Wallum on the Nabiac Pleistocene barriers, lower North Coast of New South Wales

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Abstract: Wallum is widespread on coastal dunefields, beach ridge plains and associated sandy flats in northern NSW and southern Queensland. These sand masses contain large aquifers, and the wallum ecosystem is considered to be generally groundwater-dependent.

This study describes the floristic composition and environmental relations of wallum on a Pleistocene barrier system at Nabiac (32° 09'S 152° 26'E), on the lower North Coast of NSW. Despite their minimal elevation and degraded relief, the Nabiac barriers maintain floristic patterns related to topography and hence groundwater relations. Comparative analyses identified the Nabiac wallum as representative of the ecosystem throughout large parts of its range in eastern Australia. The Nabiac wallum and nearby estuarine and alluvial vegetation supports species and communities of conservation significance.

A borefield is proposed for development on the Nabiac barriers, thereby providing a valuable opportunity for research into mechanisms of groundwater utilisation by the wallum ecosystem.

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Introduction

Wallum is the regionally distinct vegetation on coastal dunefields, beach ridge plains and sandy backbarrier flats in subtropical northern NSW and southern Queensland (Griffith et al. 2003). These sand masses are concentrated between Newcastle (33°S) and the Shoalwater Bay region (22°S) near Rockhampton, with scattered occurrences further north and south (Thompson 1983). Wallum structural formations (after Walker & Hopkins 1984) include forest and woodland, mallee forest and woodland, shrubland, heathland and sedgeland.

Australia is reliant upon groundwater to satisfy domestic, industrial and agricultural requirements (e.g. Groom et al. 2001, Murray et al. 2006, NSW Government 1997). This reliance includes extraction from sand mass aquifers supporting wallum (Davis 2000, NSW National Parks & Wildlife Service 1998), and also from similar aquifers supporting kwongan (sandplain) vegetation in south-western Australia (Dodd et al. 1984, Froend & Drake 2006).

MidCoast Water, a County Council established in 1997, is responsible for water supply to the Greater Taree and Great Lakes local government areas of NSW in the lower North Coast botanical subdivision (after Anderson 1961). Water quality in the existing Manning District Water Supply Scheme, which pumps from the Manning River into a storage reservoir, is becoming increasingly difficult to manage, especially during summer with the incidence of algal blooms. MidCoast Water proposes to better manage water supply and quality by: (a) implementing strategies for improvements in use efficiency; and (b) developing a borefield as an alternative source in wallum on a series of Pleistocene barriers at Nabiac (Watkins et al. 2006).

The Nabiac barriers (32° 09'S 152° 26'E, Figure 1) have a surface area of approximately 45 km^2 and contain two aquifers – a shallow unconfined aquifer about 2–3 m deep above an indurated sand layer (aquitard) 3–5 m thick, and a semi-confined aquifer 15–20 m deep below the indurate and above basement clay sediments and bedrock (Acacia Environmental Planning 2004). The shallow aquifer is primarily recharged by direct rainwater infiltration, the deep aquifer is in turn recharged by leakage through the indurate from the shallow aquifer, and groundwater eventually discharges into Wallis Lake via McClymonts Creek and the Wallamba and Coolongolook Rivers. The aquifers and indurated layer have a combined storage capacity of approximately 195 000 ML, and preliminary tritium analysis suggests an age of 5–10 years for water in the deeper aquifer (Acacia Environmental Planning 2004). The Nabiac barriers are a key geomorphic unit of the Wallis Lake catchment, and this region is significant for nature conservation, tourism, recreational and commercial fishing, and oyster farming (Great Lakes Council 2003).

Despite an expected increase in demand for groundwater from sand mass aquifers, research into the potential impacts of extraction upon groundwater-dependent ecosystems is generally lacking and therefore a high priority (ARMCANZ/

ANZECC 1996, NSW Government 2002). An investigation of the mechanisms of groundwater utilisation by wallum at Nabiac is proposed as an integral part of monitoring for potential impacts of borefield operation. It is envisaged that this research will have broader application to the wallum ecosystem throughout eastern Australia. On this basis the degree to which the Nabiac study area is representative of wallum in general has been assessed, and the findings of a comparative assessment of floristic composition and spatial patterns are presented herein. Although wallum on the Nabiac barriers is the primary focus of this paper, the vegetation on adjacent bedrock, estuarine and alluvial landforms is also described to improve the context of discussion about floristic patterns and conservation significance.

Climate

The climate of coastal northern NSW is subtropical with summer-dominant rainfall, although with increasing latitude there is a gradual shift towards temperate conditions and relatively uniform rainfall throughout the year (Colls & Whitaker 1990).

The Bureau of Meteorology provides climatic data for Taree (rainfall 100+ years; temperature 80+ years), which is similar in altitude (5 m a.s.l.) to the Nabiac barriers although 25 km further north. Here the average rainfall during the three wettest months (January to March) accounts for 35% of the mean annual total (1179 mm), whereas 17% falls during the three driest months (July to September). Monthly means are positively skewed relative to median values, and therefore rainfall tends to be more often drier than average in any month rather than wetter than average. Despite the average trends, the variability index [VI = (9th decile – 1st decile)/5th decile] for monthly rainfall ranges from 1.9–4.5. Relative to other parts of Australia these VI values are considered to be very high (1.5–2.0) or extreme (>2.0), and episodes of drought and flood are therefore likely.

Taree has a mean annual maximum temperature of 24.2˚C and a mean annual minimum of 12.0˚C. Mean monthly maxima are highest from December to February (28.3–28.9˚C), lowest from June to August (18.4–19.9˚C), and mean monthly diurnal variation is 10.9–13.9˚C. The highest recorded temperatures are around 43˚C in late spring and summer, and the lowest are –2 to –5ºC during late autumn and winter.

Mean monthly 9 am relative humidity for Taree varies from 67–80%, and for 3 pm the range is 51–63%. Lower values predominantly occur from mid-winter to late spring, which is also the period of generally lower mean monthly rainfall. At this time of year, during the so-called late winter – spring 'drought' of Coaldrake (1961), conditions of water deficit may arise when evaporation is high relative to rainfall.

Landforms, geology and soils

The study area is part of the Tuncurry bedrock embayment, which has formed over the last three interglacial cycles (Roy et al. 1997). The embayment comprises several barrier systems of marine-aeolian sand with associated estuarine and alluvial deposits (Melville 1984, Roy et al. 1997). The Pleistocene Nabiac barriers, west of the Wallamba River, range in age from around 80 to 260 ka. These are distinguished from the Holocene Tuncurry barrier (8–1 ka), east of the Wallamba River, which forms the present embayment shoreline (Figure 1). The Coolongolook – Wallingat River system has intersected the Nabiac barriers in the south, forming Wallis Island, and the Wallamba River intersects the barriers in the north (Roy et al. 1997).

Three beach ridge barriers with associated interbarrier and backbarrier flats (plains) dominate the study area, although localised dunefields occur at the northern and southern extremities (Melville 1984). These Pleistocene beach ridges and dunes are now degraded, probably due at least in part to the erosive force of raindrop splash (Thompson 1983); and the poorly defined, widely spaced ridges and swales (2–7 m a.s.l.) contrast with the well-defined relief of the approximately 60 shore-parallel beach ridges comprising the Holocene Tuncurry barrier (Melville 1984, Roberts et al. 1991, Roy et al. 1997).

Bedrock rises and low hills formed from the Bundook beds (Late Devonian), Booti Booti Sandstone and the Wallanbah Formation (both Early Carboniferous) adjoin the Nabiac barriers to the west and south-west, and dominant lithologies of these stratigraphic units include greywacke, lithic sandstone, mudstone and siltstone (Roberts et al. 1991). Alluvial and estuarine landforms derived from Pleistocene or Holocene deposits occur closer to Wallis Lake and its tributaries (Murphy 2005).

Soils derived from the quartzose sand of the Nabiac barriers form a catenary sequence from Podzols on well-drained sites to Humus Podzols where drainage is imperfect to poor; and Acid Peats replace podzols lower in the landscape where waterlogging is severe (Murphy 2005). Podzols dominate on the Tuncurry barrier, although Siliceous Sands and Acid Peats occur over limited areas. Siliceous Sands, Acid Peats, Humic Gleys and Solonchaks are found on estuarine landforms, whereas the soils associated with alluvial landforms include Brown Podzolic Soils, Yellow Earths and Humic Gleys. Nearby bedrock soils form toposequences, and these vary from Lithosols and Red Podzolic Soils on crests and steeper slopes, to Red, Brown and Yellow Podzolic Soils on gentler slopes, and Soloths on lower slopes and along drainage lines.

Landuse and fire history

The Worimi and Biripai Aboriginal tribes inhabited distinct, adjoining territories in the Nabiac-Tuncurry region at the time of European settlement. However, white settlers along the Manning River soon dispersed the Biripai southwards, disrupting tribal boundaries and forcing them to intermingle with the Worimi. Physical evidence of a rich Aboriginal culture includes middens, open campsites and stone artefact scatters, ceremonial grounds, and carved or otherwise scarred trees, generally in close proximity to estuaries and swamps (Collins 2004, Gilbert 1954a,b).

The Nabiac district was part of the original Australian Agricultural Company grant of the 1820s, although this and other coastal areas were soon relinquished to the Crown in exchange for lands further inland that were deemed more suitable for agricultural pursuits such as sheep grazing. Timber cutters were operating in the district by the early 1830s, initially with permits to harvest Red Cedar (*Toona ciliata*). Henry Carmichael purchased the first land grant (46.6 ha) along the Wallamba River in 1855, and by 1866 the Wallis Lake area, known at the time as Cape Hawke Settlement, was a small agricultural and timber-cutting community (Gilbert 1954a). Sections of the Nabiac barriers are revegetating following mineral sand mining, initially by Mineral Deposits Ltd during the mid 1970s to early 1980s and then by R.Z. Mines Pty Ltd during the 1990s (Acacia Environmental Planning 2004, Resource Planning 1990). Forster Local Aboriginal Land Council holds freehold title over much of the Nabiac wallum.

The Wallis Lake flora soon attracted the attention of colonial botanists, and in 1864 local Aboriginals assisted Robert Fitzgerald with the collection of a Rock Lily (*Dendrobium* sp.) on Wallis Island (Gilbert 1954a). Other noteworthy collections include the type specimens of *Allocasuarina defungens* and *A. simulans* (Casuarinaceae), obtained from the Nabiac barriers by R. G. Coveny and colleagues (Johnson 1989). Armidale historian L.A. Gilbert also collected numerous plants at Nabiac during the 1940s and 1950s, and specimens are housed in the N.C.W. Beadle Herbarium (NE) at the University of New England.

Deliberate burning of the Nabiac wallum has apparently occurred on a regular basis in the recent past to promote flowering in Christmas Bells, *Blandfordia grandiflora* for the cut-flower trade (Acacia Environmental Planning 2004). It is also likely that fire was used to promote green pick in the understorey of forests and woodlands for livestock grazing. The impact of fire frequency upon native vegetation in NSW is understood in broad terms, and current management prescriptions to maintain biodiversity in coastal vegetation such as the Nabiac wallum advocate a domain of acceptable fire intervals between approximately 7 and 30(–35) years (Bradstock et al. 2003). The impacts of fire intensity and season of burn are less well known, although a general guiding principle is to vary both as much as possible at any given locality (Bradstock et al. 2003). The same generalisation applies for fire frequency within the recommended intervals (e.g. Morrison *et al*. 1995).

Methods

Data collection

The vegetation of the Nabiac barriers and adjoining bedrock, estuarine and alluvial landforms was mapped from 1:25 000 aerial photography using conventional air photo interpretation (API), in a manner consistent with earlier mapping of coastal vegetation throughout much of north-eastern NSW (e.g. Griffith et al. 2000). API groups (map units) were primarily distinguished by growth form (after Walker & Hopkins 1984) and species dominance in the dominant (generally tallest) stratum. When circumscribed in this manner, API groups are generally analogous to plant associations sensu Beadle (1981): ‘a community in which the dominant stratum exhibits uniform floristic composition, the community usually exhibiting uniform structure (also)’. The vegetation mapping formed the basis of sample stratification in the wallum, and the following data were collected in randomly placed quadrats at 27 remotely chosen sites (NAB001.1–027.1).

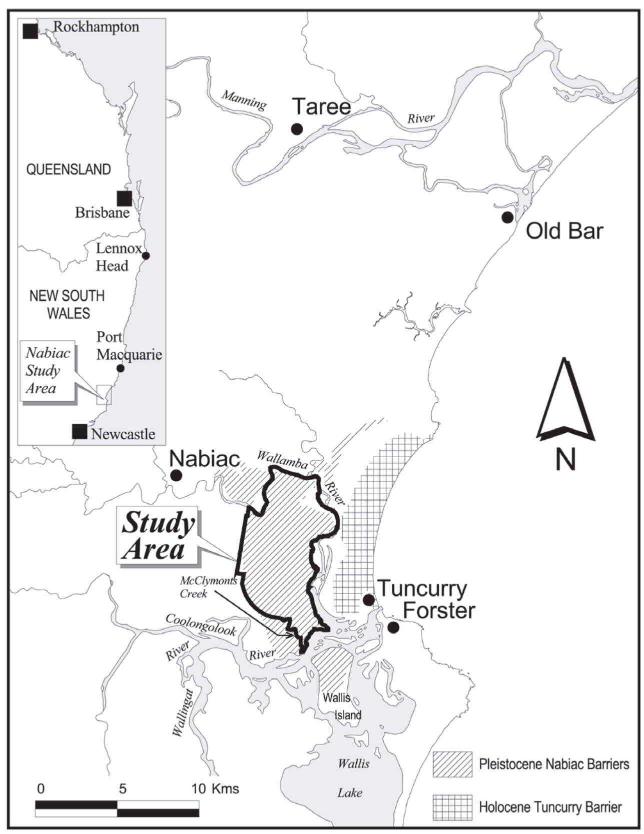

Fig. 1. Locality map of the Nabiac study area.

(a) Foliage cover (sensu Walker & Hopkins 1984) score for each vascular species in 25 m^2 (sedgeland), 100 m^2 (heathland, shrubland, mallee woodland) or 400 m^2 (forest, woodland) quadrats: 1 (<1%); 2 (1–5%); 3 (6–25%); 4 (26–50%); 5 (51–75%); and 6 (76–100%).

(b) Geology from available mapping, in this case only QSA (Quaternary sand or alluvium).

(c) Aspect (°).

(d) Slope (°).

(e) Altitude above sea level (m).

(f) Topographic position (after Speight 1984) using categories for landform morphological type (D = closed depression, F = flat, R = ridge, V = open depression) and landform element (BRI = beach ridge, DDE = drainage depression, DUN = dune, PLA = plain, SWL = swale, SWP = swamp).

(g) Geographic location (easting and northing).

(h) Degree of exposure, determined as the azimuth (°) for each of the eight principal compass bearings (N, NE, etc.).

(i) Time elapsed since last burnt (0–5 years, 5–10 years, or >10 years), estimated from counts of incremental post-fire branching in calibrated species (*Banksia ericifolia* subsp. *macrantha* and *B. oblongifolia*).

The Nabiac data are compatible with another dataset of approximately 500 quadrats for wallum and allied vegetation (other than forest and woodland) along 400 km of coastline in NSW from the Manning River north to the Lennox Head district (Griffith 2002, Griffith et al. 2003). The data from elsewhere were used for a comparative study of the Nabiac wallum. The nomenclature is generally consistent with current usage at the Royal Botanic Gardens (Sydney), and authorities are provided in Harden (1990–3, 2002) or Harden and Murray (2000).

Data analysis

Numerical analysis of foliage cover scores (1 to 6) without further transformation was performed using PATN (Belbin 1993). The Bray-Curtis association coefficient was employed in combination with the flexible UPGMA (unweighted pair group arithmetic averaging) clustering algorithm and a slightly negative (-0.1) beta value. Kent and Coker (1992) suggest that an appropriate numerical method, and hence classification, is one 'which enables a clear ecological interpretation to be made'. The Bray-Curtis coefficient was found to satisfy this requirement, and such an outcome is consistent with a view that it provides a good estimate of ecological distance, primarily because greater emphasis is placed upon similarity between common and abundant species, than upon similarity between rare species and those with low cover-abundance (Belbin 1992, 1993, Faith et al. 1987).

The data were further examined for spatial relationships between plant species and environmental variables using Canonical Correspondence Analysis (CCA). This is a multivariate method of direct ordination in which correlation and regression procedures are integrated. It depicts both patterns in floristic composition and the principal relationships with environmental variables. Biplots present the ordination output, and these display quadrats as points, numerical environmental variables as vectors, and categorical environmental variables as centroids. The ordinations were performed in an unconstrained manner (i.e. without *a priori* intuitive weighting of variables) using CANOCO (ter Braak 1988). Monte Carlo permutations (n = 999), using the eigenvalue for the first ordination axis as the test statistic, allowed examination of the null hypothesis that floristic composition is independent of the environmental variables; where P = (no. of permutations with test statistic equal to or higher than original data + 1)/(no. of permutations + 1).

Analyses were performed on the Nabiac dataset in isolation, and also on combinations of the Nabiac data for mallee, shrubland, heathland and sedgeland with data for these structural formations elsewhere in north-eastern NSW.

Results and Discussion

Wallum on the Nabiac barriers and associated flats

Dry sclerophyll forest and woodland (DSF/W)

Structure: mid-high to very tall, open woodland to closed forest.

Floristic composition: *Eucalyptus racemosa* subsp. *racemosa* is a widespread forest and woodland dominant on the Nabiac barriers (DSW in Figures 2, 3). Other large stands are dominated by *Eucalyptus pilularis* with associated *Angophora costata* (DSF–1), whereas *Eucalyptus globoidea* (DSF–2) dominates localised stands. *Corymbia gummifera*, *Eucalyptus piperita* or *E. resinifera* may be present as minor species in the tallest stratum of these forests and woodlands. Understorey species include *Banksia aemula*, *B. serrata* (+/- continuous with the tallest stratum), *Coleocarya gracilis*, *Dillwynia retorta*, *Eriostemon australasius*, *Leptospermum polygalifolium* subsp. *cismontanum*, *L. trinervium*, *Leucopogon ericoides*, *Leucopogon leptospermoides*, *Monotoca elliptica*, *M. scoparia*, *Petrophile pulchella* and *Pteridium esculentum*.

Habitat and community relations: Found on ridges (dunes, beach ridges) where the watertable is likely to be deeper than in soils supporting dry sclerophyll mallee woodland or dry sclerophyll shrubland.

Distribution and equivalent vegetation types: *Eucalypts racemosa* subsp. *racemosa* (previously *E. signata*) has a widespread distribution along the coast of NSW and southern Queensland (Pfeil & Henwood 2004) where it occurs on both sand masses and bedrock soils. Wallum occurrences of *E. racemosa* subsp. *racemosa* forest and woodland are reported for other localities in north-eastern NSW and south-eastern Queensland (e.g. Clifford & Specht 1979, Durrington 1977, Osborn & Robertson 1939, Pressey & Griffith 1992). *Eucalyptus pilularis* – *A. costata* dry sclerophyll forest occurs elsewhere in wallum on the lower North Coast in Booti Booti NP (Griffith et al. 2000) and Myall Lakes NP (Myerscough & Carolin 1986). *Eucalyptus pilularis* forests on sand in which other species associate (e.g. *Corymbia gummifera*, *C. intermedia*, *E. planchoniana*) extend to the upper North Coast (e.g. Forestry Commission of NSW (1989) as forest type No.

41 'Sandhill Blackbutt', Pressey & Griffith 1992) and continue into southern Queensland (Clifford & Specht 1979, Durrington 1977). *Eucalyptus globoidea* appears to be absent as a forest dominant in wallum to the north of Nabiac.

Swamp sclerophyll forest and woodland (SSF/W)

Structure: mid-high to very tall, open woodland to closed forest.

Floristic composition: The tallest stratum is dominated by *Eucalyptus robusta* (SSF–1 in Figures 2, 3) or *Melaleuca quinquenervia* (SSF–2), although some stands of *E. robusta* support a distinct second tree stratum of *Melaleuca sieberi* (SSW). Understorey composition varies, although common species include *Baloskion tetraphyllum* subsp. *meiostachyum*, *Banksia oblongifolia*, *B. robur*, *Baumea articulata*, *Empodisma minus*, *Gahnia clarkei*, *G. sieberiana*, *Gleichenia microphylla*, *Leptocarpus tenax*, *Leptospermum liversidgei*, *Livistona australis* (+/- continuous with the tallest stratum), *Melaleuca sieberi*, *Pultenaea villosa*, *Schoenus brevifolius*, *Sporadanthus interruptus* and *Xanthorrhoea fulva*.

Habitat and community relations: Occupies open depressions (e.g. swales, drainage depressions) and poorly-drained flats. Also borders closed depressions (swamps).

Distribution and equivalent vegetation types: Swamp sclerophyll forest and woodland dominated by *Melaleuca quinquenervia* or *Eucalyptus robusta* extends along the NSW North Coast (Forestry Commission of NSW 1989, Griffith et al. 2000, Myerscough & Carolin 1986, Pressey & Griffith 1992), and similar vegetation occurs in south-eastern Queensland (Batianoff & Elsol 1989; Dowling & McDonald 1976; Durrington 1977; Elsol & Dowling 1978).

Dry sclerophyll mallee woodland (DSMW)

Structure: very tall open mallee woodland and mallee woodland.

Floristic composition: *Eucalyptus racemosa* subsp. *racemosa* is a widespread mallee on the Nabiac barriers. Common understorey species include *Acacia quadrilateralis*, *Banksia aemula*, *Eriostemon australasius*, *Hypolaena fastigiata*, *Leptospermum polygalifolium*

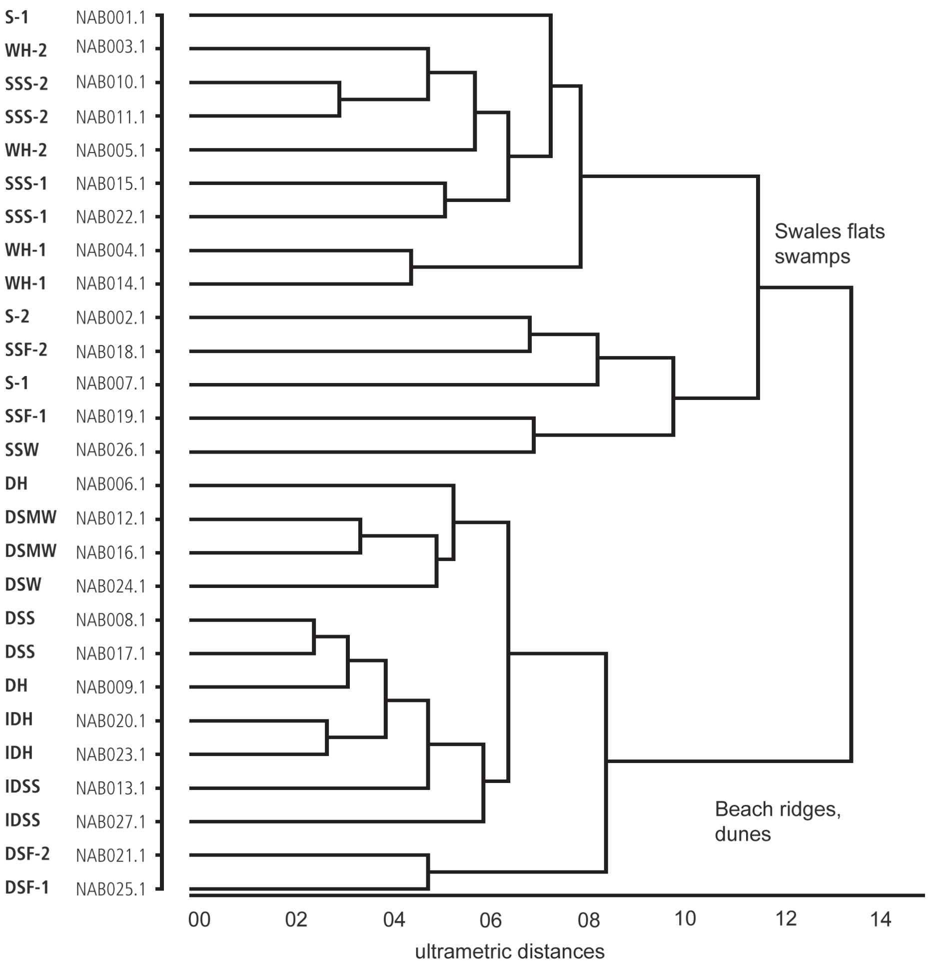

Fig. 2. Numerical classification of floristic data for wallum at Nabiac.

DH: *Banksia aemula* dry heathland; DSF-1: *Eucalyptus pilularis – Angophora costata* dry scl. forest; DSF-2: *Eucalyptus globoidea* dry scl. forest; DSMW: *Eucalyptus racemosa* dry scl. mallee woodland; DSS: *B. aemula* dry scl. shrubland; DSW: *E. racemosa* dry scl. woodland; IDH: intermediate dry heathland; IDSS: intermediate dry scl. shrubland; S-1: *Leptocarpus tenax – Baloskion pallens* etc. sedgeland; S-2: *Baumea articulata* sedgeland; SSF-1: *Eucalyptus robusta* swamp scl. forest; SSF-2: *Melaleuca quinquenervia* swamp scl. forest; SSS-1: *Banksia ericifolia* swamp scl. shrubland; SSS-2: *Melaleuca sieberi* swamp scl. shrubland; SSW: *E. robusta – M. sieberi* swamp scl. woodland; WH-1: *Banksia oblongifolia – Leptospermum liversidgei* etc. wet heathland; WH-2: *B. oblongifolia – Hakea teretifolia* etc. wet heathland. The foliage cover data are provided as Appendix 1.

subsp. *cismontanum*, *L. semibaccatum*, *L. trinervium*, *Leucopogon ericoides*, *Melaleuca nodosa*, *Monotoca scoparia*, *Ochrosperma lineare* and *Philotheca salsolifolia* subsp. *salsolifolia*; and some of these may be more or less continuous with the tallest stratum (e.g. *B. aemula*).

Habitat and community relations: Found on beach ridges. This formation is floristically similar to *E. racemosa* subsp. *racemosa* forest and woodland (Figures 2, 3).

Distribution and equivalent vegetation types: *Eucalyptus racemosa* subsp. *racemosa* mallee has a sporadic distribution on the NSW North Coast (Griffith et al. 2003), and is reported for south-eastern Queensland (Durrington 1977).

Dry sclerophyll shrubland (DSS)

Structure: tall to very tall, open to sparse shrubland.

Floristic composition: *Banksia aemula* is the characteristic dominant. *Caustis recurvata* var. *recurvata*, *Hypolaena fastigiata*, *Leptospermum polygalifolium* subsp. *cismontanum*, *L. semibaccatum*, *Leucopogon ericoides*, *Melaleuca nodosa*, *Ochrosperma lineare* and other species form a somewhat continuous understorey, certain of which (e.g. *M. nodosa*) may merge and associate with *B. aemula* in the absence of fire for long periods.

Habitat and community relations: Found on ridges (e.g. beach ridges). This subformation is floristically similar to dry heathland, and affinities are also apparent with *Eucalyptus racemosa* subsp. *racemosa* dry sclerophyll woodland and mallee (Figures 2, 3).

Distribution and equivalent vegetation types: *Banksia aemula* dry sclerophyll shrubland is widespread on the NSW North Coast (Griffith et al. 2000, Griffith et al. 2003). Similar vegetation is reported for the NSW Central Coast (Benson & Howell 1990) and south-eastern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Durrington 1977, Sattler & Williams 1999).

Swamp sclerophyll shrubland (SSS)

Structure: tall to very tall shrubland and closed shrubland.

Floristic composition: *Banksia ericifolia* subsp. *macrantha* dominates swamp sclerophyll shrubland in swales (SSS–1 in Figures 2, 3), where understorey species include *Banksia oblongifolia*, *Boronia falcifolia*, *Eurychorda complanata*, *Lepidosperma filiforme*, *Leptospermum liversidgei*, *Sporadanthus interruptus*, *Xanthorrhoea fulva* and *Xyris operculata*. *Melaleuca sieberi* also forms a shrubland on flats (SSS–2), where understorey species include *Baloskion pallens*, *Banksia oblongifolia*, *Lepidosperma limicola*, *Leptocarpus tenax*, *Leptospermum arachnoides*, *Melaleuca thymifolia*, *Ptilothrix deusta* and *Xyris operculata*.

Habitat and community relations: Occupies poorly drained open depressions (swales) and interbarrier flats, where a shallow watertable periodically rises to the ground surface.

Distribution and equivalent vegetation types: *Banksia ericifolia* subsp. *macrantha* is restricted to the North Coast in NSW (Harden 2002), and shrublands dominated by this species extend north from the Forster district (Griffith et al. 2003). *Melaleuca sieberi* is more widespread, dominating swamp sclerophyll shrubland on the NSW Central Coast (Benson 1986) and North Coast (Griffith et al. 2003), and forming equivalent or similar shrublands in south-eastern Queensland (Dowling & McDonald 1976).

Dry heathland (DH)

Structure: mid-high to tall closed heathland.

Floristic composition: *Banksia aemula* is the characteristic dominant, although other subsidiary or co-dominant heath shrubs include *Leptospermum semibaccatum*, *Melaleuca nodosa*, *Monotoca scoparia* and *Ochrosperma lineare*. The sedges *Caustis recurvata* var. *recurvata* and *Hypolaena fastigiata* are generally conspicuous.

Habitat and community relations: Found on beach ridges. Dry heathland has floristic affinities with *Banksia aemula* dry sclerophyll shrubland, and *Eucalyptus racemosa* subsp. *racemosa* dry sclerophyll woodland and mallee woodland (Figures 2, 3).

Distribution and equivalent vegetation types: *Banksia aemula* dry heathland extends north from the NSW Central Coast into south-eastern Queensland (Adam et al. 1989, Batianoff & Elsol 1989, Durrington 1977, Griffith et al. 2000, Griffith et al. 2003, McRae 1990, Myerscough & Carolin 1986), although subsidiary or co-dominant species vary with latitude.

Wet heathland (WH)

Structure: mid-high to tall closed heathland.

Floristic composition: This subformation is floristically variable. Co-dominant or subsidiary heath shrubs in swales (WH-1 in Figures 2, 3) include *Banksia ericifolia* subsp. *macrantha*, *B. oblongifolia*, *Boronia falcifolia*, *Epacris microphylla* var. *microphylla*, *Leptospermum liversidgei*, *Sprengelia incarnata* and *Xanthorrhoea fulva*, whereas *Empodisma minus*, *Gahnia sieberiana*, *Schoenus scabripes* and *Sporadanthus interruptus* are conspicuous sedges. Frequent species on flats (WH-2) include the heath shrubs *Banksia oblongifolia*, *Hakea teretifolia* subsp. *teretifolia*, *Leptospermum arachnoides* and *Xanthorrhoea fulva*, along with the sedges *Lepidosperma neesii*, *Leptocarpus tenax* and *Ptilothrix deusta*. Some of the heterogeneity in floristic composition may be attributed to fire, where frequent burning limits recruitment of seeders (e.g. *B. ericifolia* subsp. *macrantha*, *H. teretifolia* subsp. *teretifolia*, *L. arachnoides*).

Habitat and community relations: Characteristic of poorly drained open depressions (swales) and flats with a shallow watertable. In the absence of fire for extended periods, *B. ericifolia* subsp. *macrantha* may overtop shorter species to dominate as a swamp sclerophyll shrubland.

Distribution and equivalent vegetation types: Wallum wet heathland of similar floristic composition is widespread in north-eastern NSW (Griffith et al. 2000, Griffith et al. 2003) and south-eastern Queensland (Batianoff & Elsol 1989, Clifford & Specht 1979, Durrington 1977, Elsol & Dowling 1978).

Sedgeland (S)

Structure: tall to very tall closed sedgeland.

Floristic composition: *Baumea articulata* dominates in deep swamps (S–2 in Figures 2, 3), whereas *Baloskion pallens*, *Baumea teretifolia*, *Chorizandra sphaerocephala*, *Lepidosperma limicola*, *Leptocarpus tenax* and *Schoenus brevifolius* are some of the co-dominant or subsidiary species in floristically variable shallow swamps (S–1) along with certain heath shrubs (e.g. *Callistemon pachyphyllus*).

Habitat and community relations: Occupies closed depressions (swamps) where standing water accumulates, and often replaced by wet heathland, swamp sclerophyll shrubland or swamp sclerophyll forest as surface drainage improves.

Distribution and equivalent vegetation types: *Baumea articulata* sedgeland is known for other locations on the NSW North Coast (Bell 1997, Griffith et al. 2003, Pressey & Griffith 1987), and it is likely to form part of a *B. articulata – Cladium procerum – Lepironia articulata* vegetation unit reported for south-eastern Queensland (McDonald & Elsol 1984). Comparatively shallow sedgelands of *Baloskion pallens*, *Baumea teretifolia* and associated species are widespread in the wallum of north-eastern NSW (Bell 1997, Griffith et al. 2000, Griffith et al. 2003), and similar or related sedgelands occur in south-eastern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Elsol & Dowling 1978).

Vegetation associated with bedrock, estuarine and alluvial landforms

Mangrove forest and woodland

Structure: low to mid-high, open woodland to open forest (grading into tall to very tall, sparse to closed shrubland).

Floristic composition: *Avicennia marina* subsp. *australasica* dominates, and *Aegiceras corniculatum* may be present as an understorey, particularly where the tallest stratum is diffuse. The immediate ground surface is generally unvegetated except for pneumatophores, although saltmarsh species such as *Juncus kraussii* subsp. *australiensis* can occupy gaps in the tallest stratum.

Habitat and community relations: Found on intertidal flats of the Wallis Lake estuary. *Juncus kraussii* subsp. *australiensis* rushland or *Baumea juncea* sedgeland replaces the mangroves at slightly higher elevations.

Distribution and equivalent vegetation types: *Avicennia marina* subsp. *australasica* mangrove forest and woodland is widespread along the NSW coast (Beadle 1981, Adam et al. 1988, West et al. 1984), and extends into Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1982, Durrington 1977).

Wet sclerophyll forest

Structure: tall to very tall, open to closed forest.

Floristic composition: *Eucalyptus grandis* dominates, with *Casuarina glauca* and *Melaleuca quinquenervia* present as associates. Understorey species include *Gahnia clarkei*, *Livistona australis*, *Melaleuca linariifolia*, *M. styphelioides*, *Oplismenus* spp. and *Viola banksii*. The understorey is generally less mesic than expected, possibly due to frequent ground fires and livestock grazing.

Habitat and community relations: Found on flats associated with alluvial backswamps, often where barrier sands interface, and grades into swamp sclerophyll forest as soil drainage deteriorates.

Distribution and equivalent vegetation types: *Eucalyptus grandis* reaches its southern distribution limit in the vicinity of Newcastle on the lower North Coast (Chippendale 1988, Harden 2002), and forests dominated by this species are described by others for north-eastern NSW and south-eastern Queensland (Beadle 1981, Elsol & Dowling 1978, Forestry Commission of NSW (1989) as forest type No. 48 'Flooded Gum', Griffith et al. 2000, McDonald & Whiteman 1979).

Dry sclerophyll forest and woodland

Structure: tall to very tall, woodland to closed forest.

Floristic composition: *Eucalyptus pilularis* is a common dominant or co-dominant of dry sclerophyll forest on bedrock rises and low hills, although other stands are characterised by *Eucalyptus eugenioides*, *E. siderophloia* and *Corymbia intermedia*. *Corymbia maculata* is also locally dominant in forest and woodland. Associates in these bedrock forests include *Eucalyptus acmenoides*, *E. microcorys*, *E. propinqua*, *E. resinifera* and *E. tereticornis*. Smaller areas of dry sclerophyll forest and woodland occupy flats nearer the Wallamba River, where barrier and alluvial sediments are likely to intergrade. *Eucalyptus tereticornis* and *C. intermedia* primarily co-dominate on these flats, whereas *Angophora costata* is a less common dominant. Understorey composition varies, although likely species include

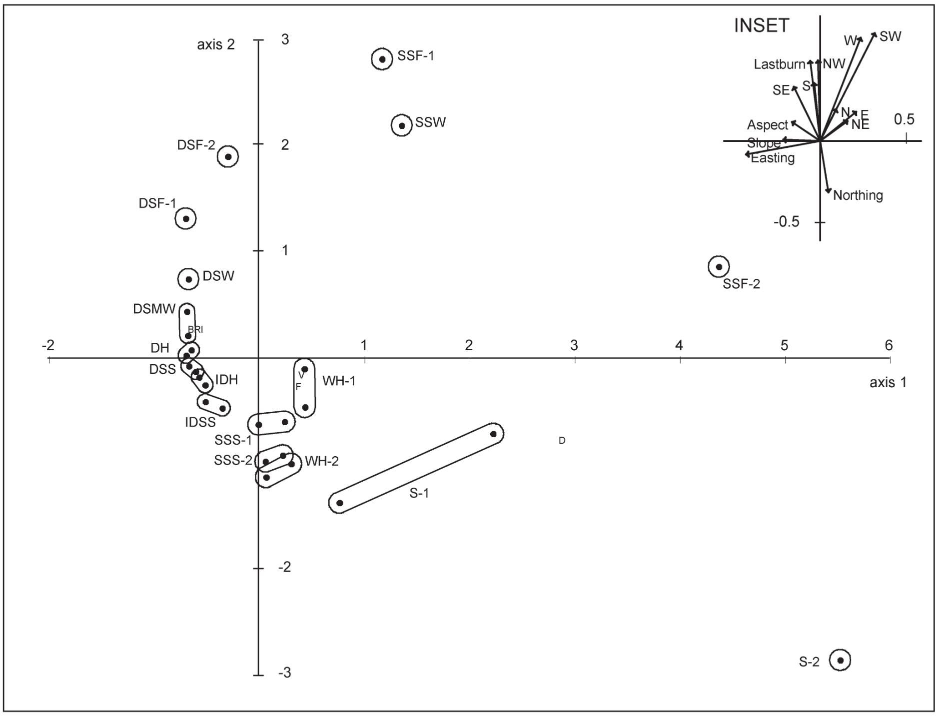

Fig. 3. Ordination of floristic and environmental data for wallum at Nabiac.

Eigenvalues: axis 1 = 0.8217; axis 2 = 0.5496. Axis 1 is significant (P = 0.03). CANOCO excluded invariate (e.g. altitude, as all sites <10 m) and collinear (e.g. SWP (swamp) with D) variables. BRI = beach ridge; D = closed depression; F = flat; V = open depression. For an explanation of formation and subformation abbreviations, see Figure 2.

Allocasuarina littoralis, *A. torulosa*, *Imperata cylindrica* var. *major*, *Jacksonia scoparia*, *Lepidosperma laterale*, *Leucopogon juniperinus*, *L. lanceolatus* var. *gracilis*, *Melaleuca nodosa*, *M. styphelioides*, *Persoonia linearis*, *Pteridium esculentum* and *Themeda australis*.

Habitat and community relations: Typical of hillcrests and hillslopes on bedrock rises and low hills, although also scattered on flats. Dry sclerophyll forest and woodland is replaced by the swamp equivalents as soil drainage deteriorates, and boundaries between these subformations may be gradational in areas of minimal relief.

Distribution and equivalent vegetation types: *Eucalyptus pilularis* is a widespread dominant of dry sclerophyll forest in coastal districts of NSW (Forestry Commission of NSW (1989) as forest type No. 37 'Dry Blackbutt', Griffith et al. 2000), and similar forests occur in south eastern Queensland (Elsol 1991, McDonald & Whiteman 1979). *Eucalyptus eugenioides*, *E. siderophloia* and *Corymbia intermedia* are characteristic dominants of coastal forests elsewhere in north-eastern NSW (e.g. Bundjalung and Yuraygir National Parks – S.J.G. and R.W. unpublished), and these would fall within the broader forest type 126 'Stringybark – Bloodwood' (Forestry Commission of NSW 1989). Related forests in which *E. eugenioides* associates with various species (including *C. intermedia*, *E. crebra*, *E. microcorys* and *E. tereticornis*) occur in south-eastern Queensland (McDonald & Whiteman 1979). *Corymbia maculata* has a predominantly coastal distribution south from the Manning River district (Hill & Johnson 1995), and forest dominated by this species falls within the *Corymbia maculata* s. lat. alliance of Beadle (1981) and the 'Spotted Gum' (*C. variegata*/*C. maculata*/*C. henryi*) forest type No. 70 of the Forestry Commission of NSW (1989), both of which are widespread in coastal NSW. Elsewhere in the Wallis Lake area, *C. maculata* dry sclerophyll forest occurs in Booti Booti National Park (Griffith et al. 2000). *Eucalyptus tereticornis* and *Corymbia intermedia* co-dominate dry sclerophyll forest or woodland elsewhere on the lower North Coast of NSW, for example in Hat Head NP, Limeburners Creek Nature Reserve and Lake Innes NR (S.J.G. and R.W. unpublished). *Eucalyptus tereticornis* and *C. intermedia* commonly associate with *Lophostemon suaveolens* on the upper North Coast (e.g. Pressey & Griffith 1992), although the latter species reaches its southern limit of distribution in the vicinity of Kempsey (Harden 2002). Equivalent forests and woodlands of *E. tereticornis* and *C. intermedia* (+/- *L. suaveolens*) occur in south-eastern Queensland (Durrington 1977, Elsol 1991). *Angophora costata* is endemic to NSW where it has a predominantly coastal distribution south from the Evans River on the far North Coast (Bale 1992, Harden 2002). Dry sclerophyll forest or woodland dominated by *A. costata* is reported for other localities (Benson 1986, Forestry Commission of NSW 1989, Griffith et al. 2000, Myerscough & Carolin 1986).

Swamp sclerophyll forest and woodland

Structure: (occasionally low to) mid-high to very tall, open woodland to closed forest.

Floristic composition: *Casuarina glauca*, *Eucalyptus robusta* and *Melaleuca quinquenervia* form more-or-less mono-dominant stands, although it is not uncommon for *M. quinquenervia* and *C. glauca* to co-occur, or alternatively *M. quinquenervia* and *E. robusta*. Minor associates in the tallest stratum include *Corymbia intermedia* and *Eucalyptus tereticornis*. *Livistona australis* and *M. quinquenervia* also co-dominate some stands, and *M. nodosa* dominates localised areas of low to mid-high swamp sclerophyll forest. The understorey is variable, probably reflecting not only site differences (e.g. extent of waterlogging and salinity) but also management (e.g. fire and livestock grazing), although likely species include *Baumea juncea*, *Entolasia stricta*, *Gahnia clarkei*, *Goodenia ovata*, *Imperata cylindrica* var. *major*, *Ischaemum australe*, *Lepidosperma quadrangulatum*, *Leptinella longipes*, *Livistona australis* (sometimes +/- continuous with the tallest stratum), *Melaleuca ericifolia*, *M. linariifolia*, *M. styphelioides* and *Phragmites australis*.

Habitat and community relations: Primarily associated with poorly drained alluvial backswamps and estuarine plains, although minor stands of *Melaleuca nodosa* occur on transferral drainage plains below bedrock rises. Dry sclerophyll forest and woodland often replaces the swamp equivalents as soil drainage improves.

Distribution and equivalent vegetation types: Swamp sclerophyll forest or woodland dominated by *Casuarina glauca*, *Melaleuca quinquenervia* or *Eucalyptus robusta* is reported by others for coastal districts of NSW (Forestry Commission of NSW 1989, Goodrick 1970, Griffith et al. 2000, Myerscough & Carolin 1986, Pressey & Griffith 1992) and southern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Durrington 1977, Elsol & Dowling 1978, McDonald & Whiteman 1979). Similar or related swamp sclerophyll forests of *Livistona australis* and *M. quinquenervia* are also known for other parts of north-eastern NSW (Myerscough & Carolin 1986, Osborn & Robertson 1939) and south-eastern Queensland (Elsol & Dowling 1978, McDonald & Elsol 1984), and these have affinities with *L. australis* subtropical ('palm', 'swamp') rainforest (Floyd 1990, Forestry Commission of NSW 1989, Griffith et al. 2000, Harden et al. 2006). *Melaleuca nodosa* appears to have a scattered distribution as a forest (or shrubland) dominant in coastal NSW and southern Queensland (e.g. Benson 1986, Coaldrake 1961, Elsol & Dowling 1978).

Swamp sclerophyll shrubland

Structure: tall to very tall closed shrubland.

Floristic composition: *Melaleuca ericifolia* dominates. Understorey species include *Baumea juncea*, *Ischaemum australe* and *Leptocarpus tenax*.

Habitat and community relations: Found on flats near the Wallis Lake estuary, at slightly higher elevations than saltmarsh vegetation such as *Juncus kraussii* subsp. *australiensis* rushland.

Distribution and equivalent vegetation types: The distribution of *Melaleuca ericifolia* extends south along the NSW coast from the Hastings River district (lower North Coast), and continues into Victoria and Tasmania (Harden 2002). The species is known to form dense stands elsewhere in south-eastern Australia (e.g. Bennett 1994, Benson 1992, Ladiges et al. 1981, Ryan et al. 1996).

Sedgeland

Structure: tall closed sedgeland.

Floristic composition: *Baumea juncea* dominates. *Casuarina glauca* and *Phragmites australis* may be present as scattered emergents.

Habitat and community relations: Found on supratidal flats of the Wallis Lake estuary, and grades into *Juncus kraussii* subsp. *australiensis* rushland at slightly lower elevations. *Baumea juncea* often extends landward as an understorey dominant in *Casuarina glauca* swamp sclerophyll forest and woodland.

Distribution and equivalent vegetation types: *Baumea juncea* sedgeland is present along much of the NSW coast (Adam et al. 1988, Clarke 1993, Griffith et al. 2000, Kratochvil et al. 1973), and it also occurs in Victoria (Head 1988) and south-eastern Queensland (Beadle 1981).

Rushland

Structure: tall closed rushland.

Floristic composition: *Juncus kraussii* subsp. *australiensis* dominates, although *Sporobolus virginicus* may be present as a shorter but continuous species. *Casuarina glauca* can be a scattered emergent.

Habitat and community relations: Extensive on tidal flats of the Wallis Lake estuary, and replaced by *Baumea juncea* sedgeland or *Casuarina glauca* swamp sclerophyll forest and woodland at slightly higher elevations.

Distribution and equivalent vegetation types: *Juncus kraussii* subsp. *australiensis* rushland is widespread on the NSW North Coast, and extends to the Central and South Coasts (Adam et al. 1988, Beadle 1981, Benson 1986, Clarke 1993, Goodrick 1970, Griffith et al. 2000, Kratochvil et al. 1973). It also occurs in south-eastern Queensland (Batianoff & Elsol 1989, Durrington 1977).

Environmental relationships of the Nabiac wallum

Swales, flats and swamps support sedgeland, wet heathland, and the swamp sclerophyll subformations of shrubland, forest and woodland. This vegetation remains floristically distinct from the dry heathland, and dry sclerophyll subformations of mallee woodland, forest and woodland found on beach ridges and dunes (Figure 2), even though the eroded landforms have minimal elevation and degraded relief. Numerical analysis (Figure 2) also identified floristic similarities between different structural formations (e.g. heathland and shrubland), and this trend is consistent with the previous study of wallum by Griffith et al. (2003).

Some stands of shrubland and heathland at Nabiac on the most degraded ridge – swale toposequences support a mix of species from both wet and dry habitats. Ordination confirmed the transitional or ecotonal character of these stands, distinguished using API as either intermediate dry heathland (IDH) or intermediate dry sclerophyll shrubland (IDSS) on the basis of structure (Figure 3).

Axis 1 in Figure 3 is consistent with a moisture gradient linked to topography, separating the driest vegetation on ridges (left of origin) from vegetation of poorly-drained flats and open depressions (near and just right of origin) and also from vegetation tolerant of standing water in closed depressions (further right). When compared with topography, a complex gradient, the singular relationships between floristic composition and each numerical environmental variable (depicted as vectors) were found to be relatively unimportant. The finding that topography is likely to be a primary determinant of vegetation pattern is consistent with previous studies in wallum (Coaldrake 1961, Griffith et al. 2003). Apart from displaying a moisture gradient, the ordination dispersed samples for vegetation formations and subformations represented by more than one API group, suggesting internal floristic heterogeneity. This trend is most evident for the sedgeland formation (S–1, S–2), and also within the swamp sclerophyll forest subformation (SSF–1, SSF–2).

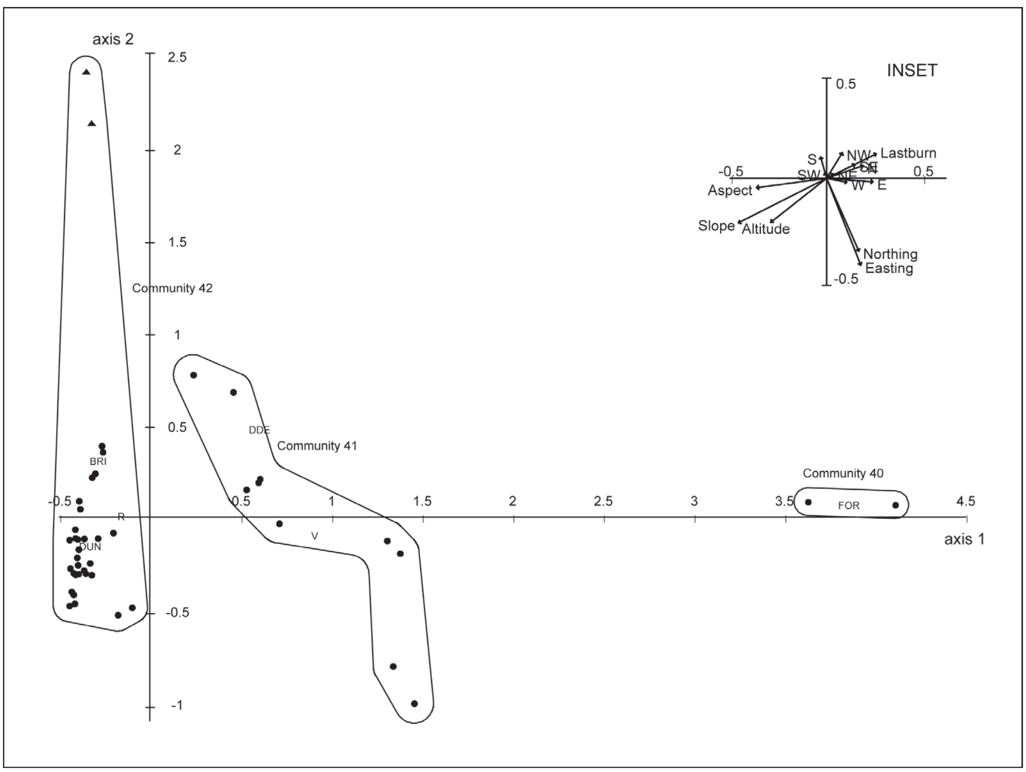

Fig. 4. Ordination of floristic and environmental data for wallum mallee at Nabiac and further north in NSW.

Eigenvalues: axis 1 = 0.7505; axis 2 = 0.3426. Axis 1 is significant ($P < 0.001$). BRI = beach ridge; DDE = drainage depression; DUN = dune; FOR = foredune; V = open depression. Nabiac samples appear as solid triangles. Communities No. 40–42 of Griffith et al. (2003) are: 40 = *Lophostemon confertus* dry scl. mallee; 41 = *Eucalyptus robusta*/*E. racemosa* subsp. *racemosa* – *Baloskion tetraphyllum* subsp. *meiostachyum* swamp scl. mallee; 42 = *Eucalyptus pilularis*/*E. planchoniana*/*E. racemosa* subsp. *racemosa* – *Leptospermum trinervium* dry scl. mallee.

Comparative analysis of the Nabiac wallum

The wallum ecosystem is highly attenuate along the coast of eastern Australia, and floristic composition varies as species reach their northern or southern limit of distribution. Nonetheless, published accounts for occurrences in south-eastern Queensland and other parts of north-eastern NSW suggest similarities with the vegetation at Nabiac (e.g. Clifford & Specht 1979, Coaldrake 1961, Durrington 1977, Griffith et al. 2003, Myerscough & Carolin 1986, Sattler & Williams 1999); and the shrubby vegetation of *Eucalyptus racemosa* subsp. *racemosa*, *Banksia aemula* and associated species that is extensive on the Nabiac barriers is certainly reminiscent of old wallum landscapes found elsewhere (e.g. Thompson & Moore 1984, Walker et al. 1981).

Species on the Nabiac barriers that appear to be absent from wallum further north include *Allocasuarina simulans*, *Callistemon citrinus*, *Lepidosperma limicola* and *Tetratheca ericifolia*. Another group of species including *Acacia quadrilateralis*, *Eucalyptus globoidea* and *Leptospermum arachnoides* are locally abundant at Nabiac but comparatively rare in the ecosystem at lower latitudes in NSW (Griffith et al. 2003). Nonetheless, most of the API groups distinguished at Nabiac for mallee, shrubland, heathland and sedgeland were found to support at least two-thirds of the species in the equivalent communities circumscribed by Griffith et al. (2003) for much of the NSW North Coast between the Manning River and the Lennox Head district. The proportion of shared species is even higher when calculations are adjusted to exclude those restricted to Nabiac.

Griffith et al. (2003) distinguished three mallee communities north of Nabiac: dry sclerophyll mallee shrubland dominated by *Lophostemon confertus* on contemporary foredunes (No. 40, Figure 4); swamp sclerophyll mallee shrubland, mallee forest and mallee woodland dominated by *Eucalyptus robusta* in open depressions, or rarely by *E. racemosa* subsp. *racemosa* on poorly drained dunes with minimal relief (No. 41); and dry sclerophyll mallee shrubland, mallee forest and mallee woodland on comparatively well-drained dunes and beach ridges dominated by varying combinations of *Eucalyptus pilularis*, *E. planchoniana* and *Corymbia gummifera*, or alternatively by *E. racemosa* subsp. *racemosa* as small, disjunct stands (No. 42). Ordination (Figure 4) confirmed similarities between *E. racemosa* subsp. *racemosa* dry sclerophyll mallee woodland on the Nabiac barriers and the equivalent community No. 42 of Griffith et al. (2003), which ranges widely along the coast of north-eastern NSW.

Seven shrublands are recognised for wallum in NSW to the north of Nabiac (Griffith et al. 2003), and an ordination (Figure 5) compares these with the shrubland data for Nabiac. The Nabiac samples for swamp sclerophyll shrubland dominated by *Banksia ericifolia* subsp. *macrantha* (swales) or *Melaleuca sieberi* (flats) align with the comparable community No. 35 of Griffith et al. (2003), which has a tallest stratum dominated by either of these species. *Banksia ericifolia* subsp. *macrantha* dominates in another community (No. 34) circumscribed by Griffith et al. (2003), although this has different species as associates or in the understorey and some do not extend south to Nabiac (e.g. *Leptospermum whitei*). The Nabiac samples for dry sclerophyll shrubland on ridges in which *Banksia aemula* is characteristic align with the equivalent *B. aemula – Phyllota phylicoides* community (No. 32) of Griffith et al. (2003), and this is widespread on the North Coast.

For wallum comprising a single stratum (e.g. heathland, sedgeland), a high degree of congruence can be expected between a vegetation classification based upon API and floristic assemblages derived by numerical classification of foliage cover data (Griffith et al. 2003). An ordination of data for single-stratum wallum at Nabiac and elsewhere in north-eastern NSW preserved the identity of formations and subformations, although also highlighting some overlap in floristic composition between, for example, wet heathland and sedgeland (Figure 6). Also included in the analysis were data for single-stratum vegetation found in clay or loam soils. This vegetation occurs on the slopes and crests of bedrock headlands and coastal hills (graminoid clay heathland, *Themeda australis* sod grassland), or otherwise associates with backbarrier flats and open depressions draining hills (*T. australis – Ptilothrix deusta* tussock grassland, wet heathland).

The Nabiac samples for dry heathland align with those for this subformation along the NSW coast to the north (Figure 6). The Nabiac samples for wet heathland similarly align with equivalent data from further north, and occurrences in swales remain floristically distinct from those on flats associated with plains and backplains (cf. Figure 3). Although included with data from further north, the sedgeland samples for Nabiac are widely dispersed, and this trend reflects floristic variation within the formation. The overlap between wet heathland and sedgeland indicates floristic similarities, particularly between a wet heathland variant in deep peat along swales and an allied sedgeland with abundant *Gahnia sieberiana* (Griffith et al. 2003). The ordination preserves the comparatively strong relationship between floristic composition and topography, although weaker correlations are evident with vectors for some numerical variables (e.g. the positive correlation of sod grassland and graminoid clay heathland with slope and altitude).

Conservation significance

The Nabiac barriers and associated flats have conservation value for the protection of nationally or regionally significant plants. These include species listed as Endangered (*Allocasuarina defungens*) or Vulnerable (*Allocasuarina simulans*, *Maundia triglochinoides*) under the Threatened Species Conservation (TSC) Act 1995, others at their distribution limit in wallum around Wallis Lake (e.g. *Banksia ericifolia* subsp. *macrantha* – southern, *Lepidosperma limicola* – northern, *Schoenus scabripes* – southern, *Tetratheca ericifolia* – northern), and also species that are generally rare or uncommon in wallum further north (e.g. *Acacia quadrilateralis*, *Almaleea paludosa*, *Callistemon citrinus*, *Caustis pentandra*, *Eucalyptus piperita*, *Gonocarpus salsoloides*, *Leptospermum arachnoides*, *Symphionema paludosum*). Stands of *Eucalyptus globoidea* forest and *Eucalyptus racemosa* subsp. *racemosa* mallee woodland are also significant at Nabiac – the former is not known from wallum further north in NSW, whereas the latter is apparently uncommon (Griffith et al. 2003).

Vegetation associated with nearby estuarine and alluvial landforms also has known or potential conservation significance. Coastal saltmarsh, for example, is an Endangered Ecological Community under the TSC Act, and this vegetation occurs on tidal flats of the Wallis Lake estuary. Several types of floodplain forest in northern NSW are also listed as Endangered, for example Swamp Oak Floodplain Forest, Sub-tropical Coastal Floodplain Forest and Swamp Sclerophyll Forest on Coastal Floodplains, as described in Keith and Scott (2005). Remnant and regrowth stands of these forests extend east of the Nabiac barriers onto alluvial landforms associated with the Wallamba River floodplain.

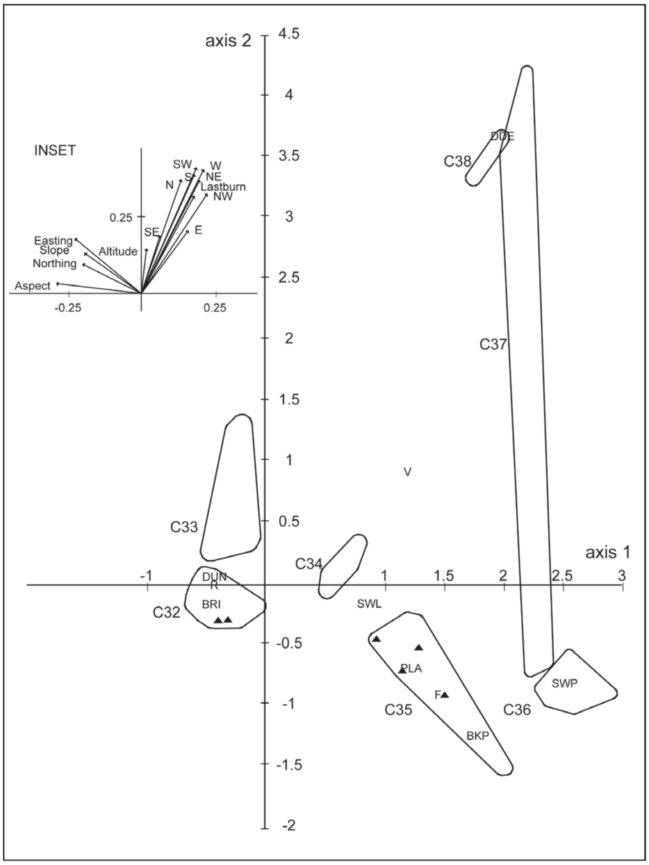

Fig. 5. Ordination of floristic and environmental data for wallum shrubland at Nabiac and further north in NSW.

Eigenvalues: axis 1 = 0.7476; axis 2 = 0.5449. Axis 1 is significant (P < 0.001). BKP = backplain (see Methods for details of other centroid codes). The SWP and D centroids coincided (later not shown). Nabiac samples appear as solid triangles. To aid interpretation of the biplot, polygons alone define the distribution of other samples (n = 86). Shrubland communities No. 32–38 of Griffith et al. (2003) are denoted: C32 = *Banksia aemula – Phyllota phylicoides*; C33 = *Banksia aemula – Allocasuarina littoralis* +/- *B. serrata*; C34 = *Banksia ericifolia* subsp. *macrantha* +/- *Leptospermum whitei – L. polygalifolium* subsp. *cismontanum*; C35 = *Melaleuca sieberi*/*Banksia ericifolia* subsp. *macrantha* – *M. thymifolia*; C36 = *Melaleuca quinquenervia – Baumea teretifolia*; C37 = *Melaleuca quinquenervia – Baumea juncea*; C38 = *Leptospermum speciosum.*

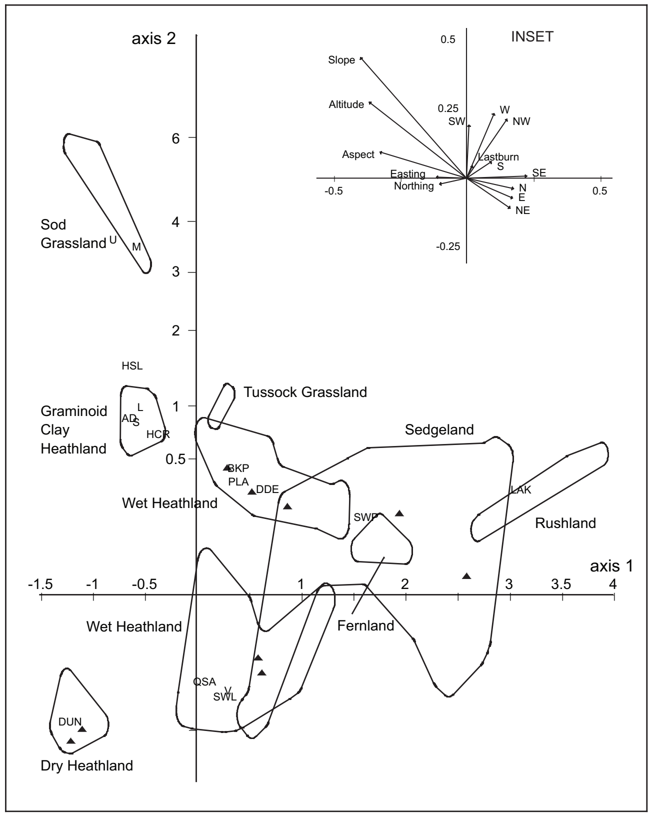

Fig. 6. Ordination of floristic and environmental data for wallum and related vegetation comprising a single stratum at Nabiac and further north in NSW.

Eigenvalues: axis 1 = 0.7344; axis 2 = 0.5777. Axis 1 is significant (P < 0.001). AD = adamellite (igneous rock); BKP = backplain; C = crest; HCR = hillcrest; HSL = hillslope; L = lower slope; LAK = lake; M = mid-slope; S = simple slope; SD = sedimentary rock (undifferentiated); U = upper slope (see Methods for details of other centroid codes). Overprinted centroids (in brackets) were omitted from the biplot to aid interpretation: DUN (with BRI and R); HCR (with C); BKP (with F); SWP (with D); HSL (with SD). To further improve interpretation, axis 2 was square root transformed after the ordination, and polygons alone define the distribution of samples (n = 360) in the respective formations and subformations (except

Research initiatives

Dunefields and beach ridge plains are characteristic landform patterns supporting wallum in eastern Australia, and the latter pattern dominates at Nabiac. Despite a long period of exposure to erosion, resulting in minimal elevation and degraded relief, the Nabiac barriers maintain floristic patterns related to topography and hence groundwater relations. From this observation, and another of strong floristic similarities with the ecosystem throughout large parts of its distribution, it is concluded that the Nabiac site is sufficiently representative to confirm its value for research into mechanisms of groundwater utilisation by wallum.

The research project at Nabiac is underway in collaboration with Dr Nigel Warwick (UNE), and this will investigate: (a) root system architecture, thereby identifying potential indicator species of adverse groundwater extraction impacts; (b) root activity and the soil water dynamics that determine this activity; (c) mechanisms of water utilisation; and (d) the role of groundwater in plant nutrition.

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Appendix 1. Foliage cover scores for vascular species in wallum samples at Nabiac

Foliage cover: 0 = absent; 1 = <1%; 2 = 1–5%; 3 = 6–25%; 4 = 26–50%; 5 = 51–75%; 6 = 76–100%. See Figure 2 for details of formations and subformations sampled in quadrats.

Sample locations:

NAB001.1: 32º08'46"S, 152º25'34"E
NAB002.1: 32º08'46"S, 152º25'10"E
NAB003.1: 32º08'55"S, 152º27'13"E
NAB004.1: 32º09'10"S, 152º26'33"E
NAB005.1: 32º09'27"S, 152º27'00"E
NAB006.1: 32º10'25"S, 152º27'15"E
NAB007.1: 32º10'25"S, 152º27'07"E
NAB008.1: 32º07'44"S, 152º25'54"E
NAB009.1: 32º07'39"S, 152º25'45"E
NAB010.1: 32º07'11"S, 152º26'41"E
NAB011.1: 32º07'42"S, 152º26'34"E
NAB012.1: 32º10'34"S, 152º27'31"E
NAB013.1: 32º10'36"S, 152º27'36"E
NAB014.1: 32º10'15"S, 152º26'11"E
NAB015.1: 32º10'05"S, 152º25'48"E
NAB016.1: 32º07'39"S, 152º25'56"E
NAB017.1: 32º07'49"S, 152º25'43"E
NAB018.1: 32º08'49"S, 152º25'09"E
NAB019.1: 32º08'49"S, 152º25'13"E
NAB020.1: 32º09'16"S, 152º26'54"E
NAB021.1: 32º09'51"S, 152º27'17"E
NAB022.1: 32º09'54"S, 152º27'16"E
NAB023.1: 32º10'30"S, 152º27'12"E
NAB024.1: 32º10'52"S, 152º27'10"E
NAB025.1: 32º10'57"S, 152º27'04"E
NAB026.1: 32º11'04"S, 152º27'08"E
NAB027.1: 32º06'49"S, 152º26'58"E

	NAB001.1	NAB002.1	NAB003.1	NAB004.1	NAB005.1	NAB006.1	NAB007.1	NAB008.1	NAB009.1	NAB010.1	NAB011.1	NAB012.1	NAB013.1	NAB014.1	NAB015.1	NAB016.1	NAB017.1	NAB018.1	NAB019.1	NAB020.1	NAB021.1	NAB022.1	NAB023.1	NAB024.1	NAB025.1	NAB026.1	NAB027.1
Class LYCOPSIDA																											
LYCOPODIACEAE																											
Lycopodiella lateralis	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
SELAGINELLACEAE																											
Selaginella uliginosa	1	0	0	1	2	0	0	0	0	2	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	3
Class FILICOPSIDA																											
BLECHNACEAE																											
Blechnum indicum	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0
DENNSTAEDTIACEAE																											
Hypolepis muelleri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Pteridium esculentum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	1	3	3	0
GLEICHENIACEAE																											
Gleichenia microphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5	0
LINDSAEACEAE																											
Lindsaea linearis	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCHIZAEACEAE																											
Schizaea bifida	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Class MAGNOLIOPSIDA – LILIIDAE																											
ANTHERICACEAE																											
Caesia parviflora var. *parviflora*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sowerbaea juncea	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARECACEAE																											
Livistona australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
BLANDFORDIACEAE																											
Blandfordia grandiflora	0	0	1	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
COLCHICACEAE																											
Burchardia umbellata	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CYPERACEAE																											
Baumea articulata	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Baumea juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
Baumea teretifolia	1	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0
Caustis pentandra	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	NAB001.1	**NAB002.1**	**NAB003.1**	**NAB004.1**	**NAB005.1**	**NAB006.1**	**NAB007.1**	**NAB008.1**	**NAB009.1**	**NAB010.1**	**NAB011.1**	**NAB012.1**	**NAB013.1**	**NAB014.1**	**NAB015.1**	**NAB016.1**	**NAB017.1**	**NAB018.1**	**NAB019.1**	**NAB020.1**	**NAB021.1**	**NAB022.1**	**NAB023.1**	**NAB024.1**	**NAB025.1**	**NAB026.1**	**NAB027.1**
CYPERACEAE *cont.*																											
Caustis recurvata var. *recurvata*	0	0	0	0	0	3	0	3	2	0	0	2	1	0	0	2	3	0	0	3	0	0	3	1	0	0	1
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Chorizandra sphaerocephala	3	0	0	3	1	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	1	0	0	0	0	0
Eleocharis sphacelata	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	1	0
Gahnia sieberiana	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	0	0
Lepidosperma filiforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma gunnii	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma limicola	0	0	0	1	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma longitudinale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Lepidosperma neesii	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma quadrangulatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Ptilothrix deusta	0	0	3	1	4	0	0	0	0	4	4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Schoenus brevifolius	2	0	2	1	0	0	0	1	0	2	2	1	1	1	2	0	1	0	3	2	2	2	0	0	0	0	3
Schoenus ericetorum	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Schoenus paludosus	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus scabripes	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus turbinatus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricostularia pauciflora	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HAEMODORACEAE																											
Haemodorum corymbosum	1	0	1	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
IRIDACEAE																											
Patersonia sericea	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Patersonia sp. aff. *fragilis*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUNCAGINACEAE																											
Maundia triglochinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Triglochin procerum s. lat.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Triglochin procerum s. str.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOMANDRACEAE																											
Lomandra glauca	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	1
Lomandra longifolia	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0
ORCHIDACEAE																											
Caleana major	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
PHORMIACEAE																											
Dianella caerulea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0
POACEAE																											
Entolasia stricta	2	0	1	1	2	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0
Hemarthria uncinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Imperata cylindrica var. *major*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ischaemum australe	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Leersia hexandra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Panicum simile	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Phragmites australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pseudoraphis paradoxa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
RESTIONACEAE																											
Baloskion pallens	1	0	0	0	0	0	3	0	1	0	0	0	2	0	1	0	1	0	0	2	0	1	1	0	0	0	1
Baloskion tetraphyllum subsp. *meiostachyum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	4	0
Coleocarya gracilis	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Empodisma minus	0	0	0	4	0	0	0	0	0	0	0	0	0	5	0	0	0	0	3	0	0	0	0	0	0	0	0
Eurychorda complanata	3	0	0	1	0	0	0	0	0	1	0	0	0	2	1	0	0	0	0	0	0	3	0	0	0	0	0
Hypolaena fastigiata	0	0	0	0	0	3	0	2	3	0	0	3	0	0	0	2	3	0	0	3	0	0	3	2	2	0	2
Leptocarpus tenax	3	0	3	1	3	0	0	0	0	3	3	0	3	0	2	0	1	0	2	2	0	1	2	0	0	0	0

	NAB001.1	NAB002.1	NAB003.1	NAB004.1	NAB005.1	NAB006.1	NAB007.1	NAB008.1	NAB009.1	NAB010.1	NAB011.1	NAB012.1	NAB013.1	NAB014.1	NAB015.1	NAB016.1	NAB017.1	NAB018.1	NAB019.1	NAB020.1	NAB021.1	NAB022.1	NAB023.1	NAB024.1	NAB025.1	NAB026.1	NAB027.1
RESTIONACEAE *cont.*																											
Lepyrodia muelleri	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepyrodia scariosa	0	0	0	0	2	0	0	0	0	0	2	0	1	1	1	0	0	0	0	2	0	0	0	0	0	0	3
Lepyrodia sp. A ('*imitans*' ms.)	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Sporadanthus caudatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Sporadanthus interruptus	0	0	0	1	0	0	0	0	1	0	0	0	0	1	2	0	1	0	0	2	0	1	3	0	0	0	0
SMILACACEAE																											
Smilax glyciphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
XANTHORRHOEACEAE																											
Xanthorrhoea fulva	0	0	0	0	3	0	0	0	0	1	0	0	0	1	2	0	0	0	1	1	0	3	0	0	0	1	0
XYRIDACEAE																											
Xyris gracilis subsp. *gracilis*	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0
Xyris juncea	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xyris operculata	2	0	1	2	3	0	0	0	0	2	2	0	0	2	1	0	0	0	0	0	0	3	0	0	0	0	1
Class MAGNOLIOPSIDA – MAGNOLIIDAE																											
APIACEAE																											
Actinotus helianthi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Centella asiatica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hydrocotyle peduncularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Platysace ericoides	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Xanthosia pilosa	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
CASUARINACEAE																											
Allocasuarina defungens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0
Allocasuarina simulans	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CLUSIACEAE																											
Hypericum japonicum	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CUNONIACEAE																											
Bauera capitata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DILLENIACEAE																											
Hibbertia acicularis	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0
Hibbertia fasciculata	0	0	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	1
Hibbertia linearis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Hibbertia obtusifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0
DROSERACEAE																											
Drosera binata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Drosera spatulata	0	0	0	1	0	0	0	0	0	2	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
ERICACEAE																											
Astroloma pinifolium	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Brachyloma daphnoides	0	0	0	0	0	2	0	2	2	0	0	1	0	0	0	0	3	0	0	0	1	0	0	1	0	0	0
Brachyloma scortechinii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Epacris microphylla var. *microphylla*	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	2	0	0	0	0
Epacris obtusifolia	0	0	0	1	2	0	0	0	0	1	1	0	0	1	2	0	0	0	0	0	0	2	0	0	0	0	0
Epacris pulchella	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	1	0	0	2	0	0	0	1
Leucopogon deformis	0	0	0	0	0	2	0	0	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leucopogon ericoides	0	0	0	0	0	0	0	2	1	0	0	3	3	0	0	2	0	0	0	0	0	0	0	3	1	0	0
Leucopogon lanceolatus var. *gracilis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0
Leucopogon leptospermoides	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	3	0	1	1	3	0	1
Leucopogon virgatus	0	0	0	0	0	2	0	1	1	0	0	1	1	0	0	0	1	0	0	1	0	0	1	1	1	0	0
Monotoca elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	1	0	0
Monotoca scoparia	0	0	0	0	0	3	0	2	3	0	0	3	0	0	0	3	3	0	0	2	1	0	1	1	3	0	1
Sprengelia incarnata	0	0	0	1	3	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Sprengelia sprengelioides	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Woollsia pungens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

	NAB001.1	NAB002.1	NAB003.1	NAB004.1	NAB005.1	NAB006.1	NAB007.1	NAB008.1	NAB009.1	NAB010.1	NAB011.1	NAB012.1	NAB013.1	NAB014.1	NAB015.1	NAB016.1	NAB017.1	NAB018.1	NAB019.1	NAB020.1	NAB021.1	NAB022.1	NAB023.1	NAB024.1	NAB025.1	NAB026.1	NAB027.1
EUPHORBIACEAE																											
Amperea xiphoclada	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Pseudanthus orientalis	0	0	1	0	0	0	0	1	0	0	1	1	2	0	1	0	1	0	0	1	0	0	1	0	0	0	1
Ricinocarpos pinifolius	0	0	0	0	0	1	0	1	1	0	0	2	0	0	0	1	1	0	0	2	1	0	2	1	1	0	0
FABACEAE – FABOIDEAE																											
Almaleea paludosa	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aotus ericoides	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	1	0	0	0	1	0	0
Bossiaea ensata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Bossiaea heterophylla	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Chorizema parviflorum	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dillwynia floribunda	0	0	1	0	0	0	0	0	0	2	2	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	1
Dillwynia glaberrima	0	0	0	0	0	1	0	2	2	0	0	1	2	0	0	0	2	0	0	2	0	0	2	1	0	0	0
Dillwynia retorta	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	3	1	0	0
Gompholobium glabratum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gompholobium pinnatum	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gompholobium virgatum var. *virgatum*	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0
Hardenbergia violacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Mirbelia rubiifolia	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllota phylicoides	0	0	0	0	0	1	0	3	2	0	0	1	0	0	0	0	3	0	0	3	1	0	0	1	1	0	0
Sphaerolobium minus	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerolobium vimineum	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FABACEAE - MIMOSOIDEAE																											
Acacia elongata	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0
Acacia longifolia subsp. *longifolia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Acacia quadrilateralis	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0
Acacia suaveolens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Acacia ulicifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
GOODENIACEAE																											
Dampiera stricta	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Goodenia paniculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Goodenia stelligera	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
HALORAGACEAE																											
Gonocarpus micranthus	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gonocarpus salsoloides	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gonocarpus tetragynus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
LAURACEAE																											
Cassytha glabella forma *glabella*	0	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1
Cassytha pubescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0
LENTIBULARIACEAE																											
Utricularia australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Utricularia gibba	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Utricularia lateriflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
LOGANIACEAE																											
Mitrasacme polymorpha	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
MENYANTHACEAE																											
Villarsia exaltata	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
MYRTACEAE																											
Baeckea diosmifolia	0	0	0	0	0	1	0	2	2	0	0	0	2	0	0	0	1	0	0	0	0	0	3	0	0	0	1
Baeckea imbricata	0	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0
Callistemon citrinus	0	0	1	1	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0	0	0	0	0
Callistemon pachyphyllus	0	0	1	2	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Calytrix tetragona	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Corymbia gummifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Darwinia leptantha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	1

	NAB001.1	NAB002.1	NAB003.1	NAB004.1	NAB005.1	NAB006.1	NAB007.1	NAB008.1	NAB009.1	NAB010.1	NAB011.1	NAB012.1	NAB013.1	NAB014.1	NAB015.1	NAB016.1	NAB017.1	NAB018.1	NAB019.1	NAB020.1	NAB021.1	NAB022.1	NAB023.1	NAB024.1	NAB025.1	NAB026.1	NAB027.1
MYRTACEAE *cont.*																											
Eucalyptus globoidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Eucalyptus pilularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Eucalyptus racemosa subsp. *racemosa*	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0
Eucalyptus robusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	1	1	0	0	0	3	0
Euryomyrtus ramosissima subsp. *ramosissima*	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	2	0	0	1
Leptospermum arachnoides	0	0	0	0	1	0	0	0	0	1	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Leptospermum juniperinum	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Leptospermum liversidgei	0	0	0	4	0	0	0	0	0	0	1	0	0	4	1	0	0	0	0	0	0	3	0	0	0	2	0
Leptospermum polygalifolium subsp. *cismontanum*		0	0	1	0	1	0	0	3	2	0	0	3	2	0	3	3	2	0	0	3	3	2	3	1	3	04
Leptospermum semibaccatum	0	0	0	0	0	3	0	4	3	0	0	3	3	0	0	2	4	0	0	4	0	0	3	0	0	0	2
Leptospermum trinervium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	0	3	2	0	0
Melaleuca linariifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0
Melaleuca nodosa	0	0	0	0	0	1	0	3	3	1	1	0	4	0	1	3	1	0	0	3	0	0	3	0	0	0	2
Melaleuca quinquenervia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0
Melaleuca sieberi	0	0	0	0	0	0	0	0	0	3	3	0	0	1	2	0	0	0	3	0	0	1	0	0	0	0	0
Melaleuca thymifolia	2	0	4	0	2	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ochrosperma lineare	0	0	0	0	0	3	0	2	0	0	0	3	3	0	0	1	1	0	0	0	0	0	1	0	0	0	0
PITTOSPORACEAE																											
Billardiera scandens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
PROTEACEAE																											
Banksia aemula	0	0	0	0	0	4	0	3	3	0	0	4	4	0	0	4	3	0	0	3	3	0	3	4	4	0	3
Banksia ericifolia subsp. *macrantha*	1	0	1	1	1	1	0	0	0	1	2	0	0	0	4	0	0	0	0	2	0	3	1	0	0	0	2
Banksia oblongifolia	0	0	4	0	2	0	0	2	0	3	4	0	2	0	3	0	2	0	0	3	0	1	2	0	0	0	2
Banksia robur	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0
Banksia spinulosa var. *collina*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conospermum taxifolium	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	3	0	0	0	0
Hakea teretifolia subsp. *teretifolia*	0	0	1	0	5	0	0	0	0	1	2	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0
Isopogon anemonifolius	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Persoonia lanceolata	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2	0	1	0	0	1	0	1	1	0	0	0	1
Persoonia virgata	0	0	0	0	0	1	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Petrophile pulchella	0	0	0	0	0	1	0	1	1	0	1	1	1	0	2	0	1	0	0	1	0	0	1	3	0	0	0
RUTACEAE																											
Boronia falcifolia	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	2
Boronia parviflora	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Boronia pinnata	0	0	0	0	0	0	0	2	1	0	0	2	0	0	0	2	2	0	0	2	2	0	0	0	1	0	0
Eriostemon australasius	0	0	0	0	0	2	0	0	2	0	0	3	0	0	0	2	0	0	0	1	1	0	0	3	2	0	0
Philotheca salsolifolia subsp. *salsolifolia*	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Zieria laxiflora	0	0	0	0	0	1	0	1	1	0	0	1	1	0	0	1	0	0	0	1	0	0	0	1	0	0	1
SANTALACEAE																											
Leptomeria acida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
STACKHOUSIACEAE																											
Stackhousia nuda	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STYLIDIACEAE																											
Stylidium graminifolium	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
THYMELAEACEAE																											
Pimelea linifolia	0	0	1	0	0	0	0	1	1	0	1	1	1	0	1	0	1	0	0	0	0	0	1	0	0	0	0
TREMANDRACEAE																											
Tetratheca ericifolia	0	0	0	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1