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Is what you see what you get? Visual vs. measured assessments of vegetation condition

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Summary

1. An important step in the conservation of biodiversity is to identify what exists, its quantity and its quality (i.e. condition). This can be a daunting task at the landscape-scale, so vegetation communities are often used as surrogates for biodiversity. Satellite imagery has improved our ability to rapidly measure vegetation parameters but the need for calibration still requires rapid and cost-effective on-ground condition assessment. Some management agencies address this need by using visual condition assessments, with unknown consequences for the different purposes of condition data. It is therefore vital to examine the comparability of visual and systematic condition assessment methods to guide their use in conservation decision making.

2. We compared visual assessments of vegetation condition with more systematic and higher resolution on-ground assessments, using a method where both assessments were made for the same quadrats. We determined both the condition parameters observers respond to when making visual assessments of condition, and the consequences of any differences for the application of these data.

3. We found that visual assessment of vegetation condition broadly represented measured assessments of the same vegetation, but that observers simplify their assessments by responding to only some of the measured condition parameters. No consistent trends were found in the parameters observers responded to across the different vegetation types sampled.

4. *Synthesis and applications.* We conclude that visual estimates of vegetation condition are only of sufficient resolution to replace more expensive, high-resolution assessments at a landscape-scale, when condition results are combined over multiple areas and vegetation types. Visual assessment methods potentially can provide an efficient measure of overall condition for conservation management agencies where practitioners can make assessments of condition in the course of their daily management activities – an important step forward. At smaller scales, idiosyncratic effects render visual estimates highly variable when compared with systematic condition assessments. This variability, especially among vegetation types, suggests that more systematic assessments are necessary when management decisions require higher-resolution estimates of changes in individual condition parameters, such as when measuring the success of individual management actions. These findings provide a valuable guide for selecting the most appropriate approach for the different objectives of condition assessments for biodiversity conservation.

Key-words: environmental management, expert opinion, ocular assessment, rapid condition assessment, subjective judgement

Introduction

Effective management of global biodiversity requires careful planning based on an understanding of distribution, abundance and variety (Parkes, Newell & Cheal 2003). Vegetation communities are often used as a surrogate for biodiversity; however, assessing vegetation communities at a landscape-scale can be a daunting task. Advances in satellite imagery and aerial photography have enabled substantial progress to be made in determining the spatial distribution of vegetation

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(Cherrill *et al.* 1995), yet the successful management of remnant vegetation also depends on understanding its attributes, which typically requires on-ground assessments (Landres, Morgan & Swanson 1999). Land management agencies have recognized the importance of understanding vegetation condition and have different definitions of condition for different purposes (Keith & Gorrod 2006). We define vegetation condition, for biodiversity conservation, as the extent to which the attributes of the vegetation differ from the average condition of mature and long-undisturbed examples of the same community (Parkes *et al.* 2003).

To use vegetation condition as a surrogate for biodiversity, the parameters measured include habitat features for many species of fauna (e.g. presence of tree hollows) and common indicators of habitat degradation (e.g. invasive species abundance; Keith & Gorrod 2006). Vegetation condition assessments can then be used to: (i) measure success (Keddy & Drummond 1996), (ii) establish offsets for biodiversity lost through development actions (ten Kate, Bishop & Bayon 2004), (iii) determine appropriate financial incentives for biodiversity conservation on private land (Oliver *et al.* 2005; USDA 2003), (iv) inform strategic management planning (NSW DEC 2005) and (v) report biodiversity conservation progress (CBD 2004). While a useful planning tool for biodiversity conservation, the costs of vegetation condition assessment methods can be prohibitively high; hence, there is an ongoing need for accurate and cost-effective on-ground vegetation condition assessments (Jensen *et al.* 2000; Beck & Gessler 2008).

There is an inherent relationship between the resolution of vegetation condition data and the cost of assessment techniques (Cohen *et al.* 2005). Many assessment methods have been developed globally (e.g. Dahms & Geils 1997; Gibbons *et al.* 2005; NCC 1990; Parkes *et al.* 2003), and generally adopt one of two approaches: systematic or visual assessments. Systematic assessments estimate condition by measuring attributes of the vegetation, then combining these into an index of condition (e.g. Rooney & Rogers 2002; Hargiss *et al.* 2008) often based on comparisons with a benchmark (e.g. Parkes *et al.* 2003; Gibbons *et al.* 2005). These assessments tend to provide more repeatable, higher-resolution estimates of condition but can be resource-intensive (Helm & Mead 2004). For landscape-scale condition assessments, purely visual assessment methods, using unstructured estimates of condition made in a largely intuitive manner (University of Ballarat 2001; Hockings *et al.* 2009), offer a lower cost alternative. Visual assessments can be made during visits to reserves made in the course of regular management activities and be applied over larger areas, but generally provide lower-resolution estimates of condition. However, the subjective nature of these judgements can generate criticism about their reliability (Burgman 2001). Where resources are limited, a compromise must be reached between the cost and resolution of estimates that still achieves the objectives of the assessment (Archaux, Berges & Chevalier 2007). We must therefore understand the degree to which different condition assessment methods can meet these different objectives to select the most appropriate technique.

Although higher-resolution estimates are often perceived as preferable to lower-resolution estimates, there have been few real tests of their ability to reflect the 'true' condition of vegetation, and repeatability may be an issue for both methods (see Gorrod & Keith 2009). Given that the appropriate compromise between the resolution and cost of condition estimates depends on the purpose of the assessment, we do not discuss the relative accuracy of systematic and visual methods in this study, but instead consider whether they can achieve the five main purposes of condition assessments.

To determine which assessment methods are most appropriate for the different purposes of condition assessments we use an assessment technique applied in protected areas in Australia as a case study. Both systematic and visual assessment methods were employed for the same quadrats, thus excluding spatial and temporal variations between the assessment types and allowing the relationship between the approaches to be examined. We use these data to investigate: (i) the degree to which visual judgements of condition reflect measured assessments; (ii) which elements of condition, if any, observers respond to when making visual assessments; and (iii) the implications for using the two assessment methods for different purposes of condition assessments.

Materials and methods

VEGETATION CONDITION ASSESSMENT TECHNIQUE

The assessment technique used here was developed by botanists within Parks Victoria and the University of Ballarat in southeastern Australia, to collect condition data from protected areas across the state of Victoria. The technique is similar to those employed internationally to assess habitat condition for management and biodiversity conservation purposes (e.g. Hargiss *et al.* 2008; NCC 1990; USDA 2003). Vegetation condition was measured relative to reference examples of the same mature community in its natural state (University of Ballarat 2001) and the results were used by managers to examine patterns of variation in vegetation condition within communities and to establish baseline conditions against which any changes might be linked to management actions. Condition was divided into four elements: floristics, structure, health and regeneration (University of Ballarat 2001). The technique was designed and carried out by a team of independent botanists with extensive experience in the relevant communities.

Systematic, measured assessment

Condition assessments were conducted in eight reserves across Victoria between November 2000 and March 2004, with data collection stratified by vegetation type (Fig. 1). Generally, the vegetation strata were ecological vegetation communities (as defined by DSE 2004) but in some reserves, strata represented groups of communities. Multiple quadrats were measured in each vegetation type (Table 1) with the number determined by the extent of the vegetation community and occasionally limited by resource constraints. The extent and heterogeneity of the vegetation were generally closely related. A set of vegetation condition parameters were measured at each quadrat (Table 2). Species diversity was determined by a count of each native species present in the quadrats. Cover estimates of all species, including those

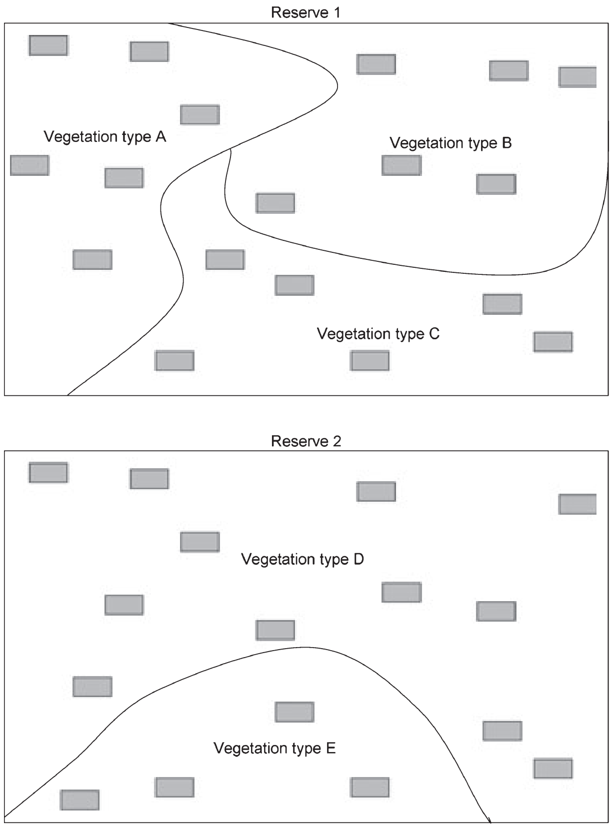

Fig. 1. Schematic diagram of the relationship between reserves, vegetation types and quadrats within the sampling design. The number of replicate quadrats sampled in each vegetation type relates to the extent of the vegetation community.

not indigenous to the vegetation community, were made according to a modified six-point Braun–Blanquet scale ($<5\%$ = few individuals, $<5\%$ = any number of individuals, then 25% increments). Regeneration was classed as the number of seedlings up to 1 m high for each overstorey species (0, <5, 6–20, >20), whereas strata integrity was calculated for up to four strata according to the detailed criteria set out for species richness, cover and tree condition (Table 2). Tree condition was assessed on a five-point scale, for each tree, according to detailed criteria and reference photos (Table 2). Dominant strata age class was determined by the diameter at breast height grouped into a maximum of five age classes.

The parameters measured were tailored to the vegetation type, with up to 16 parameters measured across 8 reserves. Typical quadrats were assessed in *c.* 45 min, but time varied from 30 to 90 min depending on the species richness of a community (Table 2). Five experienced botanists conducted the assessments over eight reserves, with all reserves assessed by one pair of botanists, except Hattah–Kulkyne, Murray–Sunset and Wyperfeld National Parks, where the size of the reserves required two or more teams. In these cases, teams worked together for at least 1 day to maximize consistency.

For each vegetation type, three reference quadrats were measured to account for natural variability within a community. The benchmark quadrats were the least modified local example of the mature vegetation community based on expert knowledge, an appropriate approach in modified landscapes (Gibbons *et al.* 2008). For most parameters, the benchmark value was the mean score from the three reference quadrats (e.g. species diversity), or was fixed at a maximum value (e.g. tree condition; Table 2).Where no local examples of 'good condition' could be found, the highest value measured across all quadrats was used. The measured condition parameters were scaled to between 0 and 1 based on their relationship to the benchmark values for the vegetation type (e.g. measured species diversity divided by the benchmark for species diversity). Where raw parameter scores exceeded those for the reference quadrats, the benchmark value was used to ensure parameters were scaled between 0 and 1. Not accounting for conditions where the benchmark is exceeded can overestimate condition, such as when disturbance results in overly dense regrowth. However, this was not the case for the communities considered here because disturbance results in a loss of the perennial understorey. The scaled parameter scores were then aggregated with equal weighting to produce a condition score for each quadrat. There are strengths and weaknesses to each of the different methods used to generate condition indices (Gibbons & Freudenberger 2006) and averaging condition parameters can be problematic when parameter scores are bimodal. However, an unweighted average of parameter scores was used here for simplicity and to allow land managers to ascribe their own weightings depending on their management objectives.

Visual assessment

Before condition parameters were measured in a quadrat, the observers conferred to make a visual condition assessment for the vegetation following a 5 min inspection of the quadrat. Quadrats were scored between 0 and 10, later rescaled to between 0 and 1 for comparison with the measured score. A limited descriptive scale (0 = completely modified vegetation, no indigenous species and 10 = indigenous vegetation in good condition) was used to calibrate their assessments of condition. Observers were aware of the condition parameters to be measured directly after the visual assessment. As the measured assessment score was not calculated in the field there was little opportunity for visual assessments to be calibrated against the measured assessment or the benchmark quadrats. However, the repetition of visual assessments and the observers' extensive experience with the vegetation communities may have influenced their assessments.

DATA PREPARATION

Data from 8 reserves sampled across Victoria covered a total of 19 vegetation types with no overlap between reserves (see Table 1), excluding data from vegetation types where 5 or fewer quadrats were measured. Quadrat size was 1000 m^2 except in reserves where patch size precluded this, in which case a 400 m^2 quadrat was used to ensure quadrats sampled were well within the specified vegetation type. Comparisons between the assessment methods within vegetation types were based on quadrats of equal size. The overall and individual parameter scores for each quadrat were used to determine whether there is an association between the visual and measured estimates.

ANALYSES

Hypothesis one: the difference between the measured and visual assessment scores deviates significantly from 0.

To test this hypothesis, the difference between the two estimates of condition for each quadrat was calculated and used as the response variable for analysis of variance (ANOVA). Quadrats were used as replicates and reserve was included as a random factor in the analysis. The correlation between the measured and visual assessment scores

Table 1. Description of each vegetation type sampled with descriptions of the disturbance and management history

Vegetation type	No. of quadrats	Description	Disturbance and management history
Barmah State Forest			
Riverine Swamp Forest	11	Tall overstorey dominated by *Eucalyptus camaldulensis* and shrub layer of *Acacia* sp. Moderate to very dense ground cover, varying with frequency and depth of flooding, often dominated by *Setaria* and *Pseudoraphis* sp. Moderate to dense litter layer.	Heavy grazing by cattle and macropods, and soil disturbance by pigs and cattle. Previous timber harvesting.
Floodplain Forest	10	Forest to woodland vegetation dominated by an open to dense overstorey of *Eucalyptus camaldulensis*. Dense ground layer dominated by *Carex*, *Setaria*, *Poa* or *Eleocharis* sp. Moderate to dense litter layer.	Heavy grazing by cattle and macropods, and soil disturbance by pigs and cattle. Previous timber harvesting.
Drier Woodlands	10	Open overstorey dominated by Box-Bark eucalypts and *Allocasuarina* sp. Sparse shrub layer of *Acacia*, *Eutaxia*, *Dodonaea* and *Pittosporum* sp. Moderate ground layer of subshrubs, grasses, sedges and herbaceous forbs. Moderate to dense litter layer.	Heavy grazing by cattle and macropods, and soil disturbance by pigs and cattle. Previous timber harvesting.
Grampians National Park			
Shrubby Woodland	11	Diverse *Eucalypt* sp. overstorey with a small tree layer dominated by *Acacia*, *Callitris* and *Allocasuarina* sp. Moderate to dense, tall shrub layer dominated by *Leptospermum* sp. A moderately dense ground layer dominated by grasses (*Microlaena* sp.) with a variety of forbs, orchid and non-vascular plant species.	Strong grazing and browsing pressure from native macropods and exotic game species (rabbits, goats and deer) introduced into the area in 1984.
Hills Herbrich Woodland	12	Comprised of an open *Eucalypt* and *Acacia* sp. overstorey, sparse, mixed tall shrub layer and a diverse, moderate to dense ground layer including a diversity of grasses, sedges, forbs, orchids and non-vascular plants. Ground layer includes exposed rock.	Strong grazing and browsing pressure from native macropods and exotic game species (rabbits, goats and deer) introduced into the area in 1984.
Hattah–Kulkyne National Park			
Drainage Line Grassy Woodland	30	Overstorey dominated by *Eucalyptus largiflorens*. Tall shrub layer of *Maireana*, *Dodonaea*, *Muehlenbeckia*, *Pittosporum*, *Chenopodium* and *Eremophila* sp. Small shrub layer of *Enchylaena*, *Einadia*, *Sclerolaena*, *Chenopodium*, *Sclerochlamys* and *Sclerolaena* sp. Ground layer of *Vittadinia*, *Austrodanthonia*, *Austrostipa* and *Atriplex* sp.	Agricultural grazing history, timber harvesting, altered hydrological regimes and grazing by macropods and rabbits and browsing by goats.
Riverine Grassy Forest	11	Overstorey of *Eucalyptus camaldulensis* and occasional *Acacia stenophylla*. Tall shrub layer dominated by *Dodonaea*, *Maireana*, *Muehlenbeckia* and *Pittosporum* sp. Small shrub layer of *Enchylaena*, *Morgania*, *Einadia* and *Solanum* sp. Ground layer dominated by *Vittadinia*, *Austrostipa* and *Chamaesyce* sp.	Agricultural grazing history, timber harvesting, altered hydrological regimes and grazing by macropods and rabbits and browsing by goats.

Table 1. (Continued)

Vegetation type	No. of quadrats	Description	Disturbance and management history
Mornington Peninsula National Park			
Riparian Forest	7	Overstorey dominated by *Acacia melanoxylon* and *Pomaderris aspera*. Tall shrub layer dominated by *Bursaria*, *Coprosma*, *Olearia* and *Solanum* sp. Variable small shrub layer dominated by *Rubus* and *Sambucus* sp. Ground layer dominated by ferns (*Dicksonia* sp.) and sedges (*Gahnia* sp.). Low to moderate litter cover.	Destructive past use (including grazing, cropping and partial clearing), grazing pressure from native and introduced fauna, pest plant and animal infestations and *Phytophthora cinnamomi* infection.
Damp Sands Herbrich Woodland	7	Open to moderately dense overstorey of *Eucalyptus* sp. Sparse tall shrub layer of *Banksia*, *Cassinia*, *Leptospermum*, *Leucopogon* and *Olearia* sp. Sparse small shrub layer of *Acrotriche, Amperea, Bossiaea, Epacris* and *Platylobium* sp. Dense ground layer dominated by grasses and forbs. Moderate litter cover.	Past land use of grazing, cropping and partial clearing, grazing pressure from native and introduced fauna, pest plant and animal infestations and *P. cinnamomi* infection.
Murray–Sunset National Park			
Belah Woodland	20	Sparse overstorey dominated by *Casuarina pauper*. Moderately dense tall shrub layer of *Beyeria*, *Senna, Eremophilla* and *Scaevola* sp. Sparse small shrub layer dominated by *Enchylaena, Chenopodium, Olearia* and *Sclerolaena* sp. Grassy ground cover.	Timber harvesting, clearing, thinning, grazing by macropods, stock and rabbits, browsing by goats.
Gypseous Plain Grassland	12	Overstorey of scattered *Myoporum platycarpum*. Understorey of native annuals.	Timber harvesting, clearing, thinning, grazing by macropods, stock and rabbits, browsing by goats.
Sandplain Grassland	9	Occasional scattered woodland trees. Dominated by perennial grasses and native annual herbs.	Timber harvesting, clearing, thinning, grazing by macropods, stock and rabbits, browsing by goats.
Plenty Gorge Parkland			
Box/Ironbark Woodland	12	Open overstorey dominated by *Eucalyptus tricarpa, E. leucoxylon* and *E. polyanthemos*. A sparse small tree layer of *Acacia* sp. A sparse tall shrub layer of *Acacia*, *Cassinia*, *Dodonaea* and *Exocarpos* sp. Small shrubs layer dominated by *Acacia*, *Acrotriche* and *Einadia* sp. Open ground cover with diverse grasses and forbs. Moderate litter cover.	Grazing by macropods and rabbits, introduced species, surrounding land use (high-density urbanization).
Escarpment Woodland	7	Open overstorey dominated by *Eucalyptus polyanthemos*, *E. macrorhyncha* and *E. goniocalyx*. Open small tree layer dominated by *Acacia* sp. Variable tall shrub layer with *Cassinia* and *Bursaria* sp. Scattered small shrub layer and open ground layer of mixed grasses and forbs including *Austrostipa* and *Lomandra* sp. Moderate litter cover.	Grazing by macropods and rabbits, introduced species, surrounding land use (high-density urbanization).
Alluvial Terraces Herbrich Woodland	10	Open overstorey mainly of *Eucalyptus microcarpa* and *E. albens*. Sparse small tree layer of *Acacia* sp. Patchy tall shrub layer dominated by *Acacia* sp. Sparse small shrub layer dominated by *Astroloma* sp. Moderately dense, diverse ground layer was moderately dense with sedges, forbs, lilies and grasses. Dense litter layer.	History of mining, timber harvesting and current grazing pressure by macropods.

Table 1. (Continued)

Vegetation type	No. of quadrats	Description	Disturbance and management history
Reef Hills Park			
Heathy Dry Forest	12	Open overstorey dominated by *Eucalyptus macrorhyncha* and *E. polyanthemos*. Sparse small tree layer of *Acacia* and *Exocarpos* sp. Sparse tall shrub layer dominated by *Brachyloma* and *Hibbertia* sp. Diverse small shrub layer including *Acrotriche, Cheiranthera, Hardenbergia and Leucopogon* sp. Moderately dense ground layer of tussock grasses (*Joycea* sp.), lilies (*Arthropodium* sp.), orchids (*Thelymitra* sp.) and other herbs (*Drosera* sp.). Moderately dense litter layer.	History of mining, timber harvesting and current grazing pressure by macropods.
Box Ironbark Forest	12	Open overstorey of *Eucalyptus macrocarpa* and *E. polyanthemos*. Sparse small tree layer of *Acacia* sp. Sparse tall shrub layer including *Acacia, Brachyloma and Cassinia* sp. Sparse small shrub layer of *Cheiranthera* and *Pultenaea* sp. Moderately dense ground layer dominated by tussock grasses, orchids and herb species. Moderately dense litter layer.	History of mining, timber harvesting and current grazing pressure by macropods.
Wyperfeld National Park			
Lake Bed Herbfield	68	Tall shrub layer dominated by *Maireana brevifolia*. Small shrub layer of *Maireana*, *Lawrencia* and *Cressa* sp. Ground layer dominated by *Malva*, *Podolepis*, *Salsola*, *Austrodanthonia* and *Austrostipa* sp.	Altered hydrological regimes, grazing by macropods and introduced herbivores.
River Redgum/Black Box Woodland	40	Overstorey dominated by *Eucalyptus camaldulensis* and *E. largiflorens*. Tall shrub layer of *Maireana* and *Pittosporum* sp. Small shrub layer dominated by *Enchylaena tomentosa*. Diverse ground layer including *Einadia*, *Nicotiana*, *Podolepis* and *Austrodanthonia* sp. Moderate litter cover.	Altered hydrological regimes, grazing by macropods and introduced herbivores.

was also calculated to examine the relationship between the two assessment methods.

Hypothesis two: the values from the visual assessments were significantly correlated with the scores for the condition parameters, and these relationships differed by vegetation type.

Multiple regression was used to test this hypothesis with the condition parameters used as explanatory variables and the visual assessment scores used as the response variable. Quadrats were used as replicates. We compared all possible models using the small sample unbiased Akaike's information criterion (AICc) and selected the most parsimonious model (see Burnham & Anderson 2002). Where multiple models were equally likely, we undertook model averaging to arrive at the final model (Burnham & Anderson 2002). Preliminary analyses indicated an interaction between the vegetation type and the condition parameter estimates and so analyses were performed independently for each vegetation type. As no vegetation types were measured at more than one reserve, reserve was not included as a factor in these models.

All variables were tested against the assumptions of linear models and non-conforming variables were transformed using $\log_e + 0{\cdot}001$ or square-root transformations where appropriate. Multicollinearity between the variables was examined and where the correlation coefficient exceeded 0·5 (Booth, Niccolucci & Schuster 1994) the variable with the lower support based on Akaike's weighting score was excluded.

Results

RELATIONSHIP BETWEEN THE VISUAL AND MEASURED CONDITION SCORES

The visual and the measured condition scores for each quadrat were correlated across the reserves (slope = 0·60, R^2 = 0·44; Fig. 2a), although the variation between the visual assessment scores for any given measured assessment score was large (Fig. 2b). For moderate condition estimates, the median condition scores match the visual estimates more closely, yet the variability of these scores was high. Although the extremes of the condition spectrum tended to yield the lowest variability between the two condition estimates, these visual condition scores also show the lowest agreement with the measured condition assessments (Fig. 2b).

The overall relationship between visual and measured condition scores (Fig. 2) did not account for differences between reserves and vegetation types. Generally, the range in measured condition scores for any one reserve was higher than that in the visual condition score (Fig. 3), but there were exceptions, as indicated by a significant reserve × condition measure

Table 2. Methods of estimation for each condition parameter in the rapid vegetation condition assessment technique analysed in this study and the estimated time required in the field to collect these data. *If cover estimates are made simultaneously then total time is likely to be 15 to 20 minutes

Condition parameters	Method of estimation	Benchmark value	Approximate field time
Species richness	Number native species identified	Mean of reference quadrats	20–30 min
Percentage of native to weedy species	Calculated from ocular estimates of native and weed species in a quadrat	Mean of reference quadrats	Calculated later
Native tree (*Eucalypt*) cover	Estimated using modified Braun–Blanquet scale (1–6 = < 5% (few individuals), < 5%, then 25% increments)	Mean of reference quadrats	5 min*
Native tree (non-*Eucalypt*) cover	Estimated using modified Braun–Blanquet scale (1–6 = < 5% (few individuals), < 5%, then 25% increments)	Mean of reference quadrats	5 min*
Native tall shrub cover	Estimated using modified Braun–Blanquet scale (1–6 = < 5% (few individuals), < 5%, then 25% increments)	Mean of reference quadrats	5 min*
Native small shrub cover	Estimated using modified Braun–Blanquet scale (1–6 = < 5% (few individuals), < 5%, then 25% increments)	Mean of reference quadrats	5 min*
Native ground cover	Estimated using modified Braun–Blanquet scale (1–6 = < 5% (few individuals), < 5%, then 25% increments)	Mean of reference quadrats	5 min*
Percentage of native to weedy ground cover	Calculated from ocular estimates of native and weedy species	Mean of reference quadrats	Calculated later
Percentage of native to weedy tall shrub cover	Calculated from ocular estimates of native and weedy species	Mean of reference quadrats	Calculated later
Percentage of native to weedy small shrub cover	Calculated from ocular estimates of native and weedy species	Mean of reference quadrats	Calculated later
Regeneration	Number of seedlings up to 1 m high (0, < 5, 6–20, > 20) for each overstorey species	100%	5 min
Strata integrity	Binary measure of integrity for each of four strata, if present Tree layer – intact if two or more individuals were present with stem diameters > 10 cm and tree condition scores of two or more Tall shrub layer – intact if species richness was > 5 and projected foliage cover was > 5%. Small shrub layer – intact if species richness was > 5 and projected foliage cover > 10% Ground layer – intact if perennial and annual native species cover was > 10%	4·0 if four strata expected	Calculated later
Tree condition	Each tree is assessed on a five-point scale: 5 – healthy, well-formed crown, no dead branches within the canopy; 4 – well-formed crown but dead branches projecting from the canopy; 3 – irregular crown, many dead branches projecting from the canopy; 2 – < 25% of tree mass alive; 1 – dead.	4·0	10 minutes
Dominant strata age class	Stem diameter at breast height measured for all trees and grouped into a maximum of five age classes based on size	4·0	10 min
Percentage of native to weedy small tree cover	Calculated from ocular estimates of native and weedy species	Mean of reference quadrats	Calculated later
Native shrub age class	Stem diameter at breast height measured for all shrubs and grouped into a maximum of five age classes based on size	Mean of reference quadrats	10 min

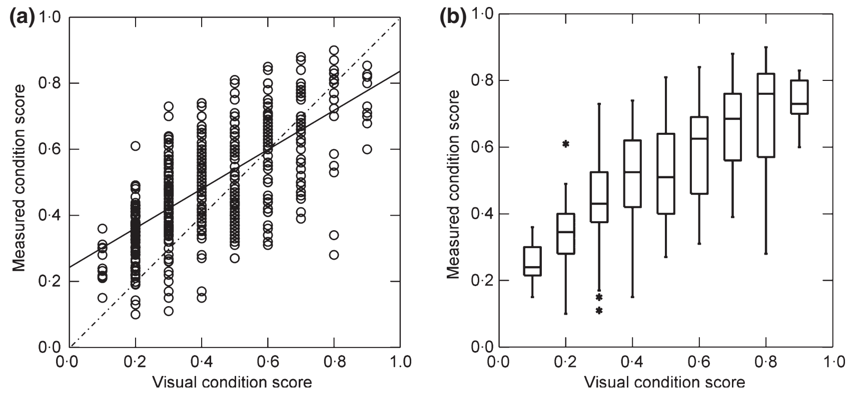

Fig. 2. The relationship between the measured condition assessments and the visual condition scores for 509 quadrats across 28 vegetation types. (a) The solid line is a linear interpolation of the visual vs. the measured estimates (slope = 0·60, R^2 = 0·44) and the dashed line represents a perfectly linear relationship between the two. (b) The median and range in measured condition estimates made for each visual condition score.

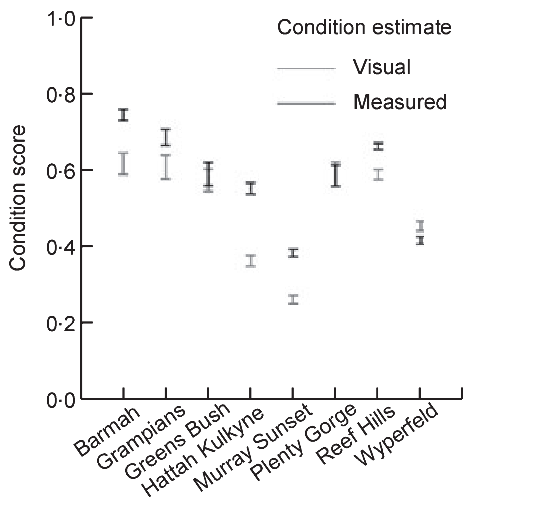

Fig. 3. The measured and visual condition estimates for each of the eight reserves in the state of Victoria, Australia, for which data were collected.

interaction ($F_{35,\ 458}$ = 2·07, P < 0·001): in Wyperfeld, the range of visual condition scores was marginally higher than the range of measured scores, and in Greens Bush and Plenty Gorge there was no difference between the range in condition scores (Fig. 3).

INTERACTION BETWEEN VISUAL ASSESSMENTS AND MEASURED CONDITION PARAMETERS

Multiple regression showed a significant relationship between the measured condition parameters and visual condition scores in 15 of 19 vegetation types assessed, whereas no significant relationship was observed in four of the vegetation types (Table 3). Where relationships were found between the measured parameters and the visual assessments, observers appeared to respond to a maximum of three condition variables within each vegetation type (Table 3). This can be demonstrated by plotting the scores for each condition parameter against the corresponding visual condition score. For example, within Box Ironbark Forest, only two parameters (*Eucalypt* cover and ground cover) explain 83% of the variation in visual assessments (Fig. 4).

The condition variables that appeared to influence the visual condition scores differed across vegetation types. There were no condition variables that consistently predicted the visual scores across all vegetation types, although ground cover and species diversity explained significant levels of variation in 5 and 6 of the 19 vegetation types, respectively (Table 2). With observers generally responding to only a small number of parameters, their overall estimates tend to be pessimistic (especially at lower visual assessment scores) and highly uncertain in relation to the measured condition estimates (Fig. 5). The best models for 9 of the 19 vegetation types explained < 55% of the variation in visual scores, suggesting that other factors also influence visual assessments.

For the vegetation types where no significant relationships between condition parameters and visual scores were detected (4 of 19), observers seemed to be qualitatively (although the relationship was non-significant) influenced by one or two variables (Fig. 6). Higher levels of replication may have resolved these differences.

Discussion

There is an inherent relationship between the detail of the information gathered through vegetation condition assessments and their cost (Cohen *et al.* 2005). Ideally, all assessments would maximize the resolution of the data collected to best inform conservation decisions, but resources are limited, and so a compromise is required between cost and resolution that still achieves the objectives of the assessment (Archaux *et al.* 2007). Given that vegetation condition assessments for biodiversity conservation are used for a range of purposes, it is necessary to select the method that best matches the stated objectives.

ACCURACY OF VISUAL ASSESSMENTS

We found that unstructured visual assessments were positively associated with higher resolution measured condition assessments when looking across a diversity of areas and vegetation types (Fig. 2); however, this association was only able to explain 44% of the variation between these methods. Although the two approaches provided broadly similar estimates of

Table 3. Stepwise multiple linear regression equations by vegetation type, indicating the condition parameters that explain the most variation in the visual condition scores. Criteria for inclusion in the model were probability less than or equal to 0·05

Vegetation types	No. of quadrats sampled	Parameters	R^2	Probability	Slope
Floodplain Forest	10	Ground cover	0·92	< 0·001	0·24
		Native:weedy species cover			1·08
Heathy Dry Forest	12	Tree condition	0·85	< 0·001	−1·14
		Species diversity			0·10
Box Ironbark Forest	12	Ground cover	0·83	< 0·001	0·05
		Eucalypt cover			0·23
Lake Bed Herbfield	68	Ground cover	0·52	< 0·001	0·23
		Tall shrub cover			0·03
		Regeneration			0·01
River Redgum/Black Box Woodland	40	Tree condition	0·46	< 0·001	0·56
		Species diversity			0·55
		Dominant strata age class			0·15
Belah Woodland	20	Native : weedy tall shrub cover	0·46	0·001	0·31
Escarpment Woodland	7	Ground cover	0·87	0·002	0·09
Drainage Line Grassy Woodland	30	Species diversity	0·37	0·002	0·43
		Strata integrity tree condition			0·29
Alluvial Terraces Herbrich Woodland	10	Non-*Eucalypt* cover	0·61	0·007	0·03
Gypseous Plain Grassland	12	Species diversity	0·54	0·007	0·08
		Strata integrity			0·22
Sandplain Grassland	9	Species diversity	0·64	0·010	0·49
Riparian Forest	7	Native : weedy species cover	0·41	0·035	0·66
		Eucalypt cover			0·22
Riverine Swamp Forest	11	Ground cover	0·39	0·040	0·21
Box/Ironbark Woodland	12	Species diversity	0·51	0·042	0·38
		Regeneration			0·06
Shrubby Woodland	11	*Eucalypt* cover	0·37	0·047	0·12
Riverine Grassy Forest	11	Tree condition	0·32	0·071	0·43
Damp Sands Herbrich Woodland	7	*Eucalypt* cover	0·29	0·085	0·16
Drier Woodlands	10	Species diversity	0·30	0·103	0·39
Hills Herbrich Woodland	12	Species diversity	0·91	0·541	−0·04

condition, the effect of the observed differences was to even out the uncertainty between estimates when used across multiple vegetation types and reserves. However, for any given quadrat the agreement between the two assessment methods was variable, particularly for moderate condition scores (Fig. 2). Therefore, the use of visual assessments could provide uncertain outcomes when used at smaller spatial scales.

Our analyses lend support to the use of lower-resolution, visual condition assessments across large spatial scales; however, these data are likely to present an optimistic scenario for visual assessments of vegetation condition. The assessment protocol was conducted by a small number of experienced botanists who made visual assessments of condition before measuring a predefined set of condition parameters. The observers were aware of the parameters they were about to measure and had the opportunity to specifically consider those condition attributes when making their visual assessments. Using the same protocol with less experienced or a more diverse array of observers may weaken the association observed between the two condition measures. The lack of independence generated by using the same observers for both assessment methods to standardize the variation between individuals may also result in an underestimate of the differences between the two condition methods. Additional tests designed to investigate interobserver variability for both assessment methods would add to a discussion of the likely universality of these findings. The potential for observers to adapt their visual estimates relative to their measured assessments with repetition may also lead to greater concordance between the two techniques. However, any learning effect is likely to be minor because measured scores for quadrats were relative to the reference quadrats and calculated after the fieldwork was completed.

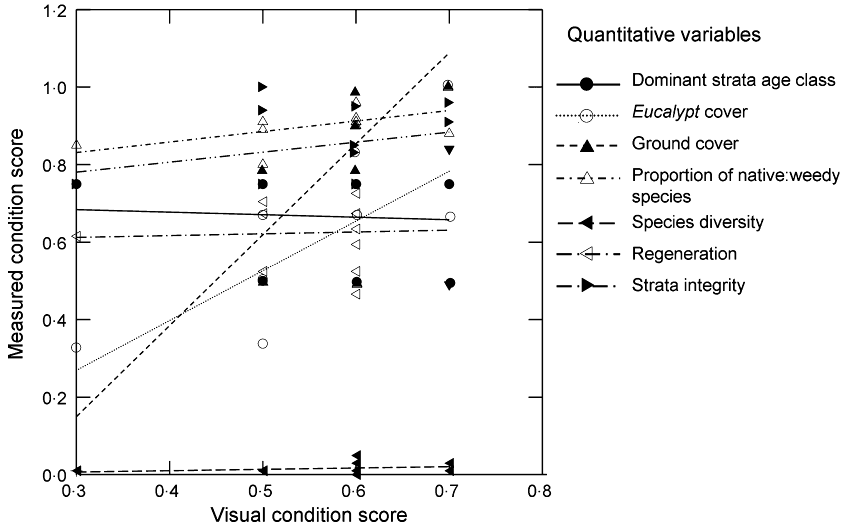

Fig. 4. Measured condition scores (with linear interpolation lines for each parameter derived from multiple regression) plotted against the corresponding visual condition scores for Box Ironbark Forest. *Eucalypt* cover and ground cover explain the majority of variation in these data.

TO WHICH CONDITION ATTRIBUTES DO OBSERVERS RESPOND?

For most vegetation types, observers appeared to be heavily influenced by one or two condition parameters when making their visual assessments, but these parameters were not consistent among vegetation types, possibly explaining some of the variation between the visual assessment and measured condition scores. Although the subset of condition parameters that most strongly correlate with the visual assessment scores may partly be explained by the measured parameters being specifically tailored to the different vegetation types, some parameters, particularly ground cover and species diversity, were more often seen to drive the relationship (albeit in various combinations). Changes in these parameters are generally readily observable and observers may be simplifying the visual assessment process by reacting to a subset of easily gauged parameters. Although this is a logical approach to distilling a complex concept-like condition, it is problematic when the other condition parameters in the assessment protocol are generally accepted to also be important components of vegetation condition (see Oliver, Jones & Schmoldt 2007). It is possible that the observers subconsciously give greater weight to some condition parameters, suggesting a decoupling of the priorities of the visual observers and those of the management agency when measuring condition. Observers may also employ nonlinear combinations of condition parameters when deriving their visual assessment scores. Alternatively, visual assessments may differ from the measured parameters owing to subjective or fundamental differences between the plots and vegetation types surveyed. Although this study could not distinguish between these hypotheses, the result is the same: the observed variability precludes the development of a heuristic to reliably judge condition based on a subset of condition parameters across all vegetation types.

For four of the vegetation types examined, no measured condition parameters significantly explained the observed variation in visual assessments. Although the number of quadrats measured in these vegetation types may have been insufficient to distinguish trends above the background variation, the observed variability also suggests that any relationship is inconsistent or that observers respond to attributes that were not measured. Further investigation would be necessary to resolve these competing hypotheses. Based on these data, however, visual assessments may not be broadly representative of all vegetation types.

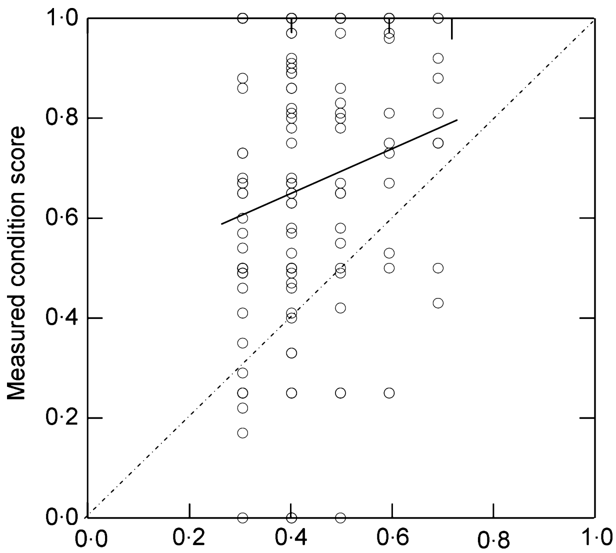

Fig. 5. Measured condition scores (with linear interpolation line – solid line) plotted against the corresponding visual condition scores for Drainage Line Grassy Woodland. The dashed line represents a linear relationship between the two with points above the line indicating pessimistic visual condition assessments.

All estimates of the 'true' vegetation condition will be subject to uncertainty (Regan, Colyvan & Burgman 2002). Therefore, measured assessments of condition are also somewhat uncertain and other studies have found that interobserver variability can be problematic for some systematic assessment tools

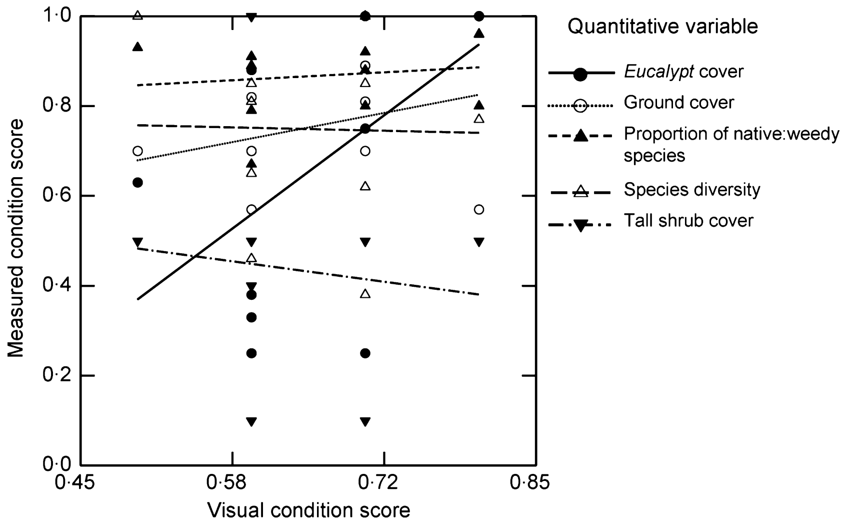

Fig. 6. Measured condition scores (with linear interpolation lines for each parameter derived from multiple regression) plotted against the corresponding visual condition scores for Damp Sands Herbrich Woodland.

(Gorrod & Keith 2009). Some of the disparity between the two estimates may therefore relate to error in one or both of the condition measures used. Nevertheless, any condition estimate used for vegetation management will contain error and it is still necessary to consider how comparable the different assessment techniques are when selecting which is most appropriate for a given purpose. Whether the trends observed in this study relate specifically to the tool investigated here, or are consistent for visual and systematic condition assessment techniques more generally, requires further investigation. The nature of the observers and the condition index used, such as simple average (University of Ballarat 2001), additive (Parkes *et al.* 2003) or multiplicative (Gibbons *et al.* 2005) may influence the conclusions drawn, as could the definition of condition and the choice of benchmarks used. Similar studies, focused on a range of common assessment methods, should provide a better indication of the overall consistency of visual and systematic assessment methods.

IMPLICATION FOR CONDITION ASSESSMENT METHODS

The level of precision required from a condition assessment technique varies with the objectives of the assessment (Archaux *et al.* 2007). The diversity of existing condition assessment methods is owing to the range of purposes for which these data are collected (Gibbons & Freudenberger 2006). The value of condition assessments for different purposes will depend on the resolution required of these estimates and the scale of the management decisions (Parsons, Swetnam & Christensen 1999). Where individual parameter estimates may be of interest, high-resolution condition data are best suited. This would includes cases where decisions need to be made about the success or otherwise of management interventions (Landres *et al.* 1999) or when determining appropriate incentive payments (Parkes *et al.* 2003) and offsets (ten Kate *et al.* 2004) to conserve biodiversity on private land. Our results suggest that visual assessments are not of sufficient resolution to determine changes in individual parameters or to make consistent comparisons between small numbers of reserves. At this scale, visual assessments are likely to be highly variable and will underestimate or overestimate condition relative to measured assessments. For these purposes, high-resolution approaches, while likely to still include some uncertainty (Gorrod & Keith 2009), are more appropriate.

Where the purpose of condition assessments involve combining condition assessments across large areas, such as for reporting on overall condition of a protected area network or making assessments about biodiversity conservation progress generally (CBD 2006), then visual estimates of condition provide broadly similar condition assessments to those achieved with higher-resolution techniques. Averaging condition assessments over many reserves may act to reduce the impact of interobserver variability, biases in estimates of high or low condition quadrats and the variation between different vegetation types that seem to be associated with lower-resolution estimates. The reduced cost of these lower-resolution estimates is a major advantage for funding-limited management agencies (James, Gaston & Balmford 1999) or at large scales, where it is generally unrealistic to commit the necessary resources for more systematic techniques (Sheil 2001). The systematic assessments examined here required between 30 and 90 min per quadrat for multiple quadrats per vegetation type and multiple vegetation types per reserve, compared with 5 min for each visual assessment. Even including travel time to a reserve, the cost savings of visual assessments at a large scale is likely to be substantial.

Conclusion

This study has provided insight into the overall comparability of visual assessments of condition and their likely value to conservation decision making at different scales. Although visual condition assessments provide a general indication of the vegetation condition across a range of areas and vegetation types, they are unlikely to be sufficiently accurate to replace more rigorous and expensive site-level assessments of condition that target specific management or conservation questions applied at small scales. The variability that visual assessments display in relation to specific condition parameters and vegetation types suggests that they should not be used for high-resolution management decisions, which require details about individual condition parameters. There is a real need for cost-effective condition information to inform management decisions (Jensen *et al*. 2000), and for methods that provide sufficiently rigorous data. Our results should provide managers with the confidence to apply cost-effective, visual assessments across large scales, while reserving the more resource-intensive techniques for high-priority areas to answer specific management questions. This dual approach should lead to condition information being collected for much larger areas within existing resource constraints.

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