear differentiation between bogs and other wetland types within the NETB.

Previous research has shown that bogs within the NETB are ecologically and functionally distinct dominated by taxa with traits dissimilar to those of the sympatric other wetland types such as fens and wet meadows (Hunter 2016a). Bogs form generally on low nutrient and acid soils with fire as a more frequent disturbance due to the dominance of oil-bearing resprouting shrub species. Bogs are the only wetland types to more consistently allow de-
Table 3. Comparison of species density and general environmental data for each alliance.

| Hierarchy | Scientific Name | Mean species density per 400 m² | Elevation (m a.s.l.) | Mean vegetation height (m) | Water depth (m) | Rock type |
|-----------|----------------|-------------------------------|---------------------|---------------------------|-----------------|-----------|
| Alliance 1-1: | Lepidosperma gunnii – Lechnaagrostis filiformis | 27 | 940–1372 | 0.2–6 | 0–0.2 | Granite, acid volcanic, basalt |
| Alliance 1-2: | Schoenus apogon | 22 | 920–1040 | 0.2–3 | 0–0.2 | Granite |
| Alliance 1-3: | Carex appressa | 18 | 446–1120 | 0.3–1.2 | 0–0.2 | Granite, metasediment, acid volcanic, basalt |
| Alliance 1-4: | Carex appressa | 18 | 780–1400 | 0.3–1 | 0–0.2 | Granite, metasediment, basalt, sediment |
| Alliance 2-1: | Lepidosperma gunnii | 14 | 800–1000 | 0.1–1 | 0–0.5 | Granite |
| Alliance 2-2: | Lepidosperma gunnii | 10 | 800–1300 | 0.1–1 | 0 | Basalt, granite |
| Alliance 2-3: | Myriophyllum varifolium | 13 | 1040–1400 | 0.1–1 | 0–1.5 | Basalt, granite |
| Alliance 2-4: | Glyceria australis | 11 | 700–1400 | 0.2–1.2 | 0–0.2 | Granite, metasediment, acid volcanic, basalt, shale, sediment |
| Alliance 2-5: | Juncus australis | 8 | 1200–1350 | 0.2–1 | 0–0.1 | Basalt, Metasediment |
| Alliance 2-6: | Carex tereticaulis | 22 | 1000–1350 | 0.5–1.5 | 0 | Metasediment, sediment |
| Alliance 2-7: | Poa sieberiana | 17 | 980–1350 | 0.15–1.2 | 0 | Granite, metasediment, basalt, mudstone, acid volcanic |
| Alliance 2-8: | Schoenus apogon herbfield | 11 | 930–1100 | 0.15–0.3 | 0 | Basalt |

Development of *Sphagnum* and it forms a major component of peat in patches less frequently burnt or more generally by restionaceous materials. The other mire types identified all predominantly occur on higher nutrient soils, do not generally burn and almost never contain *Sphagnum* as a component, with peat largely derived from cyperaceous and grass root and above ground materials.

Our numerical analysis approach has highlighted a deficiency in previous supervised or semi-supervised techniques to describe the variation within mires within the NETB. Nearly half of the alliances we have circumscribed are not represented within published state PCTs and even less of the 28 previously published associations are currently recognised as accepted PCTs. A similar result was also found when comparing an unsupervised analysis of arid and semi-arid ephemeral wetlands within New South Wales to accepted PCTs, classes and formations (Hunter and Lechner 2017). More concerning is the Regional Ecosystem (RE) approach of Queensland, in which half of our circumscribed assemblages do not have an equivalent type and the remainder would all be placed within a single RE in spite of this classification being attributed to the association level (Addicott et al. 2018). This RE appears to be more aligned with our macrogroup level rather than association or alliance (Table 2) and thus we would suggest that the RE system may be operating at a different thematic scale and may not be closely aligned to association as the authors suggest.

What we consider as a single macrogroup is distributed across three classes and two formations within the New South Wales system which calls for the need to review the clarity and consistency of those accepted higher hierarchical levels (Hunter and Lechner 2017). We consider a more appropriate conceptualisation is that all the wetlands within our analysis be considered as types of mires and contained within a single hierarchical level. Thus, our macrogroup is floristically and biogeographically distinct, i.e. a New England Tableland Montane Mires (Table 1). This conceptualisation is supported both floristically and geographically. Floristically, Whinam and Chilcott (2002), Hunter and Bell (2013) and Hunter and Hunter (2016) have shown this region is floristically distinctive in terms of bog and wet meadow floristics. Lechner et al.
Table 4. Synoptic table of the most important species (≥ 5% mean constancy or ≥ 50% constancy in at least one alliance) of mire alliances of the New England Tableland Bioregion. Values in the columns are percentage constancies. Species with 50% or more in at least one alliance are listed under the alliance where they reach the highest constancy. Those species that did not reach 50% constancy in any of the alliances are listed under “Companion species” according to decreasing mean constancy. See Suppl. material 2 for full synoptic table. 1-1 Baeckea omissa – Epacris microphylla shrubby bog, 1-2 Lepidosperma gunnii – Lepidosperma limicola herbaceous bog, 2-1 Carex appressa herbaceous fen, 2-2 Carex gaudichaudiana – Isachne globosa herbaceous fen, 2-3 Philydrum lanuginosum – Potamogeton tricarinatus herbaceous ephemeral marsh and fen, 2-4 Lachnagrostis liiflormis herbaceous wet meadow or marsh, 2-5 Myriophyllum varifolium – Eleocharis acuta herbaceous ephemeral marsh, 2-6 Glyceria australis grassy wet meadow, 2-7 Juncus australis – Cenchrus purpurascens herbaceous wet meadow, 2-8 Carex tereticulata – Asperula conferta herbaceous wet meadow and fen, 2-9 Poa sieberiana – Themeda triandra grassy wet meadow, 2-10 Leptorrhynchos squamatus – Schoenus apogon herbfield.

| Alliance 1-1 | Mean | 1-1 | 1-2 | 2-1 | 2-2 | 2-3 | 2-4 | 2-5 | 2-6 | 2-7 | 2-8 | 2-9 | 2-10 |
|-------------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| Baeckea omissa | 13.5 | 100 | 60 | 2 | – | – | – | – | – | – | – | – | – |
| Epacris microphylla | 16.1 | 100 | 80 | 7 | – | – | – | – | – | – | – | – | 6 |
| Gonocarpus micranthus | 11.3 | 76 | 40 | 5 | 4 | – | – | – | 2 | – | 9 | – | – |
| Lepidosperma gregarium | 5.9 | 7 | – | – | – | – | – | – | – | – | – | – | – |
| Baloskion stenocoleum | 11.9 | 63 | 60 | 20 | – | – | – | – | – | – | – | – | – |
| Callistemon ptyoides | 4.9 | 59 | – | – | – | – | – | – | – | – | – | – | – |
| Hakea microcarpa | 6.0 | 55 | – | 11 | – | – | – | – | – | – | – | – | 6 |
| Alliance 1-2 | | | | | | | | | | | | | |
| Austrostipa pubescens | 8.3 | – | 100 | – | – | – | – | – | – | – | – | – | – |
| Damperia stricta | 9.0 | 8 | 100 | – | – | – | – | – | – | – | – | – | – |
| Goodenia bellidifolia | 14.7 | 73 | 100 | – | – | – | – | – | – | – | – | – | 3 |
| Persoonia oleoides | 8.7 | 4 | 100 | – | – | – | – | – | – | – | – | – | – |
| Pteridium esculentum | 9.8 | 10 | 100 | 2 | – | – | – | – | – | – | – | – | 6 |
| Dillwynia phyllicola | 7.0 | 4 | 80 | – | – | – | – | – | – | – | – | – | – |
| Entolasia stricta | 11.1 | 53 | 80 | – | – | – | – | – | – | – | – | – | – |
| Hovea heterophylla | 6.7 | – | 80 | – | – | – | – | – | – | – | – | – | – |
| Lepidospernum arachnoidea | 10.6 | 47 | 80 | – | – | – | – | – | – | – | – | – | – |
| Petrophile canescens | 7.3 | 8 | 80 | – | – | – | – | – | – | – | – | – | – |
| Aristida jenichoensis | 5.0 | – | 60 | – | – | – | – | – | – | – | – | – | – |
| Banksia spinulosa | 7.6 | 31 | 60 | – | – | – | – | – | – | – | – | – | – |
| Diacella caerulea | 5.5 | 6 | 60 | – | – | – | – | – | – | – | – | – | – |
| Lepidospernum gunnii | 5.8 | 10 | 60 | – | – | – | – | – | – | – | – | – | – |
| Lepidospernum limicola | 9.3 | 51 | 60 | – | – | – | – | – | – | – | – | – | – |
| Lepidospernum tartussum | 5.5 | 6 | 60 | – | – | – | – | – | – | – | – | – | – |
| Leptospermum minutifolium | 6.3 | 10 | 60 | 5 | – | – | – | – | – | – | – | – | – |
| Lepisandra scariosa | 7.9 | 35 | 60 | – | – | – | – | – | – | – | – | – | – |
| Lindsaea linearis | 6.5 | 18 | 60 | – | – | – | – | – | – | – | – | – | – |
| Lomandra multiflora | 7.0 | 14 | 60 | – | – | – | – | – | – | – | – | – | 6 |
| Melichrus procumbens | 5.2 | 2 | 60 | – | – | – | – | – | – | – | – | – | – |
| Primula linifolia | 6.2 | 14 | 60 | – | – | – | – | – | – | – | – | – | – |
| Rytidosperma indicum | 5.0 | – | 60 | – | – | – | – | – | – | – | – | – | – |
| Selaginella uliginosa | 5.3 | 4 | 60 | – | – | – | – | – | – | – | – | – | – |
| Styliodium graminifolium | 6.0 | 12 | 60 | – | – | – | – | – | – | – | – | – | – |
| Alliance 2-1 | | | | | | | | | | | | | |
| Carex appressa | 14.9 | 2 | – | 100 | 37 | – | – | 4 | 10 | – | – | 26 | – |
| Rubus angoecandicans | 17.4 | 2 | – | 64 | 37 | – | – | 6 | 27 | 20 | 50 | 3 | – |
| Rumex crispus | 15.6 | – | – | 64 | 46 | – | 31 | 21 | 8 | – | 17 | – | – |
| Verbena bonariensis | 19.0 | – | – | 64 | 26 | 33 | 31 | 6 | 26 | – | 33 | 9 | – |
| Alliance 2-2 | | | | | | | | | | | | | |
| Halocar lanatus | 41.8 | 4 | – | 41 | 100 | 33 | 8 | 45 | 64 | 80 | 67 | 59 | – |
| Carex gaudichaudiana | 19.9 | 2 | – | 23 | 98 | 33 | – | 26 | 17 | 20 | 17 | 3 | – |
| Epilobium billardianum | 15.1 | 6 | – | 41 | 78 | – | – | 28 | 16 | – | – | 12 | – |
| Stellaria angustifolia | 14.3 | 2 | – | 27 | 76 | – | – | 17 | 9 | – | – | 15 | 25 |
| Isachne globosa | 7.7 | 24 | – | – | 65 | – | – | 2 | 1 | – | – | – | – |
| Geranium solandri | 24.7 | 37 | 40 | 45 | 63 | – | 8 | 6 | 32 | 20 | 33 | 12 | – |
| Cyperus spheroideus | 7.3 | 2 | – | 27 | 50 | – | – | 9 | – | – | – | – | – |
| Alliance 2-3 | | | | | | | | | | | | | |
| Philydrum lanuginosum | 8.8 | – | – | 4 | 100 | – | – | – | – | – | – | – | – |
| Asperula conferta | 14.0 | – | – | 9 | 67 | – | 4 | 14 | – | 33 | 41 | – | – |
| Brachyscome tenuiscapa | 8.4 | 2 | – | – | 67 | – | 8 | – | – | 24 | – | – | – |
| Carex breviculmis | 10.2 | – | – | – | 67 | – | 9 | – | 17 | 29 | – | – | – |
| Alliance | Mean | 1-1 | 1-2 | 2-1 | 2-2 | 2-3 | 2-4 | 2-5 | 2-6 | 2-7 | 2-8 | 2-9 | 2-10 |
|----------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Number of plots | 59 | 5 | 22 | 77 | 4 | 14 | 57 | 87 | 5 | 7 | 36 | 4 | |
| Plantago lanceolata | 24.8 | 2 | – | 41 | 7 | 67 | – | 6 | 30 | 40 | 33 | 47 | 25 |
| Alliance 2-4 | Lathyrus japonicus var. fendleri | 25.5 | 4 | – | 23 | 17 | – | 100 | 74 | 18 | – | 17 | 3 | 50 |
| Conyza bonariensis | 17.0 | – | – | 27 | 11 | – | 77 | 17 | 26 | 40 | – | 6 | – |
| Trifolium repens | 24.3 | – | – | 32 | 26 | 33 | 54 | 17 | 42 | 40 | – | 47 | – |
| Alliance 2-5 | Myriophyllum varifolium | 12.1 | 2 | – | – | 7 | 33 | – | 100 | 3 | – | – | – |
| Alliance 2-6 | Glycera australis | 22.8 | – | – | 9 | 11 | 67 | – | 26 | 100 | 20 | – | 41 | – |
| Cirsium vulgare | 32.8 | 6 | – | 60 | 52 | – | 31 | 23 | 79 | 60 | 33 | 35 | 25 |
| Alliance 2-7 | Juncus australis | 29.3 | – | – | 41 | 26 | 33 | – | 28 | 49 | 100 | 17 | 47 | – |
| Cvenchura purpurascens | 26.8 | 10 | – | 36 | 17 | 33 | – | 19 | 31 | 80 | 17 | 53 | 25 |
| Carex disticha | 10.8 | – | – | 5 | 35 | – | – | 1 | 18 | 60 | – | 12 | – |
| Alliance 2-8 | Carex tereticaulis | 8.5 | – | – | – | – | – | – | 2 | – | 100 | – | – |
| Anthoxanthum odoratum | 23.5 | 2 | – | 9 | 43 | 33 | 15 | 15 | 32 | – | 83 | 50 | – |
| Carex inversa | 11.0 | 2 | – | 14 | 28 | – | – | 4 | 3 | – | 50 | 6 | 25 |
| Alliance 2-9 | Poa sieberiana | 23.3 | 14 | – | 9 | 4 | 67 | – | 2 | 30 | 20 | 33 | 100 | – |
| Hypochaera radicata | 31.9 | 22 | – | 50 | 30 | – | 69 | 17 | 26 | 40 | 33 | 71 | 25 |
| Themeda triandra | 14.6 | 35 | – | – | 67 | 35 | – | 5 | – | – | 68 | – | – |
| Schoenus apogon | 14.3 | 29 | – | 9 | 4 | – | – | 15 | 12 | – | – | 53 | 50 |
| Haloragis heterophylla | 14.3 | 8 | – | 36 | 28 | 33 | – | 9 | 8 | – | – | 50 | – |
| Alliance 2-10 | Leptorynchus squamatus | 8.8 | – | – | – | – | – | – | 2 | 3 | – | – | – |
| Paspalum dilatatum | 35.3 | – | – | 73 | 20 | 33 | 31 | 34 | 25 | 60 | 33 | 15 | 100 |
| Eleocharis atrica | 6.3 | – | – | – | – | – | – | – | – | – | – | – | 75 |
| Hydrocotyle tripartita | 15.6 | – | – | 23 | 22 | – | 8 | 47 | 6 | – | – | 6 | 75 |
| Juncus subsecundus | 8.7 | 16 | – | 5 | 4 | – | 4 | – | – | – | – | – | 75 |
| Eragrostis curvula | 5.5 | – | – | 5 | – | – | – | 2 | 9 | – | – | – | 50 |
| Phleum pratense | 4.5 | – | – | – | – | – | – | 4 | – | – | – | – | 50 |
| Sporobolus creber | 5.6 | 2 | – | – | – | – | – | – | – | – | – | – | 15 | 50 |
| Companion species | Ranunculus lappaceus | 15.3 | 18 | – | 14 | 39 | 33 | – | 4 | 12 | 20 | 17 | 26 | – |
| Taraxacum officinale | 15.3 | 2 | – | 14 | 22 | 33 | 8 | 13 | 43 | – | 33 | 15 | – |
| Echichinum spathicos | 11.2 | 14 | – | 9 | – | 33 | 15 | 6 | 13 | 20 | – | 24 | – |
| Ammi majus | 10.3 | – | – | – | – | – | 46 | – | 26 | – | 33 | 21 | – |
| Rumex brownii | 9.5 | – | – | – | – | 8 | 2 | 33 | 2 | 16 | 20 | – | 24 | – |
| Rumex inodatus | 8.5 | – | – | 9 | 24 | 33 | – | 36 | 6 | – | – | 6 | – |
| Persicaria rostrata | 8.5 | – | – | 18 | – | – | 38 | – | 17 | – | – | 25 | – |
| Eleocharis acuta | 8.4 | – | – | 36 | 9 | – | 47 | 6 | – | – | 3 | – | 50 |
| Festuca elatior | 8.4 | – | – | 32 | 48 | – | – | 4 | – | – | 17 | – | – |
| Persicaria hydropiper | 8.3 | – | – | 23 | 30 | – | – | 19 | 8 | 20 | – | – | – |
| Hypericum gramineum | 8.1 | 29 | 20 | 5 | 7 | – | – | 2 | 3 | – | – | 6 | 25 |
| Lythrum salicaria | 8.0 | 4 | – | 5 | 48 | 33 | – | 3 | – | – | 3 | – | – |
| Lomandra longifolia | 7.9 | 29 | 20 | – | 4 | 33 | – | – | – | – | 9 | – | – |
| Hemarthria uncina | 7.3 | 2 | – | 9 | 9 | – | 8 | 28 | 6 | – | 17 | 9 | – |
| Poa labillardien | 7.3 | – | 40 | 5 | 9 | 33 | – | – | 1 | – | – | – | – |
| Juncus usitatus | 7.3 | 2 | – | 18 | 9 | 33 | – | 0 | 4 | – | – | 21 | – |
| Phalaris aquatica | 6.8 | 12 | – | 14 | – | – | – | 27 | – | 17 | – | 12 | – |
| Rumex conglomeratus | 6.8 | – | – | 23 | 13 | – | – | 2320 | – | 3 | – | – | – |
| Hypericum japonicum | 6.7 | 16 | – | 5 | 20 | – | – | 6 | 1 | 20 | – | 12 | – |
| Cymodocea falcata | 6.6 | – | – | 9 | – | 33 | – | 11 | 3 | 20 | – | 3 | – |
| Eleocharis sphacelata | 6.2 | 4 | – | 5 | 24 | – | – | 38 | 3 | – | – | 3 | – |
| Setaria pumila | 6.0 | 6 | – | – | 7 | – | – | 4 | 4 | – | 17 | 9 | 25 |
| Eleocharis pusilla | 5.9 | – | – | 11 | 33 | – | 15 | 6 | – | – | 6 | – | – |
| Prunella vulgaris | 5.8 | 6 | – | 14 | 17 | – | – | 2 | 4 | 20 | – | 6 | – |
| Viola hederaea | 5.8 | 22 | 20 | – | 4 | – | – | – | – | – | – | 17 | 6 |
| Geranium neglectum | 5.7 | – | – | – | 2 | 38 | 2 | 3 | – | 17 | – | 6 | – |
| Eleocharis gracilis | 5.4 | – | – | 5 | 17 | – | 40 | 3 | – | – | 6 | – | – |
| Juncus fasciculatus | 5.4 | – | – | 5 | 11 | – | 8 | 34 | 1 | – | – | 6 | – |
| Oxalis perennans | 5.3 | 4 | – | 5 | – | – | – | 3 | – | – | 17 | 35 | – |
| Ranunculus palustris | 5.2 | – | – | – | – | – | 38 | 6 | 1 | – | 17 | – | – |
| Sagittaria japonica | 5.2 | 4 | – | – | 33 | – | – | 1 | – | 24 | – | – | – |
(2016) showed the New England Region formed distinct ecoregions in terms of the occurrence of mapped mires of all types. Furthermore, the highland region of the New England Tablelands Bioregion is disconnected from more southern highland areas by the Hunter Valley.

Most of the NETB mires are currently listed as endangered communities on state and national acts (Hunter and Bell 2007; Bell et al. 2008; Hunter and Bell 2009; Hunter and Hunter 2016) and thus an understanding of the natural variation and interrelationships between these systems is important. Clear distinction of vegetation units is a necessity for conservation and management. Indistinct or ill-defined systems can lead to inappropriate management actions (Hunter and Hunter 2016; Hunter 2018). For example, semi-permanent or ephemeral marshes of the NETB are considered a distinct floristic association, class and formation within current New South Wales classification schema (Keith 2004; Benson et al. 2010). In addition, semi-permanent or ephemeral marshes are currently listed as an endangered ecological community both under the state Biodiversity Conservation (BC) Act 2017 (Upland Wetlands of the Drainage Divide of the New England Tableland Bioregion), and the federal Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Upland wetlands of the New England Tablelands and the Monaro Plateau).

Upland wetlands (lagoons) are a geomorphologically defined landscape element that contains a number of vegetation types within it (Bell et al. 2008; Hunter and Bell 2009; Hunter and Hunter 2016; Hunter 2018). However, only the floristics and not the geomorphological features are the dominant criteria used to distinguish this threatened community legislatively, but the system contains a number of distinct floristic types (fens, marshes, wet meadows). In practice this means that ‘lagoons’ are classed as an endangered vegetation community but this same community may also contain within it other endangered vegetation communities including Carex fens dominated by Carex appressa, which has its own listing, and bogs dominated by Carex gaudichaudiana, which also has its own listing and wet meadows which is under threat and may warrant listing in the near future (Hunter and Hunter 2016). Thus, within the one location two endangered communities can occur within another yet they are all supposed to be based on distinct floristic composition. This is further exacerbated by the fact that most of these ‘lagoons’ may only wet a few times a century and thus cannot be defined by floristics alone. The confusion of listing a geomorphological feature as an endangered system but defining it based on floristics has led to a distortion in understanding. We believe defining clear and distinct floristic units clarifies logical community listings and is also separated from other closer related fen types (Hunter and Bell 2009). This is in spite of the fact that such determinations are meant to be based on floristic uniqueness and determined by largely by species composition.

Classification within Australia has largely been driven by the need to manage natural resources from both conservation and production perspectives and is linked to mapping outputs with a recent emphasis on unsupervised modelling techniques such as segmentation (Hunter 2016b; Gellie et al. 2017). However, undescribed vegetation types cannot be modelled and poorly circumscribed entities are likely to be inaccurately modelled and mapped (Hunter 2016b; Hunter and Lechner 2017). This is particularly a problem with wetland types, especially semi-permanent or ephemeral wetlands. Recent vegetation modelling within part of the NETB provided only a 10% accuracy of wetland extent
and types (Hunter 2013; Hunter 2018). Similar inaccuracy rates for modelled wetlands have been found with other recent state mapping programs (Hunter and Hawes 2013; Hunter 2016b). The lack of clear delineation of wetland vegetation types and the poor accuracy of modelled maps severely hampers our ability to understand and conserve these highly threatened systems.

Our results and those of other recent work (Hunter and Lechner 2017) has highlighted that wetlands within eastern Australia have been generally poorly sampled, at times ill-defined and often contain significant underscribed variation whose interrelationships have not been properly understood. This has led to poor circumscription of listed threatened ecological communities and difficulty in modelling for mapping and conservation purposes. While we have attempted to provide some clarity within a new proposed hierarchical classification schema for the NETB, there is a need to better circumscribe all Australian terrestrial wetland systems. There is significant utility in the creation of a well-defined hierarchical schema of vegetation types that is non-jurisdiction based and scalable to enable better understanding and management, and increase our ability to protect and conserve them.

Author contributions

J.T.H. and V.H.H. conceived and undertook all field work. J.T.H. completed all analyses and J.T.H. wrote the majority of the manuscript with V.H.H. providing comment and additional text.

Acknowledgements

We wish to thank the late Dr. Dorothy Bell for her assistance in collecting data and the many discussions that help our understanding of the wetland systems of the NETB.

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Supplementary material

Supplementary material 1
Images of the circumscribed NETB montane mire alliances
Link: https://doi.org/10.3897/VCS/2020/48765.suppl1

Supplementary material 2
Full synoptic table of the 12 distinguished alliances
Link: https://doi.org/10.3897/VCS/2020/48765.suppl2