Australasian Journal of Environmental Management

ISSN: 1448-6563 (Print) 2159-5356 (Online) Journal homepage: https://www.tandfonline.com/loi/tjem20

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To cite this article: Ian Oliver, Megan J. McNellie, Greg Steenbeeke, Lachlan Copeland, Marianne F. Porteners & Julian Wall (2019) Expert allocation of primary growth form to the New South Wales flora underpins the biodiversity assessment method, Australasian Journal of Environmental Management, 26:2, 124-136, DOI: 10.1080/14486563.2019.1595186

To link to this article: https://doi.org/10.1080/14486563.2019.1595186

Published online: 30 May 2019.

AUSTRALASIAN JOURNAL OF ENVIRONMENTAL MANAGEMENT
2019, VOL. 26, NO. 2, 124–136
https://doi.org/10.1080/14486563.2019.1595186

Expert allocation of primary growth form to the New South Wales flora underpins the biodiversity assessment method

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ABSTRACT

Biodiversity values under the New South Wales (NSW) *Biodiversity Conservation Act 2016* are assessed in part according to the number and cover of native plant species within each of six growth form groups (trees, shrubs, grasses and grass-like, forbs, ferns, and others). Here we revise 19 growth form descriptions and use an independent expert process to allocate the most common (primary) growth form to the native terrestrial vascular plant flora of NSW. Independent allocations made by three botanists concurred for 6,153 taxa (84.7 per cent of the flora) and the remaining 1,112 taxa were resolved via a structured consensus making process. Allocation of each taxon to primary growth form has generated a single point of reference for the most common growth form for each native vascular plant species, expressed in its mature state across the extent of its range in NSW. The work presented here was undertaken to support transparent, repeatable and rigorous assessments of the richness and cover of growth form groups for the NSW Biodiversity Assessment Method. However, our approach and findings will be relevant to any government agency, industry group or researcher that uses plant growth forms to simplify ecological complexity or to assess the site-scale biodiversity values of terrestrial vegetation.

KEYWORDS

Growth form; vegetation; legislation; expert; biodiversity assessment method

Introduction

Under the New South Wales (NSW) *Biodiversity Conservation Act 2016*, the Biodiversity Offsets Scheme establishes a framework to avoid, minimise and offset the impacts of development on biodiversity. It is underpinned by the Biodiversity Assessment Method (*BAM*; see NSW Government 2017). A range of biodiversity values are assessed by the BAM including the presence of threatened species and threatened species habitat. However, the focus of this work is supporting the assessment of the biodiversity value 'vegetation integrity' which

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measures the condition of vegetation attributes at a site. These attributes include (amongst others) the number and cover of all native terrestrial vascular plant species within different plant growth forms such as trees, shrubs and grasses. Assessments according to a standard set of aggregated ecological entities based on plant form and function ground the practice of assessing biodiversity values and contribute to better biodiversity policy.

Plant growth forms as aggregated ecological entities

Grouping plant species by their form and function is a long-standing foundation in plant ecology (Warming and Vahl 1909; Raunkiaer 1934). The use of plant growth forms or life forms (hereafter growth forms) to convey information on the form and function of individual species or to simplify the complexity of entire plant communities is well established. Growth forms have been used to capture information on community composition and dynamics (Cain 1950; Whittaker 1975; Box 1996), the effects of disturbance (McIntyre, Lavorel, and Tremont 1995; Letcher 2014), species dispersal distances and migration rates (Svenning and Sandel 2013), adaptations to climate (Smith 1913), morphology (Halloy 1990; Engemann et al. 2016), growth stage (the Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie (BBCH) scale in references such as Finn, Straszewski, and Paterson 2007), and resource use (Chapin, Johnson, and McKendrick 1980; Eckstein and Karlsson 1997; Franks and Farquhar 1999; Santiago and Wright 2007). Growth forms as aggregated ecological entities help to reveal patterns in habitats, resources and communities (McGill et al. 2006).

However, the allocation of many thousands of plant species to a predefined set of growth forms is challenging and quite unlike any taxonomic grouping which can be unveiled using taxonomic keys and references. A species' growth form may vary due to genetic and/or environmental (phenotypic) variation (Rowe and Speck 2005) and may not be apparent until maturity. This leaves scope for botanists to have wide and varied opinions about which species belong in which growth form and when (e.g. differing stages of maturity and environmental conditions). This challenge has plagued science for more than a century, with Warming and Vahl (1909) stating 'it is an intricate task to arrange the growth forms of plants in a genetic system, because they exhibit an overwhelming diversity of forms and are connected by the most gradual intermediate stages'.

These challenges have resulted in a variety of growth form classifications with variously ambiguous growth form descriptions (Walker and Hopkins 1990; Duckworth, Kent, and Ramsay 2000; Pérez-Harguindeguy et al. 2013; DEE 2017). Despite the well-founded and long-standing traditions of developing growth form descriptions, they alone do not facilitate an operational and consistent approach to assigning species to growth forms. When allocation of the same species to the same growth form by different observers underpins field practices such as those required by Australian biodiversity regulatory tools, a single, transparent and repeatable one-to-one relationship between each taxon and its primary growth form will facilitate operational consistency.

Growth form richness and foliage cover in biodiversity regulatory tools

In Australia, transparent and repeatable regulatory tools are used to assess the biodiversity values of sites proposed for development, or conservation, or restoration actions.

Biodiversity values include: the presence of threatened species or their habitats; the conservation status of the vegetation community (e.g. amount of original distribution remaining); and the condition of the vegetation. This article is concerned with the assessment of vegetation condition which is based largely on the status of vegetation attributes at sampled plots, compared with a benchmark state for those attributes. Values for the benchmark state variously represent best-on-offer (Eyre et al. 2015) or long or relatively undisturbed (DSE 2004; Gibbons et al. 2009) conditions for vegetation of the same type. Vegetation attributes are therefore used as the operational surrogate for the status of site-scale biodiversity and so guide decisions concerning the clearing of native vegetation at development sites and the funding of conservation and restoration actions at stewardship or offset sites. In these assessments, the amount of native plant foliage cover and the number of native plant species (richness) within different growth forms (aggregations of data for multiple species within a growth form) feature heavily.

The Australian Vegetation Attribute Manual (see Table 6 in DEE, 2017, 37) guides states and territories by listing 25 vascular, non-vascular, terrestrial and aquatic plant growth forms. These descriptions have been developed to classify Australian vegetation, as per Walker and Hopkins (1990) within the National Vegetation Information System (DEE 2017). Different states and territories use these growth forms in different ways. For example, in Queensland, *BioCondition* condenses: all 25 growth forms into four groups to assess richness (trees, shrubs, grasses, and forbs/others); and condenses 15 growth forms into three groups to assess cover (trees, shrubs and perennial grasses; Eyre et al. 2015). In Victoria, *Habitat Hectares* expands the list of terrestrial growth forms and considers varied height classes of some growth forms to assess the richness and cover of 20 different vascular and non-vascular growth forms (DSE 2004; DEPI 2014). For both *BioCondition* and *Habitat Hectares*, descriptions and illustrations help guide on-site allocation of native species to growth form. Although these descriptors and illustrations are useful, they fail to provide a single, transparent and repeatable one-to-one relationship between each taxon and its growth form, potentially leading to inconsistent allocation of species to growth form by field assessors.

In 2017, the New South Wales regulatory tool the Biodiversity Assessment Method (NSW Government 2017) also adopted an assessment of the foliage cover and richness of native vascular plant species within growth forms as a key component of its metric-based approach to assessing vegetation condition. These growth forms, their descriptions, and the consistent allocation of each plant taxon in the native terrestrial vascular plant flora of NSW to a single primary growth form is the focus of this article. This final point is a significant and necessary development supporting transparent, repeatable and robust regulatory tools because inconsistent allocations may result in incorrect assessments of vegetation condition and consequently result in poor decisions concerning the clearing of native vegetation or the funding of conservation or restoration actions.

Despite the potential complexity surrounding the growth forms of some species, consistent allocations of species to growth forms are possible when a single, transparent and repeatable one-to-one relationship between each taxon and its growth form is fixed. A fixed relationship facilitates consistent allocation of the same species to the same growth form by different field assessors. It also facilitates the creation of growth form richness and cover benchmarks (representing best-on-offer, or long or relatively undisturbed conditions) when these draw upon empirical floristic data. For this purpose, a fixed relationship ensures that each species contributes to benchmarks for the same growth form at all plots at which the species was recorded. Fixed allocation of species to growth form therefore supports consistent allocation in the field and to benchmarks and thereby, consistent assessment of vegetation condition. We accept that this approach may not capture the full range of a species' growth form diversity and by consequence may attract criticism. However, we are not alone in seeking the benefits of single fixed allocations of plant species to growth forms as has been demonstrated by the recent endeavours to assign primary growth forms to 67,413 vascular plant species from North, Central and South America (Engemann et al. 2016).

The aims of our study were to improve growth form descriptions and develop a fixed one-to-one relationship for the NSW terrestrial native vascular plant flora to support transparent, repeatable and robust assessment of vegetation condition. Specifically, we have: (1) aggregated 19 terrestrial vascular plant growth forms into six higher-order categories suitable for benchmarking native richness and cover for different vegetation types; (2) revised the descriptions of the 19 growth forms for improved clarity and better discrimination; and (3) used an independent expert panel process to allocate each species across the entire NSW native terrestrial vascular plant flora to one of 19 primary growth forms. Although the work presented here has been undertaken to support the NSW BAM, our approach and findings will be relevant to any government agency, industry group or researcher that uses plant growth forms to simplify ecological complexity or to assess vegetation condition as a component part of site-scale biodiversity values.

Methods

Growth form aggregation and description

The first aim of this work was to aggregate the 19 terrestrial vascular plant growth forms from Walker and Hopkins (1990) and DEE (2017) into a smaller number of aggregated units (growth form groups) for which benchmarks could usefully be developed and deployed in the BAM. To achieve a smaller number, we considered that most growth form groups should be present in most vegetation types, and that for each growth form group the benchmark values in most vegetation types would be high enough to provide discrimination among plots of differing condition. For example, we considered it impractical to create richness and cover benchmarks for the *hummock grass* growth form which is mostly restricted to arid ecosystems and is only represented by a few species in NSW. Our approach therefore aimed to arrive at a similar hierarchical arrangement of multiple growth forms nested under a set of broader growth form groups as used by *BioCondition* (see Eyre et al. 2015, Appendix 7). To aggregate the 19 growth forms into a smaller practical number of growth form groups we canvassed the views of 23 professional botanists and ecologists in a workshop setting (16) or via email.

Our second aim was to revise the descriptions of these 19 growth forms for improved clarity of description and discrimination among growth forms. Revisions were iterative and commenced with initial proposed changes by the authors to the descriptions in Walker and Hopkins (1990) and DEE (2017) being reviewed by 11 professional botanists and ecologists in a second expert workshop. Further improvements were made by the expert botanists as part of the consensus workshop (see below) and these were finalised by the authors.

Independent allocation of primary growth form to the native NSW flora

The final and most important aim of this study was to allocate each taxon in the entire NSW native vascular plant flora to a single primary growth form to ensure consistency of species allocation both for benchmark generation and for field application. Our step-wise process was based on the consensus approach used by Engemann et al. (2016) for assigning the vascular plant flora of North, Central and South America to primary growth forms. Our process was undertaken by three expert botanists (GS, LC, MFP). Experts were selected based on availability, practical experience with plot-based vegetation survey, and their knowledge of the flora of NSW. Time and cost constraints limited independent assessment to three experts. The steps were: (1) extract the list of native vascular plant taxa and supply the list and growth form descriptions to each botanist; (2) each botanist independently allocated each taxon to one of the 19 growth forms; (3) undertake initial consensus seeking process when one botanist's allocation differed from the other two; (4) hold a consensus workshop to resolve remaining differences and finalise growth form allocations and descriptions.

Supply of taxa and growth form descriptions

An export of all native vascular plant taxa was sourced as a *Census of Australian Plants list* from the NSW BioNet Atlas database (NSW Government 2019a). Each record included family, genus, species, and sub-species names and code and authority. The export yielded 7,265 records.

The 19 terrestrial vascular plant growth form descriptions provided in Walker and Hopkins (1990) and DEE (2017) were initially revised by the authors and then refined at the second experts' workshop. Both the list of 7,265 taxa and the growth form descriptions table were provided to the three botanists to guide their allocations.

Independent allocation of the primary growth form to each taxon

With reference to the growth form descriptions table, each expert botanist independently allocated to each taxon record the most common (primary) growth form expressed by the species in its mature state across the extent of its range in NSW. Whether the allocation was based on personal experience or literature was also recorded. We accept that this method does not describe the full range of a species' growth form diversity, but concur with Engemann et al. (2016) that it provides a useful estimate of the growth form most commonly encountered in mature individuals of a species.

Initial consensus seeking

Where an allocation was equivalent across all three botanists the allocation was accepted as 'full consensus'. Where one botanist's allocation differed from the other two ('part consensus'), he/she was provided the opportunity to accept the allocation of the other botanists, or to discuss the allocation at a review workshop. Where all three botanists' assignments differed ('no consensus') the taxon was included in the list for workshop review.

Final consensus workshop and growth form descriptions review

A face-to-face facilitated review workshop was held to resolve remaining 'part consensus' and 'no consensus' records. Each taxon was discussed and additional references were consulted, with the aim of reaching consensus on the most appropriate primary growth form for all species (see Engemann et al. 2016). Growth form descriptions were also reviewed at the workshop to further improve clarity and reduce ambiguity and to ensure they were consistent with all allocations. Where descriptions were considered to have not been sufficiently clear prior to this effort, descriptions were improved and those taxa allocated to that growth form were again reviewed to ensure that the amended growth form description was the most appropriate.

Results

Growth form aggregation and description

Our two workshops and email consultative processes with professional botanists and ecologists resulted in the aggregation of 19 terrestrial vascular plant growth forms into the six growth form groups: trees, shrubs, grasses and grass-like, forbs, ferns, and those not otherwise classified 'others' (Table 1). These six growth form groups are the higher-order categories for which native vascular plant richness and cover benchmarks have been developed and deployed within the *BAM*. Table 1 also shows the final growth form descriptions that resulted from the iterative review process. Where appropriate the descriptions draw on taxonomic entities to further improve clarity, discriminate among competing growth forms, and ultimately facilitate consistent allocation of the same species to the same growth form.

Independent allocations of primary growth form to the native NSW flora

The expert botanists' independent allocations of the 7,265 taxa to primary growth forms resulted in full consensus for 6,153 taxa (84.7 per cent), part consensus for 1,107 taxa (15.2 per cent), and no consensus for 5 taxa (0.1 per cent). The initial consensus seeking process applied to part consensus taxa (one botanist's allocation differed from the other two) resulted in full consensus for a further 1,011 taxa (the single botanist accepted the allocation of the other two). The face-to-face consensus review workshop therefore dealt with the remaining 96 part consensus taxa and the 5 no consensus taxa (1.4 per cent). The final consensus workshop (facilitated by JW) considered additional references and the opinions of each of the three botanists for each of the 101 taxa and reached consensus on the most appropriate primary growth form for all remaining taxa.

The consensus approach resulted in a total of 7,265 taxa being allocated to a single primary growth form. Over 2,000 taxa were allocated to each of the forb and shrub growth forms, while considerable numbers were also allocated to the tree and tussock grass growth forms (Table 2). Growth forms represented by 20 or fewer taxa included hummock grass, mallee shrub, palm and palm-like, tree fern, and Xanthorrhoea. At the higher-order level of growth form groups, the shrub group was allocated the most species (n = 2,704) and the fern group the fewest (n = 210). Assignments for all species are available at NSW Government (2019b).

Discussion

The aggregation of growth forms into a smaller number of growth from groups will always be fraught. Our expert workshops and subsequent email discussions represented a range of

Table 1. Growth form groups, their constituent growth forms and revised growth form descriptions for native terrestrial vascular plants in NSW

Growth form group	Growth form*	Growth form description*
Tree	Tree	Woody perennial plant usually with a distinct trunk. Usually more than 6 m tall when mature.
	Mallee tree	Primarily species of *Eucalyptus* with multiple stems arising from a lignotuber. Usually more than 6 m tall when mature.
Shrub	Shrub	Woody perennial plant, multi-stemmed at the base (or within 750 mm from ground level). Usually less than 6 m tall when mature. Not a mallee, heath or chenopod shrub.
	Mallee shrub	Primarily species of *Eucalyptus* with multiple stems arising from a lignotuber. Usually less than 6 m tall when mature.
	Heath shrub	Woody perennial shrub, commonly with ericoid leaves (nanophyll or smaller). Commonly occurs on nutrient-poor substrates.
	Chenopod shrub	Woody perennial shrub or sub-shrub from the family Chenopodiaceae (excludes forb-like chenopods). Single or multi-stemmed, may be semi-succulent, or leafless with fleshy, jointed stems (e.g. *Tecticornia* and *Sarcocornia*).
Grass & grass-like	Tussock grass	Any tussock or bunch grass that forms discrete but open tussocks usually with distinct individual shoots. Includes clumping species with deep subterranean rhizomes, e.g. *Imperata* and the reed *Phragmites*.
	Hummock grass	Coarse xeromorphic grass with a mound-like form often dead in the middle. Includes all members of *Triodia*.
	Other grass	Member of the family Poaceae that generally has a mat-forming habit (rhizomatous and/or stoloniferous, 'sod' grasses), rather than a distinctive tussock, reed or hummock habit.
	Sedge	Herbaceous, usually perennial erect plant generally with a tufted habit. Includes all members of the family Cyperaceae.
	Rush	Herbaceous, usually perennial erect plant that is neither a grass nor a sedge. Includes all members of the families Eriocaulaceae, Juncaceae, Lomandraceae, Restionaceae, Sparganiaceae and Typhaceae.
Forb	Forb	Herbaceous or slightly woody, annual, biennial or sometimes perennial plant. Includes bulbous or tuberous herbs, ground orchids, lilies and irises from the families Amaryllidaceae, Anthericaceae, Araceae, Asphodelaceae, Blandfordiaceae, Commelinaceae, Hypoxidaceae, Iridaceae, terrestrial/geophytic Orchidaceae, Philydraceae and Phormiaceae. Includes some aquatic or semi-aquatic life forms. Includes all members of the family Juncaginaceae, plus members of the genera *Lemna*, *Wolffia, Potamogeton* and *Vallisneria*. Includes forb-like chenopod species (e.g. *Einadia* spp., some *Atriplex*, *Chenopodium*, *Dysphania* and *Maireana* species).
Fern	Fern & fern allies	Characterised by large and usually branched leaves (fronds), herbaceous, terrestrial to aquatic, can be epiphytic or lithophytic. Includes all members of the families Adiantaceae, Aspleniaceae, Azollaceae, Davalliaceae, Grammitaceae, Marsileaceae, Psilotaceae, Pteridaceae, Polypodiaceae, Lycopodiaceae, Selaginellaceae and Isoetaceae. Excludes tree-ferns and all members of the families Cyatheaceae, Dicksoniaceae, Osmundaceae and Marattiaceae.
Other	Tree fern	Characterised by large and usually branched leaves (fronds), arborescent and terrestrial. Includes all members of the families Cyatheaceae, Dicksoniaceae, Osmundaceae and Marattiaceae.
	Palm & palm-like	Palm and other arborescent monocotyledons. All members of the families Agavaceae, Arecaceae, Doryanthaceae or the genus *Cordyline*.
	Cycad & cycad-like	Palm-like plant, stemless to arborescent with fruit in cones. Includes all members of the family Zamiaceae and the genus *Pandanus*.
	Vine	Climbing, twining, winding, scrambling or sprawling plants.
	Epiphyte & lithophyte	Plant with roots attached to the aerial portions of other plants or rocks. Includes angiosperm epiphytes, mistletoes, parasites and some orchids. Includes all members of the families Loranthaceae and Viscaceae. Excludes lithophytic or epiphytic ferns which are included in fern and fern allies.
	Xanthorrhoea	Grass tree. All members of the genus *Xanthorrhoea*.

*Modified from Walker and Hopkins (1990) and DEE (2017).

Table 2. Growth form groups, their constituent growth forms and counts of taxa allocated to each.

Growth form group	Growth form*	Count of taxa allocated
Tree	Tree	776
	Mallee tree	39
		815
Shrub	Shrub	2,326
	Chenopod shrub	208
	Heath shrub	159
	Mallee shrub	11
		2,704
Grass & grass-like	Tussock grass	452
	Sedge	268
	Rush	143
	Other grass	42
	Hummock grass	10
		915
Forb	Forb	**2,187**
Fern	Fern and fern allies	**210**
Other	Vine	252
	Epiphyte and lithophyte	103
	Cycad and cycad-like	27
	Xanthorrhoea	20
	Tree fern	17
	Palm & palm-like	15
		434

*Modified from Walker and Hopkins (1990) and DEE (2017).

views on the appropriate smaller number of growth form groups. Our arrival at six groups represented a trade-off between practicality and consistency of form and function within groups. Trees, shrubs, grass and grass-like, forbs and ferns share among their constituent species similarities in form and function. The same cannot be said for our growth form group ‘others’ which contains tree ferns, palms, cycads, grass trees (*Xanthorrhoea*), vines and twiners, epiphytes and lithophytes. In other regions of Australia, or in other countries, where particular ‘other’ growth forms dominate, more growth form groups may be desirable. Our study does provide the necessary data to enable the creation of additional growth form groups for the NSW flora should they be required.

Our study efficiently delivered expert consensus on the growth form most commonly expressed by each of 7,265 native terrestrial vascular plant taxa in their mature state across the extent of their range in NSW. Although our study involved only three experts, their initial independent consensus for nearly 85 per cent of species suggested that a sufficient number of experts were consulted. Were a lower level of consensus reached, a greater number of experts may have been required (see Dorrough, Oliver, and Wall 2018).

Although our study presents a consensus outcome, certainty of allocation to growth form is likely to have varied among species and among experts. Where time and resources permit, we would recommend to others that our approach could be improved by eliciting confidence statements from experts for each allocation. We would expect that species allocated with lower confidence would be more variable in the expression of their mature growth form state across the extent of their range. Identifying such species could potentially lead to enhancements in assessment approaches that accommodate such variability. Ignoring such variability with a one-to-one relationship between species and growth form is accepted as a limitation of our approach. There will be situations encountered by field assessors where the growth form of a mature individual in the field differs to the primary growth form specified in our reference list. Also, our approach only caters for the mature state of species and ignores changes in growth form that may occur at different growth stages. Other assessment methods have attempted to accommodate this variability (see Eyre et al. 2015) but doing so was beyond the scope of this study.

Growth forms as practical surrogates for biodiversity

The use of practical surrogates for the assessment of biodiversity remains contentious (Lindenmayer et al. 2002), meanwhile development decisions and conservation actions affecting biodiversity continue to occur. Biodiversity surrogates are a way of making complex information simpler and can be used to inform better decision making (Margules and Pressey 2000). A common surrogate of terrestrial biodiversity is native vegetation composition, structure and function (Noss 1990; DSE 2004; Gibbons et al. 2009; Eyre et al. 2015). However, even these primary attributes of biodiversity are broad and difficult to measure. The richness and cover of native plant growth forms offers a pragmatic solution to deconstructing the complexity of biodiversity and upscaling the simplicity of single species assessments. Plant growth forms offer a middle ground upon which sound development and conservation decisions can be made.

Since 2005, decisions on clearing, conserving or restoring native vegetation in NSW have considered site-scale vegetation composition based on a tally of native vascular plant species at survey plots, compared with the expected number of species in a relatively-undisturbed plot of the same vegetation type (the species richness benchmark value; see Gibbons et al. 2009). A single species richness number tells us little about the composition of a plot and evidence suggests that the effects of plant species on ecosystem function should be attributed to the functional traits of species rather than to species number *per se* (Díaz and Cabido 2001). Assessments of total plot-scale species richness are unlikely to provide an indication of key ecosystem functions because plant species vary considerably in both their responses to the environment and their effects on ecosystem function. Therefore, the loss or addition of the same number of plant species can have quite different effects on ecosystem function, depending on the identity of the species (Díaz and Cabido 2001).

The incorporation of plant growth form richness in biodiversity assessment methods goes some way towards accommodating the advice of Díaz and Cabido (2001, 653) that ‘functional richness and composition, and especially the traits of the dominant plant species, deserve particular attention’. Our five growth form groups; trees, shrubs, grass and grass-like, forbs, and ferns, are all different in form and function. The presence of, and number of species within, each of these five growth form groups conveys considerably more information about the compositional and functional state of a plot than does a single tally of all species at the plot. Similarly, the cover of each of these structurally-different groups provides important information on the presence and diversity of different types of fauna habitat (McElhinny et al. 2006). Our sixth ‘other’ growth form group contains a wide variety of different expressions of both form and function, but resulted from the need for a practical number of higher-order categories because many of the constituent growth forms contained small numbers of species.

Our delivery of six growth form groups for the NSW BAM aligns with other biodiversity assessment methods in common use in Australia (DSE 2004; Eyre et al. 2015) and recognises the important roles that growth form richness and cover play as practical surrogates for biodiversity. The separate assessments of growth form richness and cover provide crucial information on the compositional, structural, and functional state of vegetation. The approach not only contributes to a more robust assessment of vegetation condition, but also clearly identifies those growth form groups which are degraded or missing and in need of conservation or restoration.

Benefits of a fixed allocation of primary growth form to native species

Whilst floristic databases are well established with fixed links between species and origin (native or exotic) or lifespan (annual, bi-annual, perennial) or other plant traits (Kattge et al. 2011; Díaz et al. 2016), fixed links between species and growth form have been underutilised in Australia. This is primarily because some species can exhibit different growth forms at different stages of maturity or under different environmental conditions or following different disturbance regimes. However, we move in concert with other expansive floristic databases (e.g. Engemann et al. 2016) towards fixed links, or allocation of species to the most common (primary) growth form expressed by the species in its mature state across the extent of its range.

For vegetation management guided by metrics (scores) derived from regulatory tools, a fixed link between species and growth form is crucial. It is crucial for field practitioners as it removes the subjective and potentially inconsistent nature of allocations. It may also improve efficiency for field practitioners when fixed-links are built into digital data collection devices or databases and growth form is automatically allocated according to species name. It is also crucial for ensuring that each species is allocated in the field to the same growth form to which it was allocated for creating benchmarks such that condition assessment and the resultant biodiversity values are correctly calculated.

Using our independent expert panel-based consensus approach we have linked each of 7,265 native terrestrial vascular plant taxa to the growth form most commonly expressed in each species' mature state across the extent of its range in NSW (NSW Government 2019b). With this resource, we can consistently and transparently allocate species to their primary growth form and generate accurate and repeatable assessments of vegetation condition based on growth form group richness and cover. Moreover, these assignments contribute to a more global endeavour of assigning species to growth forms (Engemann et al. 2016).

Implications for empirical condition benchmarks

By creating a fixed reference table linking each of 7,265 native species to a single primary growth form, the extensive floristic data generated by several decades of vegetation survey across NSW becomes available for developing growth form-specific plot-based richness and cover benchmarks for different vegetation types in NSW. To support the BAM, the native plant species recorded from more than 36,000 full floristic vegetation plots have been linked to their primary growth form to enable the modelling of best-on-offer richness and cover benchmarks (Eyre et al. 2015) for the six growth form groups (trees, shrubs, grass & grass-like, forbs, ferns and others). Modelled best-on-offer benchmarks have been created for more than 650 bioregional vegetation types (Yen et al. *in review*) which are based on combinations of 95 vegetation classes within NSW (Keith 2004) and the 18 IBRA regions found in NSW (Thackway and Cresswell 1995; DEE 2016). They are akin to the Regional Ecosystems benchmarked in Queensland and used in *BioCondition* (Queensland Government 2019). The NSW bioregional vegetation type benchmarks are available on the NSW BioNet database and are fundamental to the NSW regulatory tool the Biodiversity Assessment Method (NSW Government 2017).

The reference list generated by this study linking native terrestrial vascular plant taxa to primary growth forms supports transparent, repeatable and robust vegetation condition assessment. This list, the supporting growth form descriptions, and the condition benchmarks built upon them are embedded into the NSW Biodiversity Assessment Method to support evidence-based decision making in accord with the *NSW Biodiversity Conservation Act 2016*.

Acknowledgements

Thanks to the many botanists and ecologists both within NSW Office of Environment and Heritage (OEH) and within industry, who participated in the first workshop which led to the creation of the six growth form groups within which the 19 growth forms were nested. Thanks are also extended to the experts who attended the second workshop and provided subsequent email contributions resulting in further refinement of the growth form definitions - Josh Dorrough, Emma Gorrod, Charles Huxtable, Miranda Kerr, Steve Lewer, Dani Murphy, Michael Somerville, Mark Tozer, Ken Turner, Chris Watson and Matt White. Allan Kwok recoded and transcribed the meeting into an expert workshop report. Philip Gleeson extracted CAPS census of NSW native flora and ensured data integrity to link growth forms to taxonomic records in the NSW BioNet Atlas database.

Disclosure statement

No potential conflict of interest was reported by the authors.

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