Department of Science, Information Technology and Innovation

Method for the Establishment and Survey of Reference Sites for BioCondition

Queensland Herbarium

Version 3

Queensland Government

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Cover photo: Reference site for regional ecosystem 11.3.9, *Eucalyptus platyphylla* with scattered *Corymbia intermedia* and a grassy understorey dominated by *Heteropogon contortus*, and *Chrysopogon fallax*. Photo: Jesse Rowland

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1 Introduction

Natural resource management policy demands and expectations have conceptualised vegetation condition as a major component of native vegetation management, primarily to assist decision making for developmental approvals, incentive payments, market-based investments and demonstration of environmental duty of care (Keith & Gorrod 2006; Neldner 2006). Methods to assess vegetation condition are therefore required, with a simple, rapid assessment approach highly desirable, as it facilitates widespread application by a range of users (Andreasen et al. 2001). Accordingly, most condition assessment tools utilise key attributes or surrogates of biodiversity values that can be rapidly measured in the field (Gibbons & Freudenberger 2006). In Australia, the 'Habitat Hectares' approach in Victoria (Parkes et al. 2003) instigated development of similar vegetation condition assessment frameworks such as BioMetric in New South Wales (Gibbons et al. 2008), TASVEG in Tasmania (Michaels 2006) and BioCondition in Queensland (Eyre et al. 2015). The frameworks vary in accordance with jurisdictional legislation and policy, however they all share four properties: a set of weighted assessable attributes thought to be important to biodiversity; methods to assess the attributes; comparison against benchmark values based on the same communities under 'reference' conditions; and a final overall metric or 'score' that represents a condition state.

BioCondition is an assessment framework that provides a measure of how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values. It is a site-based, quantitative and therefore repeatable assessment procedure that provides a numeric score along a continuum of 'functional' through to 'dysfunctional' condition. The BioCondition score is based on a comparison between measurements of specific site-based attributes and a benchmark value for each of those attributes, specific to a particular Regional Ecosystem (RE). A benchmark value is based on the average or median value from a range of sites in the reference state, in order to capture inherent natural variability in the attributes. A regional ecosystem in its reference state is refers to a stable state that is mature and long undisturbed, or Best on Offer (BOO), given few ecosystems are totally free of impacts of threatening impacts in the contemporary landscape (Michalk and Norton, 1980; Landsberg and Crowley, 2004).

Benchmarks for REs in Queensland will be derived from quantitative data and expert elicitation and will be posted on the Queensland Government BioCondition website by the Queensland Herbarium as they are validated and become available. However, due to the large number of REs across Queensland, many have not yet been benchmarked. Where benchmarks are not yet available, or an assessment needs to be conducted during less than optimal conditions, then quantitative benchmark data can be derived by locating and setting up a local reference site. Reference site assessment does require high level botanical and habitat assessment skills, requiring the measurement and recording of vegetation floristics and structure.

The assessment method detailed in this manual is for the location, establishment and recording of floristic and structural vegetation attributes specifically for the generation of benchmarks for the BioCondition Vegetation Condition Assessment framework. The benchmark data derived using this method is to be used in conjunction with the companion manual: BioCondition – A condition assessment framework for terrestrial biodiversity in Queensland (Eyre et al. 2015).

There are 10 attributes in BioCondition that require benchmarks for the scoring system (Table 1). However, not all attributes require measurement at reference sites. This is because their benchmarks

are either effectively zero or scores are qualified in the BioCondition scoring system. Attributes that do not require assessment at reference sites include recruitment of canopy species, non-native plant cover and the attributes relating to landscape context.

Table 1 Site-based attributes measured at BioCondition reference sites

Attribute	Measure
Native plant species richness	Number of species
Tree canopy cover	Percentage (%)
Tree canopy height	Median (m)
Shrub layer cover	Percentage (%)
Native perennial grass cover	Percentage (%)
Large trees	Number of trees over a diameter at breast height threshold
Coarse woody debris (m)	Length (m)
Litter cover	Percentage (%)

BioCondition provides an assessment of the condition of an ecosystem in relation to its functioning for the maintenance of biodiversity values. However, practitioners need to evaluate their objectives, as there may be additional information required in order to meet the data requirements of their study. If more detailed assessments are required for biodiversity survey or monitoring by appropriately skilled operators, then the following methods are recommended:

Flora: Neldner, V.J., Wilson, B.A., Dillewaard H.A. and Butler, D. W. (2017) Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 4.0. Queensland Herbarium, Queensland Department of Science, Information Technology and Innovation, Brisbane.

Fauna: Eyre, T.J., Ferguson, D. J., Hourigan, C.L., Kelly, A.L., Venz, M.F., Mathieson, M.T., Smith, G. C. and Rowland, J. (2014). Terrestrial Fauna Survey Assessment Guidelines for Queensland. Version 2.0. Queensland Herbarium, DSITI, Brisbane.

For information or advice regarding reference site assessment or the status of Regional Ecosystem Benchmark development for Queensland's regional ecosystems, please contact the authors (contact details are provided in Appendix 1)

2 What is required for the assessment?

The assessment of the reference site is constrained within a 100 x 50 m sampling area. The following field equipment is recommended:

- 100 m transect tape
- 50 m transect tape
- compass
- diameter tape or tree callipers
- this current manual
- clinometer or hypsometer for measuring tree heights
- digital or print film camera
- 1 m^2 quadrat
- x star pickets or tyres and wire (to peg down tyre) to mark out each end of the transect line (if continual monitoring of site is desired).
- clipboard, pencils and eraser.
- pocket calculator
- flagging tape
- global positioning system (GPS)
- plant press for collecting specimens

3 Locating reference sites

The appropriate location and establishment of reference sites is essential to the development of relevant and effective benchmarks. Canopy height and cover vary within RE's according to environmental conditions. Therefore areas to be assessed should be compared with a reference site that occurs close to the area to be assessed and has similar environmental conditions, i.e. the same regional ecosystem, vegetation community, similar climate (same subregion), similar landscape conditions (soil, slope, position in the landscape, geology etc) and similar natural disturbance (cyclone impacts or fire history). For this reason, field measurements of the height, canopy cover and species composition of the area of interest are compared, where possible, to measurements from a local reference area, i.e. a nearby area of comparable vegetation that is known to be remnant, such as a shadeline or road reserve.

As much as practicable, a reference or BOO site should:

- be homogenous with regard to RE and condition status
- be selected in RE's with no extensive chemical or mechanical disturbance to the predominant canopy evident on the aerial photograph archive (from 1960s to recent) or on the ground
- represent an undisturbed, late mature or BOO of the required RE. That is, the site must have minimal modification through timber harvesting, grazing, fire, erosion, dieback, flood, and/or weed infestation
- be located within a reasonably large (> 5 ha) intact patch of remnant vegetation (to avoid issues of edge effects)

- be located at least 50 m from a roadside, track, or other major disturbance
- be remote from artificial water sources e.g. > 6 km from permanent water (Fensham and Fairfax 2008)
- exclude areas subject to recent major management change.

An effective strategy for locating reference sites, that best represent a BOO state for the RE of interest, is to first look at the extent remaining of the RE using the latest available Queensland Herbarium Regional Ecosystem mapping. Free RE maps are available as downloadable pdf/printable maps for properties and as digital data from the Regional Ecosystems page on the Queensland Government website. The hardcopy maps and digital data can be used to produce a map specific for the area representing the extent of the RE or the local area from which reference sites are required. The applicability of the RE mapping should be assessed in the field to check if it is relevant at the scale at which the assessment is being conducted. REs are defined at scales which range from 1:50 000 (e.g. South East Queensland) to 1:100 000 (e.g. rangeland bioregions) and a single polygon may contain several mapped REs (heterogeneous polygons).

Large patches of the RE of interest located in public land reserves such as national parks, state forests, and road reserves can often represent the RE in an undisturbed or BOO state. In addition, staff from the Queensland Herbarium and/or local natural resource managers can often provide information about suitable locations representing the least disturbed patches remaining of the RE of interest.

To obtain a reasonable representation of the natural variation inherent in vegetation condition attributes within the geographic range of an RE, there must be a minimum of three local reference sites located and measured. It is preferable that the reference sites are not located proximally, and are established at least 3 km apart to account for potential geographic variation. In some cases, particularly in highly fragmented bioregions, it may not be possible to collect benchmark data for all attributes within the one reference site, e.g. a recent fire may have impacted upon shrub cover and the number of understorey species present, but not the number of large trees. It is acceptable to establish a reference site that provides benchmark data for one or more attributes only. However, it will need to be made clear on the datasheets that it is a partial reference site only.

4 Field assessment

4.1 When to assess

Reference site assessment during the peak of summer or following a period of drought is not recommended, as there is likely to be a reduction in plant diversity during these times, particularly in the forb and grass life form groups. Seasonally, the best time of year for assessment, in the rangelands in particular, is during the growing season of May to June, when plant diversity is generally at its greatest. However, this is a general rule and the appropriate time to assess should be guided by local climate and knowledge.

In regions north of the tropic of Capricorn, site assessment should be conducted after the wet season, ideally between March and May to ensure adequate sampling of ground cover species (Neldner et al. 2004). South of the tropic of Capricorn, site assessment should be generally conducted in May or June following the wetter summer months. An exception would be following an unseasonably wet winter or spring when plant species are flowering.

4.2 Setting up the assessment site

The assessment site constitutes a 100 m x 50 m nested plot design. The layout of the site and nested subplots are shown in Figure 1. Demarcation of the reference site is established by positioning a 100 m tape, which constitutes the centre line of the plot. Flagging tape can be used to identify the outer boundaries of the plot, which is 25 m each side of the centre transect. The plot boundary must be a minimum distance of 50 m from a major disturbance or discontinuity such as a road or disturbed edge. In topographically diverse areas, the plot should be oriented so that its long axis follows the contour, or topographic position (e.g. gully, midslope, ridge). Plot location is recorded at its centre point (the 50 m point along the 100 m transect). A global positioning system (GPS) is recommended to record the position of the centre and start points of the transect line in the field. This position should be checked against a 1:100 000 or larger scale topographic map for the area. The altitude recordings on GPS can be inaccurate and are better derived from the topographic map. The use of star pickets, metal tags attached to trees or pegged down tyres at the beginning and end of the 100 m transect will aid in relocating the site for future monitoring.

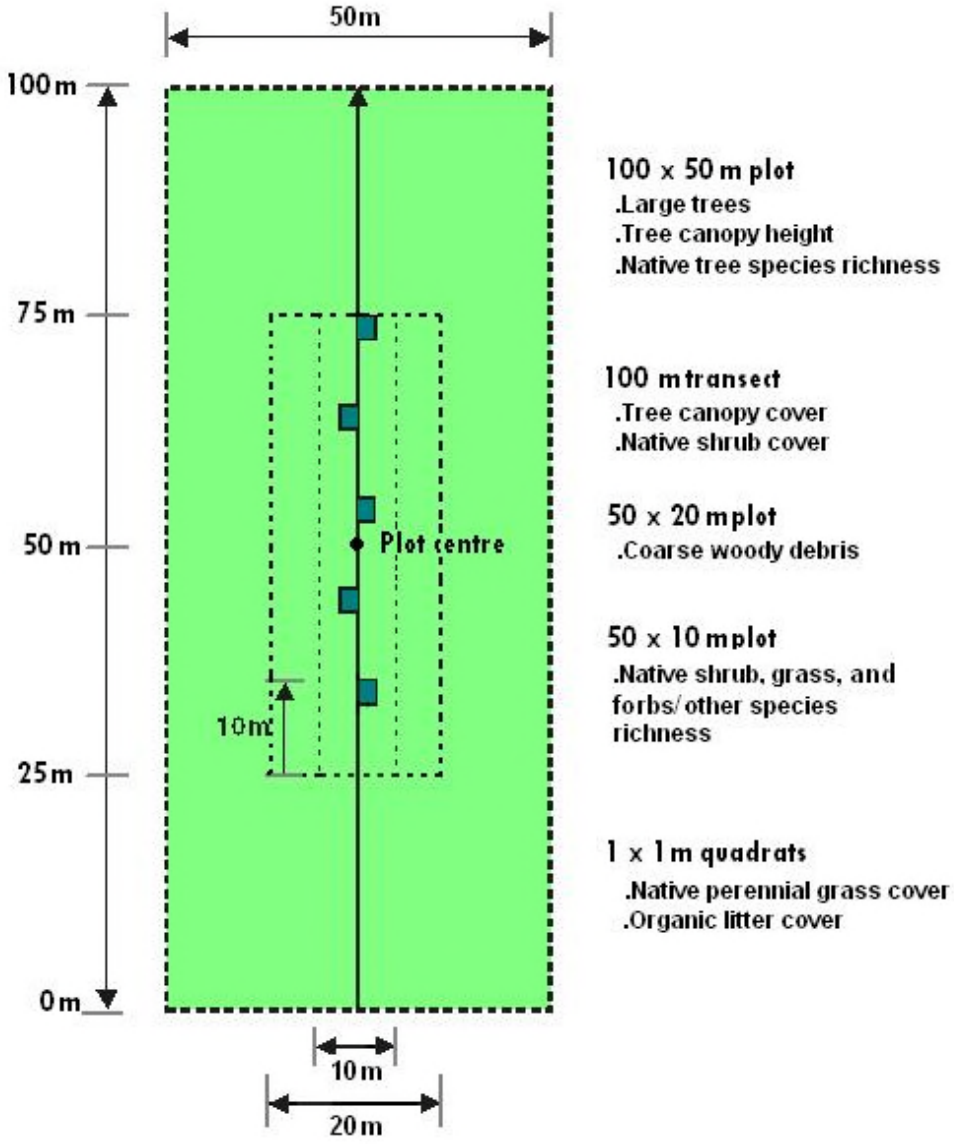

Figure 1 BioCondition reference site area and layout

4.3 Data collection

Five sampling areas form the basis for and approach to data collection. A series of subplots are used to sample the floristic, habitat and disturbance components, and are summarised as follows;

- **100 x 50 m area:** records all potential large trees >20 or >30 cm diameter at breast height (DBH); depending on the tree species, see Large tree section 4.3.1. Site information and disturbance, tree species richness and tree canopy height are also assessed in the 100 x 50 m area.
- **100 m transect:** records tree and shrub canopy cover.
- **50 x 20 m area:** records the length of all coarse woody debris >10 cm diameter and >50 cm in length.

- **50 x 10 m area:** records the number of floristic species by lifeform group (Native plant species richness) for Shrub, Grass, and 'Forbs and Other' species.
- **1 x 1 m subplots:** records Native Perennial Grass cover and Organic Litter cover.

A datasheet to aid the collection of reference site data is provided in Appendix 2. It is important to ensure that the plot remains within the regional ecosystem to be sampled. Therefore it may be necessary to reduce the width of the plot for narrow ecosystems, e.g. riparian ecosystems. In these situations the length of the plot may be increased to enable the sampling of an adequate area.

4.4 100 x 50 m assessment area

4.4.1 Site information

Within the greater 100 x 50 m assessment area assess the site location, general physical characteristics and disturbance information (although note that a reference site should have minimal disturbance) relevant to the site.

Location and site information

Plot location	Record three locations, one at a convenient road point, another at the start of the 100 m central transect and another at the plot centre, the distance and bearing from the road to the plot centre and the plot alignment (to aid future relocation of the plot). Record location to the nearest metre using a Global Positioning System (GPS) receiver. Record the datum to which the GPS is set. It is recommended that GDA94 or if not available WGS84 is used as the datum.
Plot bearing	Refers to the compass bearing or direction the plot is oriented from the start of the transect.
Locality description	Record a general description of where the plot is situated. Include the state forest/national park number and/or name, or a property name or description, the name of the nearest road if applicable and any other information relevant to the locality. Include the tenure of the land parcel on which the plot occurs by reference to the Digital Cadastral Data Base (DCDB)
Bioregion	Record the Queensland bioregion name.

Regional Ecosystem

Habitat description	Record a detailed description of the site including the key species and density of all tree, shrub and ground layers.
Regional Ecosystem	REs were defined by Sattler and Williams (1999) as bioregional vegetation communities that are consistently associated with a particular combination of geology, landform and soil. The RE description database (REDD) is updated regularly and is available on the Queensland Government website. The RE for the site can be determined by querying the RE mapping and comparing the descriptions of the mapped REs for the location, in order to decide which

RE the site represents. If the description is not a good match with any of the mapped REs, then check others in the appropriate bioregion and land zone. Occasionally the specific RE may not be mapped because:

- Regional ecosystem mapping is usually at 1:100 000 scale, but in some cases mapped at 1:25 000 scale.
- Vegetation mapping often uses the concept of mosaics where, again because of scale restraints, a single vegetation polygon is classed as being a mix of several different vegetation types (and thus REs).
- For this reason the RE maps should be used as a guide and the habitat description should be detailed enough to enable the classification of the actual community into a single RE.

Land form

Slope position	Record the slope position, using codes given on the datasheet.
Slope degree	Measure the general slope of the plot using a clinometer and record in degrees. For flat areas record slope as 0 degrees.
Slope aspect	Record the compass direction, in degrees, of the downward slope of the plot. For flat areas record a dash (-).

Site photos

At the 50 m centre point of the plot collect four photos, north, south, east and west, and at the commencement of the central transect. In addition, spot photos can be useful to capture the variability in ground cover within the five 1 x 1 m quadrats. See Appendix 3 for an outline on taking photos at reference sites.

Disturbance

Disturbance is visually assessed over the whole reference site. These data are not actually required for benchmarking, but it is helpful to have a record of any disturbance if present as information on the current condition of the site at the time of assessment. As outlined earlier, ideally the reference site should have minimal disturbance.

For each disturbance type a code is used to rank its relative severity (from 0 = no discernible disturbance to 3 = severe). Codes are also used to record an estimated time since the last event for each disturbance (A: <1 year; B: 1-3 years, C: 5-10 years, D: 10-20 years, D: > 20years), and how the disturbance was estimated (1 = visual estimate, 2 = from historical records, 3 = from informant, 4 = from imagery or mapped source). Assessment of disturbance should be considered in the context of impact on the RE's structure, composition and function. Assessment needs to take into account the capacity of the community to recover after the event – that is, disturbances can appear to be severe soon after their occurrence. It is important to try to gauge how this event will affect the community beyond the short term.

Wildfire	Refers to major previous hot fire disturbance, the severity of which can be based on the extent of fire scars on standing trees relative to their height and diameter. Time since such an event can be estimated on the height of

	any post-burn regeneration, charring on ground woody debris which may have fallen since the event, diameter growth around fire scars on standing live trees, extent of crown recovery or from the aerial photograph or satellite imagery archive or web fire mapping sites. Record the mean height of fire scars on standing stems.
Prescribed Burn	Refers to the cool, frequent (annual or biennial) burns used to reduce fuel loads and/or increase grazing potential of the grassy understorey. The nature of these burns dictates that the intensity of this disturbance would rarely be recorded as severe. However, if the fire regime is too frequent then impact on the ground and shrub layers can be deemed severe.
Logging	Record information on past logging events. Severity should be the total of all logging events and time for the latest event. If there have been several logging events record details in the notes section.
Treatment	Treatment is defined as the destruction of individual trees by ringbarking or poisoning, in contrast to ‘logging’ of individual trees for product harvesting and ‘clearing’ by mechanical means. Standing dead and fallen trees should be examined closely for marks indicating past treatment. These can be at waist height or near ground level for basal injection treatment.
Grazing	Grazing impact can be assessed by the presence of manure, compaction, presence of stock trails, and eaten off grasses. It will probably not be possible to estimate grazing severity for older grazing events. However, inspection of fencing and stock infrastructure in the vicinity may give some indication of the time since grazing activity.
Non-native plants	Non-native plants include all exotic species, and those declared or assumed to be noxious.
Erosion	Record information on erosion seen in the plot, e.g. gully erosion. Erosion outside the plot but in the vicinity should be noted.
Other	Specify any other disturbance types noted e.g. dieback, soil disturbance.

4.4.2 Large trees

Large trees are an important resource within forest and woodland ecosystems. They provide greater leaf material, nectar and bark-surface area for foraging purposes, and are more likely to contain hollows and crevices for nesting and sheltering purposes. What is considered 'large' will vary between species and communities. Trees growing under poor environmental conditions can never obtain the diameter of trees growing in more productive environments, and other species are slow growing or short-lived and so are unlikely to obtain the relatively large diameters. A method for determining an appropriate threshold for what is considered large is therefore required.

The threshold above which a tree is considered ‘large’ is obtained by assessing the average stem size of all live trees over a certain stem size, depending on the community or species group. The data is used in

two ways; 1) to derive a threshold value of what is considered to be a large tree in the ecosystem that is being sampled; and 2) to derive a benchmark of the number of large trees per hectare to be used in the BioCondition assessment. As a general guide, the trees included in the assessment should include all the living mature trees in a stand (standing dead trees are not included).

In eucalypt forests and woodlands and rainforests (excluding vine thickets), the threshold diameter at breast height (DBH) from which to start recording trees and their diameters is 30 cm. In *Melaleuca, Acacia, Callitris* and all other non-eucalypt and vine thicket dominant ecosystems, the threshold is 20 cm DBH. Where communities are mixed those species that have a greater capacity to reach a larger size such as the *Eucalyptus, Corymbia, Syncarpia, Lophostemon* and larger rainforest trees will be included in the data if > 30 cm DBH, while the smaller stemmed trees, generally sub-canopy trees such as *Melaleuca, Acacia, Callitris, Eremophila* and *Casuarina* will be included if >20 cm DBH.

In some cases there will be exceptions to this rule, where it is acceptable to increase or decrease the threshold in response to the inherent structural characteristics of the ecosystem being assessed. For example, in most *Acacia harpophylla* dominated ecosystems the 20 cm threshold is appropriate, however in the *A. harpophylla* low woodland RE 4.9.19 mature trees rarely exceed 20 cm, therefore a 15 cm threshold may be more appropriate from which to start recording the trees for the large tree sample. In BOO *Melaleuca viridiflora* low open-woodlands on Cape York Peninsula, the average tree DBH is only 12 cm, therefore all trees greater than 10 cm DBH need to be included to determine the appropriate large tree threshold.

It is important to note that the ‘large tree’ benchmark is derived from calculating the average DBH of trees greater than the threshold, and then counting the number of trees greater than this average value. Therefore, selecting an inappropriate threshold, which either over- or under-represents the mature tree component will lead to the derivation of an inappropriate benchmark for the large tree attribute.

The species and DBH of larger trees are recorded within either a 100 x 50 m; 100 x 20 m; or 100 x 10 m plot area (Figure 2) depending on the evenness and distribution of the stems, i.e. the selection of plot area to record the number of large trees will be determined by the inherent stand structure of the RE being assessed.

In general, the 100 x 50 m plot area should be used for most eucalypt dominant REs such as woodlands and open forests and in rainforest communities with larger unevenly distributed trees, as the large, mature trees are often widely dispersed. The smaller plot areas can be used for REs with many, and/or uniform sized trees. For example, 100 x 20 m plots should be used for rainforest communities with a greater level of variability in the stems, and in open mallee communities. The 100 x 10 m (or equivalent 50 x 20 m) plot should be used in communities with uniform stem sizes and even distributions of stems such as in vine thickets, and in closed mallee. The selection of the plot area can be guided by an aim to obtain a reasonable sample (> 25 trees) of the stand (note that all trees above the threshold within the plot area selected are measured. i.e. continue measuring even when 25 trees are sampled).

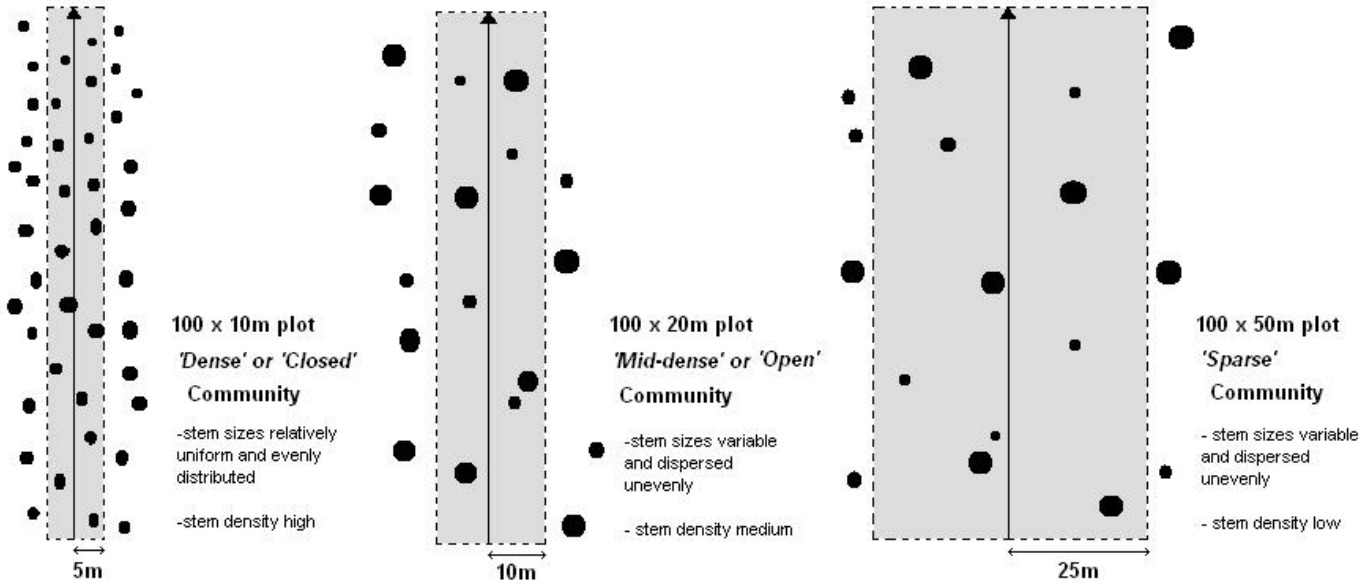

Figure 2: Plot size selection for large tree threshold attribute

Regional ecosystem 11. 4.3a - Black tea-tree (*Melaleuca bracteata)* woodland. The evenness and density of stems would suit a 100 x 10 m plot. All trees greater than 20cm DBH would be measured in a 100 x 10 m (or 50 x 20 m) plot.

Regional ecosystem 12.5.13 – Vine forest. The unevenness of stem sizes and distribution of stems would suit a 100 x 20 m plot. All trees greater than 20cm DBH would be measured in the 100 x 20 m plot.

Regional ecosystem 11.3.2 – Poplar box (*Eucalyptus populnea*) woodland. The unevenness of stem sizes and open random distribution of stems would require a 100 x 50 m plot to assess the large tree attribute. All 'eucalypt' trees greater than 30cm DBH would be measured in the 100 x 50 m plot.

4.4.3 Tree canopy height

Tree canopy height refers to the median canopy height in metres estimated for trees in the ecologically dominant layer (EDL) (canopy layer) (Appendix 5). If there are emergent and/or subcanopy layers present, then median height of these layers needs to be assessed also. The median canopy height is the height that has 50 per cent of canopy trees larger and smaller than it (Figure 3). The height of woody vegetation is measured from the ground to the tallest live part of the tree (Neldner et al. 2017).

The maximum heights of the crown of at least three trees that are estimated to represent the median canopy height are measured for height, using a hypsometer or clinometer and tape measure (measured to the top of the highest leaves).It is recommended that a clinometer or hypsometer be used if available. When using a clinometer, adjustments are also made for the height of the recorder and any slope in the land surface. A method for assessing tree heights is provided in Appendix 5.

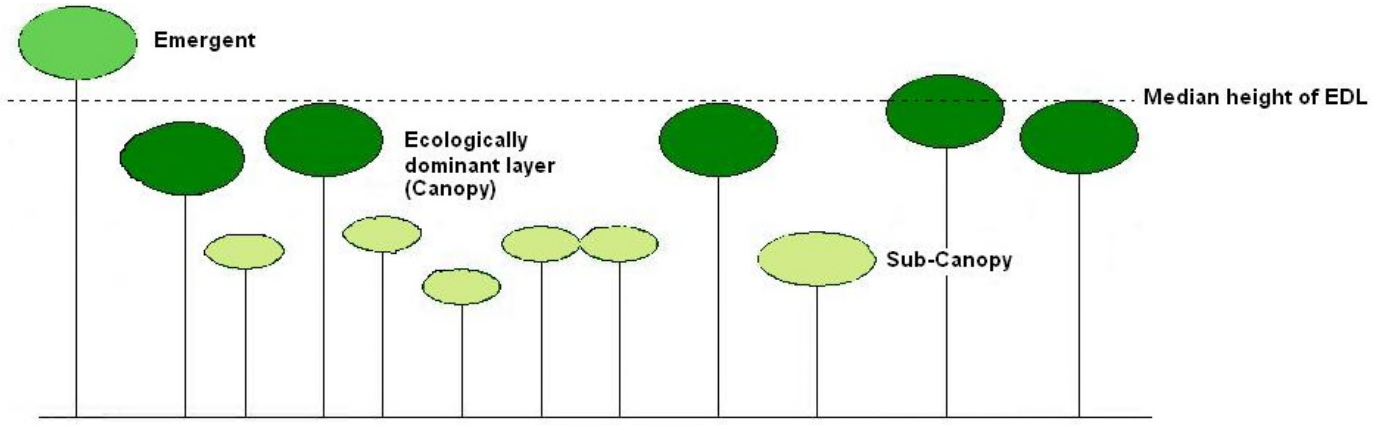

Figure 3: Median height of the Ecologically Dominant Layer (EDL)

4.4.4 Tree species richness

Native tree species richness is assessed by slowly criss-crossing each half of the plot from the centre-line and tallying the number of tree species within the 100 x 50 m plot area.

4.5 100 m transect

4.5.1 Tree canopy cover

Tree canopy cover refers to the estimation of the percentage canopy cover of the living, native tree layer along the 100 m transect, using the line intercept method (Greig-Smith 1964). For this attribute, only the cover of the species making up the EDL or tree canopy cover is assessed for the majority of REs. Canopy cover equates to crown cover as defined by Walker and Hopkins (1990). The vertical projection of the tree canopy over the 100 m transect is recorded (Figure 4 and Box 1). The total length of the projected canopy of each layer is then divided by the total length of the tape to give an estimate of percentage canopy cover on the site. Individual species can be recorded, but it is not required for the derivation of tree canopy cover benchmarks.

If there is a distinct emergent or subcanopy layer (See Appendix 4 for identifying strata), then the canopy cover of each of these layers (EDL, emergent and subcanopy) is assessed separately.

4.5.1 Shrub canopy cover

Shrub canopy cover refers to the estimate of the percentage cover of native shrubs recorded along the 100 m transect (similar to the estimation of tree canopy cover using a vertical projection of shrub crowns downwards and above the centre line transect). Shrub cover can be identified to species level, but species is not required for the derivation of shrub canopy cover benchmarks.

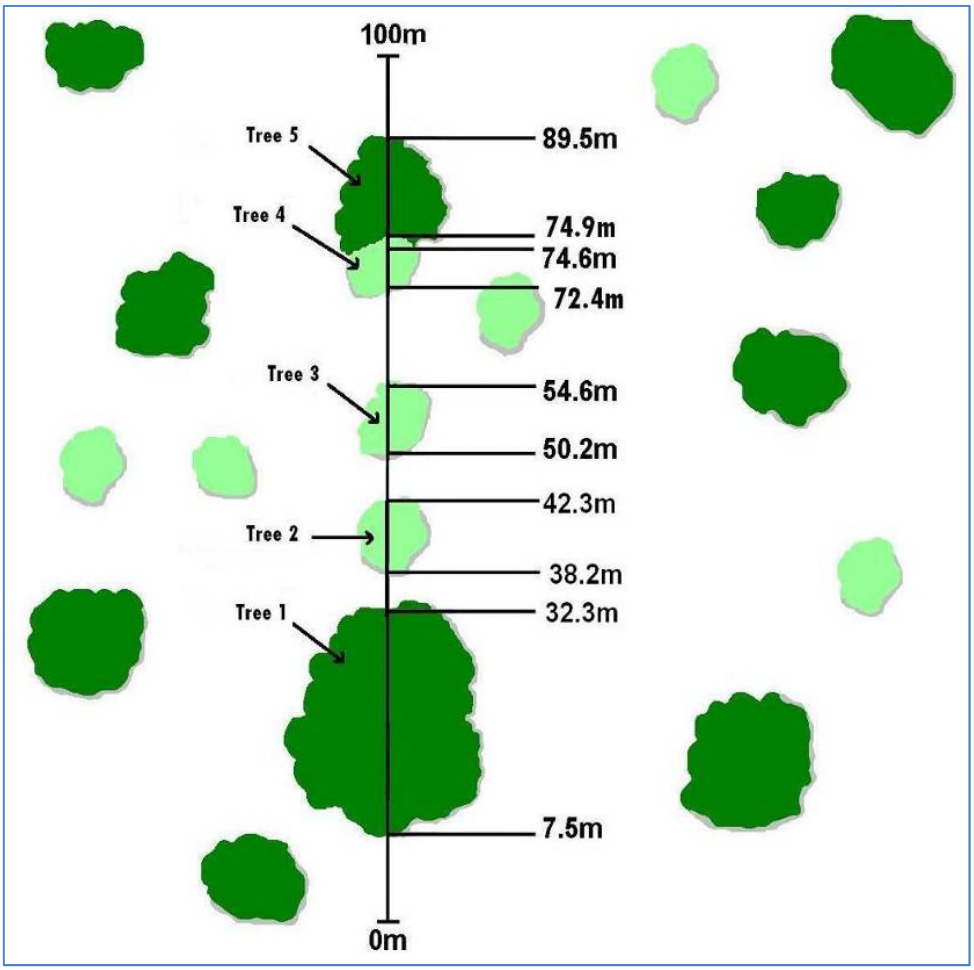

Figure 4: Example of assessing tree canopy cover (%).

Box 1: Calculation of tree canopy cover

In this regional ecosystem there is a canopy (EDL) (dark green) and a subcanopy (light green).

The canopy cover (EDL) is 39.7%, calculated as:

= (canopy cover Tree 1) + (canopy cover Tree 5)

= (32.3–7.5) + (89.5–74.6) = 24.8 + 14.9 = 39.7%.

The subcanopy cover is 11%, calculated as:

= (cover Tree 2) + (cover Tree 3) + (cover Tree 4)

= (42.3 – 38.2) + (54.6 - 50.2) + (74.9 –72.4) = 4.1 + 4.4 + 2.5 = 11%

4.6 50 x 20 m plot area

4.6.1 Coarse woody debris

Coarse woody debris (CWD), for the purpose of the BioCondition reference site assessment, refers to logs or dead timber on the ground that are >10 cm diameter and >0.5 m in length (and more than 80 per cent in contact with the ground). Note: branches that are attached to the log, are measured if they meet the size thresholds, regardless of whether they are touching the ground. All CWD within the assessment area are measured to the boundary of the 50 x 20 m plot (i.e. 0.1 hectare). The total measured value is multiplied by 10 to generate the benchmark and is expressed as total length in metres per hectare. Any woody debris smaller than this is included as litter cover.

4.7 50 x 10 m plot area

4.7.1 Native plant species richness

Native plant species richness for shrubs, grass and forbs/other species are recorded within the 50 x 10 m plot. The number of native plant species are assessed into one of four life-form groups, to assist assessment and benchmarking; trees, shrubs, grass, and forbs/other (see Appendix 6 for groupings). Native plant species richness is assessed by slowly walking along each side of the centre-line and tallying the number of species in each of three life-forms: shrubs, grasses and forbs/other. NB: Tree species richness is assessed in the 50 x 100 m plot.

4.7.2 1 x 1 m quadrats

Ground cover data are recorded from each of the five 1 x 1 m subplots centred along the central transect. For benchmarking purposes, quantitative data are required only for native perennial grass cover and organic litter cover. However, it is recommended that all components of the ground cover are recorded, to ensure 100 % of the ground cover is estimated. Ideally the botanical names of each species observed in each quadrat are recorded. The datasheet provided for the collection of data for deriving benchmarks (Appendix 2) provides space to record cover estimates for; native perennial grass cover, native annual grass cover, native forbs and other species, native shrubs (< 1m height), non-native grass, non-native forbs and shrubs, litter, rock, bare ground and cryptogams (NB: the total cover for a quadrat should come to 100%). If botanical knowledge is sufficient, a separate datasheet can be used to collect all floristic data from the 1 x 1 m quadrats as per the CorVeg method (Neldner et al. 2017). This datasheet can be obtained from the Queensland Herbarium.

4.7.3 Native perennial grass cover

Perennial grass cover refers to the average percentage cover of native perennial grasses, assessed within each of the five 1 x 1 m quadrats and averaged to give a benchmark value for the site. The ground cover is measured by a vertical projection downwards of the living and attached plant material. A stylised guide is provided in Figure 5 to help estimate cover percent. This cover equates to the projected foliage cover (Walker and Hopkins 1990). A value for the reference site for each component is obtained by averaging the values from the five sub-plots. The sum of all ground cover components will equal 100 per cent in each subplot.

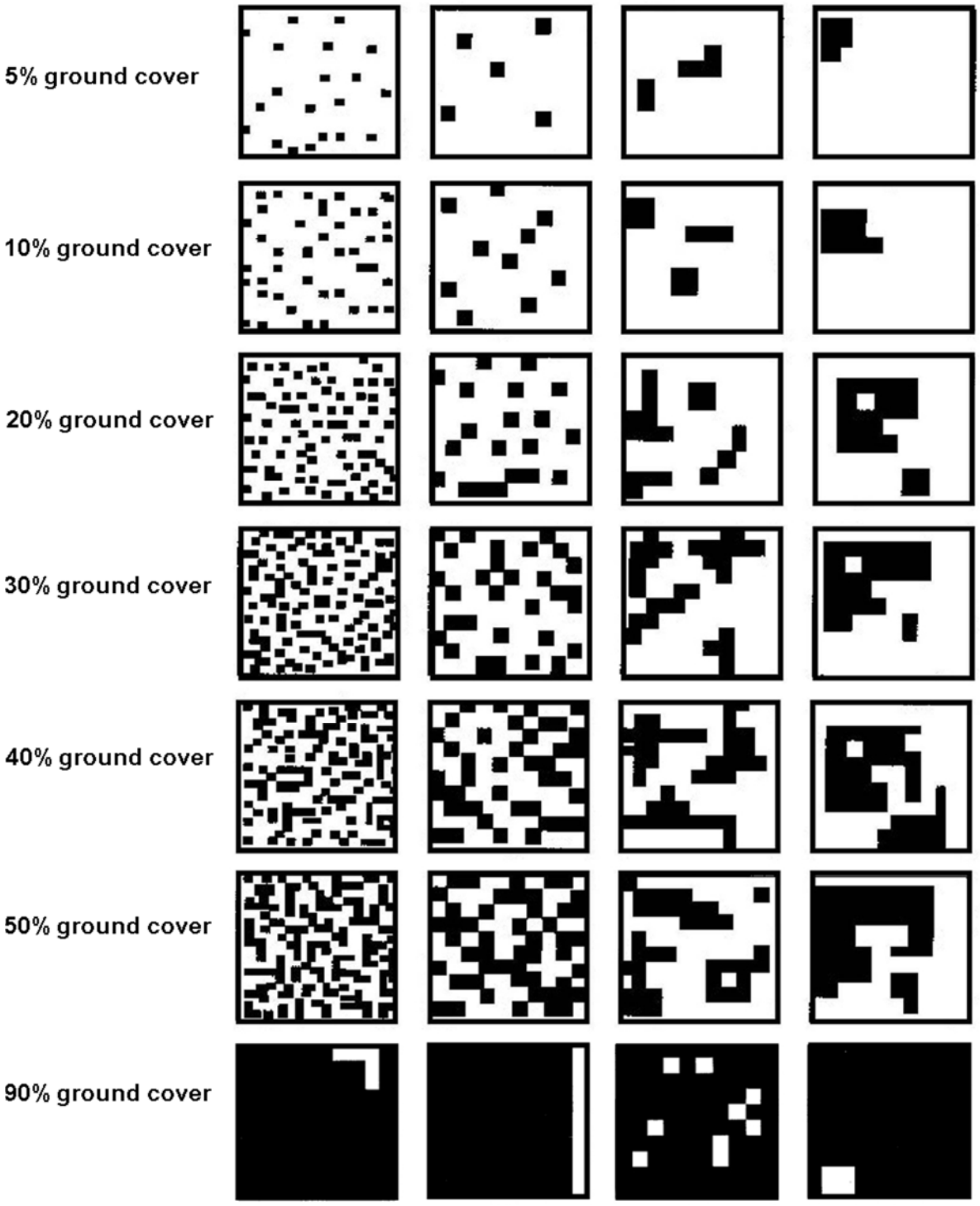

Figure 5: Stylised examples of ground cover proportions. Various ground cover amounts (as a percentage) can be evenly spread across the quadrat or distributed in patches.

4.7.4 Organic litter cover

Litter is defined to include both fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter. Organic litter cover refers to the average percentage cover assessed within each of the five 1 x 1 m quadrats (Figure **6**). Note: in quadrat plots with high cover of living plant material, it is only the organic litter cover observed through the living plant material that is included.

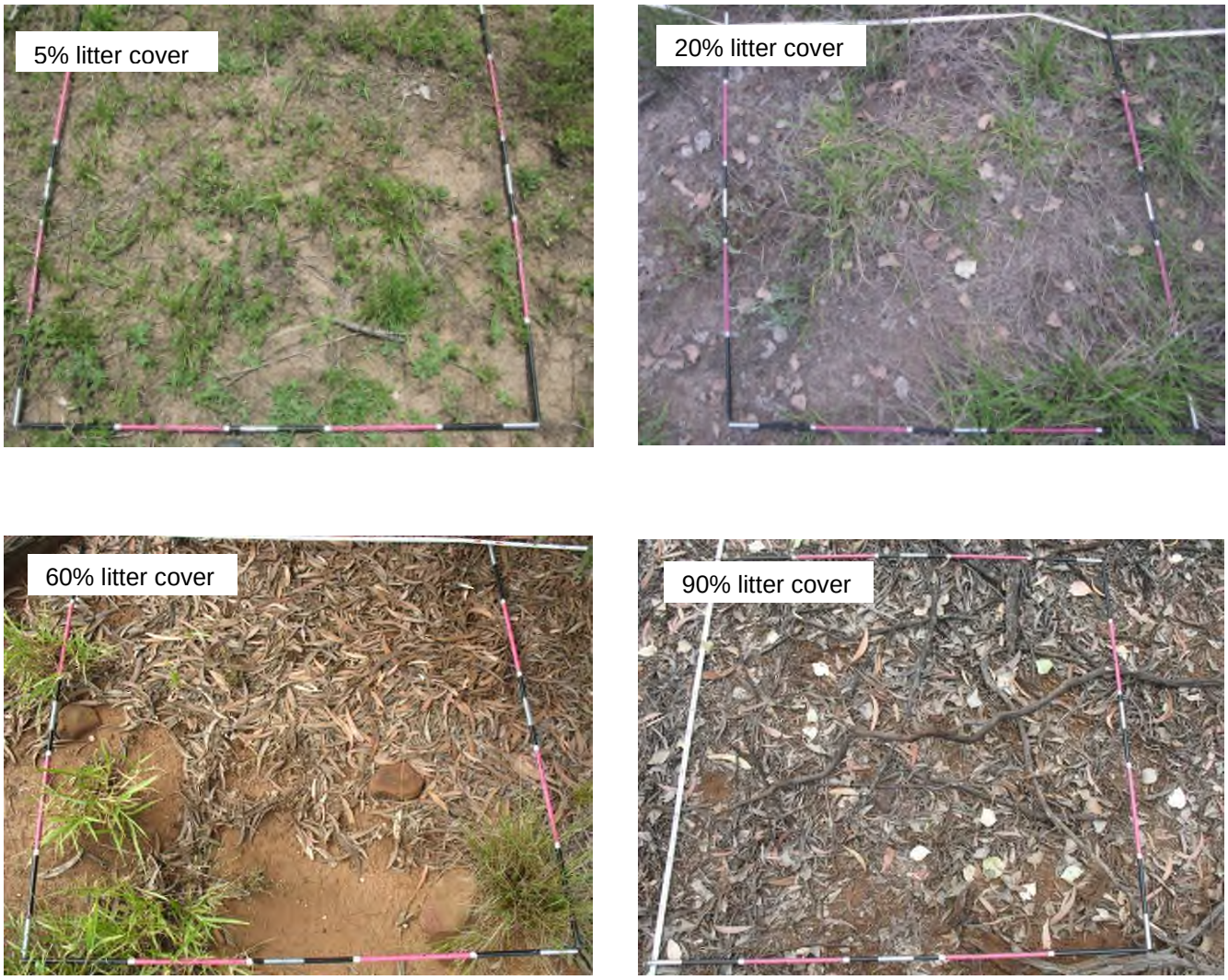

Figure 6: Examples of various litter cover proportions in 1 x 1 m quadrats

5 Deriving Benchmarks from the data

If reference site data are collected and collated from more than one plot for a particular RE, then the benchmark for an attribute is derived by taking the average value for each attribute from the range of sites (Box 2). However, if there is data from more than three reference sites then the benchmark is derived by taking the median value for each attribute from the range of sites. The median is a measure of central tendency, and is the 50th percentile of the data collected from more than one site for a particular attribute. It is the value for which 50 per cent of the values fall below the median and 50 per cent of the values are greater than the median.

Box 2: Example for deriving benchmarks from reference site data

Reference site data has been collected from three sites in the one RE in a local area. The values collected for tree height, tree canopy cover, shrub canopy cover and perennial grass cover for the three sites, and the average values are shown below. The average values are the benchmark values for each attribute, rounded down to the nearest whole number.

Values collected for four attributes across three reference sites within one RE, and the median values obtained:

Site	Tree height	Tree canopy cover	Shrub canopy cover	Perennial grass cover
1	33	25	12	25
2	30	25	10	35
3	32	23	7	20
Average	31.6	24.3	9.6	26.6

Therefore, for this RE, the benchmark for tree height = 31 m; tree canopy cover = 24 %; shrub canopy cover = 9 %; and perennial grass cover = 26 %.

To derive benchmarks for the large tree attribute (see Box 3), first the threshold DBH at which a tree is considered 'large' needs to be determined. This threshold can be determined by calculating the average DBH for each genus measured from one or more reference sites within an RE. It is important to have a 'large tree' threshold for each genus recorded in the reference site as different genera have varied growth habits e.g. in a mixed forest of cypress pine (*Callitris glaucophylla*) and poplar box (*Eucalyptus populnea*) (RE 11.10.11), a large cypress pine tree may be > 25 cm DBH, whereas a large poplar box may be > 50 cm. Trees are then grouped into eucalypts and non-eucalypts for simplicity of assessment.

Once the large tree DBH threshold has been determined, the median value from a range of sites can be calculated as outlined above for other attributes.

Box 3: Example for determining a large tree threshold

Plot size: 100 x 50 m plot

Regional Ecosystem: 11.10.11

Data:

Species	Diameter at breast height (DBH)
Eucalyptus populnea	30.4, 30.1, 30.6, 31.4, 35.4, 35.7, 35.4, 36.5, 36.2, 36.3, 37.2, 37.1, 38.1, 39.3, 41.8, 41.2, 43.8, 44.2, 47.1, 51.7, 52.2, 62.2, 63.1
Callitris glaucophylla	20.4, 20.9. 20.2, 20.6, 21.4, 21.6, 22.4, 22.6, 24.4, 24.4, 24.3, 24.7, 25.4, 24.2

Determining the large tree DBH threshold:

Average DBH for *E. populnea* trees > 30 cm DBH = 940/23 = 40.8

Average DBH for *C. glaucophylla* trees > 20 cm DBH = 317.5/14 = 22.7

Therefore, for this reference site, the DBH threshold indicating a 'large' tree is 40 cm DBH for the Eucalypts and 22 cm DBH for *Callitris*. (threshold is rounded off for simplicity in application)

Determining the large tree benchmark from this reference site:

Number of eucalypt trees > 40 cm = 18 trees per hectare (9 trees in 100 x 50 m plot x 2)

Number of non-eucalypt trees > 22 cm = 16 trees per hectare (8 trees in 100 x 50 m plot x 2)

6 References

Abed, T. and Stephens, N.C. (2002). *Tree measurement manual for farm foresters - Practical guidelines for farm foresters undertaking basic inventory in farm forest plantation stands,* National Forest Inventory, BRS, Canberra.

Andreasen, J.K., O'Neill, R.V., Noss, R., and Slosser, N.C. (2001). Considerations for the development of a terrestrial index of ecological integrity. *Ecological Indicators* 1, 21–35.

Beadle, N. C. W. & Costin, A. B. (1952). Ecological classification and nomenclature. *Proc. Linn. Soc. N.S. Wales*, 77, 61-82.

Bostock, P.D. & Holland, A.E. (eds) (2010). *Census of the Queensland Flora 2010.* Queensland Herbarium,

Executive Steering Committee for Australian Vegetation Information (ESCAVI) (2003). *Australian Vegetation Attribute Manual.* National Vegetation Information System, Version 6.0, Department of the Environment and Heritage, Canberra.

Eyre T.J., Kelly A.L., Neldner V.J, Wilson B.A., Ferguson D.J., Laidlaw, M.J. and Franks, A.J. (2015) *BioCondition – a condition assessment framework for terrestrial biodiversity in Queensland. Assessment Manual. Version 2.2.* Queensland Herbarium, Department of Science, Information Technology and Innovation, Brisbane.

Fensham, R. J., and Fairfax, R. J. (2008). Water-remoteness for grazing relief in Australian arid-lands. Biological Conservation 141, 1447-1460.

Gibbons, P., and Freudenberger, D. (2006). An overview of methods to assess vegetation condition at the scale of the site. *Ecological Management and Restoration* 7, S10-S17.

Gibbons, P., Ayers, D., Seddon, J., Doyle, S., and Briggs, S. (2008). *Biometric, Version 2.0. A Terrestrial Biodiversity Assessment Tool for the NSW Property Vegetation Plan Developer – Operational Manual.* NSW Department of Environment and Climate Change, Canberra.

Greig-Smith, P. (1964). *Quantitative Plant Ecology.* Butterworths, London.

Hnatiuk, R.J., Thackway, R., and Walker, J. (1990). *Vegetation. In Australian Soil and Land Survey Field Handbook. Third edition.* CSIRO publishing, Melbourne, pp. 73-125.

Kanowski, J., and Catterall, C. P. (2006) *Monitoring revegetation projects for biodiversity in rainforest landscapes. Toolkit Version 1.0.* Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns. <www.rainforest-crc.jcu.edu.au>

Keith, D., and Gorrod, E. (2006). The meanings of vegetation condition. *Ecological Management and Restoration* 7, S7–S9.

Landsberg, J., and Crowley, G. (2004). Monitoring rangeland biodiversity: Plants as indicators. *Austral Ecology* 29, 59–77.

Michaels, K. (2006) *A Manual for Assessing Vegetation Condition in Tasmania, Version 1.0.* Resource Management and Conservation, Department of Primary Industries Water and Environment, Hobart.

Michalk, D.L., and Norton, B.E. (1980). The value of reference areas in the study and management of rangelands. *Australian Rangeland Journal* 2: 201–207.

Neldner, V.J. (1984). South Central Queensland. *Vegetation Survey of Queensland. Botany Bulletin No. 3.* Queensland Department of Primary Industries, Brisbane.

Neldner, V.J., Kirkwood, A.B. and Collyer, B.S. (2004). Optimum time for sampling floristic diversity in tropical eucalypt woodlands of northern Queensland. *The Rangeland Journal* 26: 190-203.

Neldner, V.J. (2006). Why is vegetation condition important to government? A case study from Queensland. *Ecological Management and Restoration* 7, S5-S7.

Neldner, V.J., Wilson, B.A., Dillewaard H.A. and Butler, D. W. (2017) Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 4.0. Queensland Herbarium, Queensland Department of Science, Information Technology and Innovation, Brisbane.

Parkes, D., Newell, G., and Cheal, D. (2003). Assessing the quality of native vegetation: The 'habitat hectares' approach. *Ecological Management and Restoration* 4, 29–38.

Sattler, P.S and Williams, R.D. (eds) (1999). *The conservation status of Queensland's bioregional ecosystems*. Environmental Protection Agency, Brisbane.

Specht, R.L. (1970) 'Vegetation' in G.W.Leeper (ed*), The Australian Environment, 4th edition,* CSIRO and Melbourne University press, pp. 44-67.

Walker, J., and Hopkins, M.S. (1990). Vegetation. In McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J., and Hopkins, M.S. (Eds.), *Australian Soil and Land Survey Field Handbook. Second edition.* Inkata Press, Melbourne, pp. 58–86.

7 Glossary of terms

Annual species	Annual species are short-lived plants, completing their life-cycle within a single vegetative period, which can vary from a few weeks to several months. Annuals usually die within one year. Annual grasses are generally characterised by short growth, not forming large tussocks or root mass, lack of evidence of previous seasonal growth (i.e. remains of last season's tiller bases and absence of stolons or rhizomes), with reproduction generally from seed.
Benchmark	A description of a regional ecosystem that represents the median characteristics of a mature and relatively undisturbed ecosystem of the same type.
BioCondition Score	The score assigned to the assessed site that indicates its condition relative to the benchmarks set for the regional ecosystem being assessed. The score can be expressed as a percentage, on a scale of zero to one, or as a category of 1, 2, 3, or 4.
Biodiversity	The diversity of life forms from genes to kingdoms and the interactions and processes between.
Canopy	The layer formed collectively by the crowns of adjacent trees or shrubs in the case of shrublands. It may be continuous or discontinuous. The canopy usually refers to the ecological dominant layer.
CORVEG	Queensland Department of Environment and Resource Management Herbarium database for field data.
Cryptogam	A collective term referring to biological soil crusts, a highly specialized community of cyanobacteria, mosses, and lichens.
Diameter at Breast Height (DBH)	DBH is a measure of the size of the tree and is consistently measured at 1.3 m. On sloping ground, DBH is measured on the high side of the tree from bare earth ground level. Try and ensure that the tape is straight when reading the diameter. On leaning trees, on level ground, 1.3 m is measured from the underside of the lean. If a whorl, bump scar or other abnormality occurs at the 1.3m mark, measure the diameter at a nominated height (measured in whole 0.1m increments) above the defect. If a representative measure as described above cannot be taken (e.g.: presence of strangler figs), a reasonable estimate of the diameter should be made viewing the tree from two different directions. For multiple stems, a diameter is recorded for each stem, when it forks below 1.3m.
Dominant species	A species that contributes most to the overall above-ground biomass of a particular stratum (= predominant species).
Ecologically Dominant Layer or species (EDL)	The EDL contains the greatest amount of above-ground vegetation biomass, usually referred to as the canopy layer.
Emergent layer	The tallest layer/stratum is regarded as the emergent layer if it does not form the most above-ground biomass, regardless of its canopy cover e.g. poplar box (*Eucalyptus populnea*) trees above a low woodland of mulga (*Acacia aneura*).
Eucalypt species	Under BioCondition, a eucalypt species is any species from the following genera: *Eucalyptus, Corymbia, Angophora*, *Lophostemon, Syncarpia, Tristaniopsis, Welchiodendron* and *Xanthostemon*.

Forb	Herbaceous or slightly woody, annual or sometimes perennial plant that is not a grass or life form defined under 'Other species'. Note: members of the Cyperaceae, Juncaceae and some other families may have a grass-like (graminoid) appearance but are recorded as forbs rather than grasses.
Grass	A collective term for the following plant life forms: tussock grass which forms discrete but open tussocks usually with distinct individual shoots; hummock grass which are coarse xeromorphic grasses with a mound-like form often dead in the middle e.g. genus *Triodia*; other grasses of the family Poaceae, but having neither a distinctive tussock nor hummock appearance.
Grassland RE	A remnant RE described as having a structure code that does not include the terms 'forest', 'scrub', 'vineland', 'shrubland', 'heath' or 'woodland' in the Regional Ecosystem Database found at <www.derm.qld.gov.au>.
Large tree	A living tree identified as 'large' by a DBH threshold as defined in the benchmark document relevant to a RE. In some REs a different large tree threshold will be identified for eucalypt and non-eucalypt species due to the variation in potential size of these two tree types. For the purpose of defining large trees eucalypts include trees of genera *Angophora, Eucalyptus, Corymbia* and *Lophostemon.* If a large DBH threshold is not provided in the benchmark document, then generic thresholds of >20 cm DBH for non-eucalypts and >30 cm DBH for eucalypts can be used.
Native species	A native species is one that is considered to have evolved in Queensland unaided by humans or has migrated to and persisted in Queensland without assistance from humans (Bostock and Holland 2010).
Non-eucalypt species	Under BioCondition, a non-eucalypt species is defined as any species that is not listed as a eucalypt.
Non-native plant	Any plant that is not a native species.
Non-remnant vegetation	Non-remnant vegetation is vegetation that fails to meet the structural and/ or floristic characteristics of remnant vegetation. It may include regrowth, heavily thinned or logged and significantly disturbed vegetation, and cleared areas. Non-remnant vegetation may retain significant biodiversity values and includes areas mapped as 'high-value' regrowth.
Organic Litter	Includes both fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter.
Other species	All plant life-forms that are not trees, shrubs, grasses or forbs.
Perennial species	Perennial species are long-lived plants, tending to persist for three or more years. Generally perennial grasses are characterised by larger bulk than annual grasses i.e. forming tussocks and large root mass with evidence of previous seasons growth i.e. remains of last years tiller bases, and presence of stolons or rhizomes.
Reference Site	An area that represents an example of a Regional Ecosystem in 'Functional ' Condition, i.e. in a relatively undisturbed and mature state. As not all RE's will have examples of totally undisturbed states, sites of this kind are meant to represent the 'Best On Offer ' for that RE in that area. Data obtained from Reference sites will be used to establish benchmarks for each of the attributes used within BioCondition.
Regional Ecosystem (RE)	Regional ecosystems were defined by Sattler and Williams (1999) as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. For up to date descriptions of regional ecosystems check the Queensland Government website.

Remnant vegetation	Remnant vegetation is defined in the Vegetation Management Act 1999 as vegetation shown on a regional ecosystem or remnant map. A map showing remnant regional ecosystem is the same as a 'remnant endangered (or of concern or not of concern) regional ecosystem map' defined under the Vegetation Management Act 1999. Where there are no maps available, remnant vegetation is defined as vegetation where the dominant canopy has greater than 70 per cent of the height and greater than 50 per cent of the cover relative to the undisturbed height and cover of that stratum and dominated by species characteristic of the vegetation's undisturbed canopy.
Shrub	Woody plant that is multi-stemmed from the base (or within 200 mm from ground level) or if single stemmed, less than 2 m tall.
Shrub canopy cover	The estimation of the percentage canopy cover of the living shrub layer (see Shrub).
Shrub canopy height	The median canopy height in metres, as estimated for the shrub layer (see Shrub canopy cover).
Stratum	A layer in a community produced by the occurrence at approximately the same level (height) of an aggregation of plants of the same habit (Beadle and Costin 1952).
Tree	Woody plants, more than 2 m tall with a single stem or branches well above the base.
Tree canopy cover	Refers to the estimation of the percentage canopy cover of the canopy tree layer
Tree canopy height	The median canopy height in metres, as estimated for the canopy tree layer (see Tree canopy cover).

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Appendix 2 BioCondition Reference Site Datasheet

BIOCONDITION REFERENCE DATASHEET

Queensland Government

OFFICE USE ONLY
Entered:..................
Checked:.................
Corrected:...............

Site ID: ....

DATE: ....../....../......

Survey number: ....

OBSERVERS: ....

☐ Full reference Site? ☐ Partial reference Site? (tick attributes below to indicate those completed)

100 x 50m area:

☐ Native plant spp richness ☐ Coarse woody debris
☐ Tree Canopy height ☐ Litter Cover
☐ Tree Canopy cover ☐ Native perennial grass cover
☐ Shrub layer cover ☐ Large Trees

SITE INFORMATION

LOCATION: (GPS reference) Bioregion: _ _ _ _ _ _ _ _ _ _ _ _ _

Datum: ☐ AGD84 ☐ GDA94 (WGS84) OTHER: _ _ _ _ _ Location derivation: _ _ _ _ _ _

Road: zone: _ _ easting: _ _ _ _ _ _ northing: _ _ _ _ _ _ _ Plot Centre Direction: _ _ _ m at _ _ _ degrees

Plot Origin: zone: _ _ easting: _ _ _ _ _ _ northing: _ _ _ _ _ _ _ _ Accuracy: _ _ _

Plot Centre zone: _ _ easting: _ _ _ _ _ _ northing: _ _ _ _ _ _ _ _ Accuracy: _ _ _

Plot bearing: _ _ _ Plot alignment description: _

Locality description (include tenure and reserve number): _

REGIONAL ECOSYSTEM AND TREE HEIGHTS:

Habitat Description _

Regional Ecosystem: _ _ _ _ _ Median Tree Canopy height: .... m Emergent ht: m subcanopy ht: m

LANDFORM: Slope Position:.......... Slope Degree: .... Slope Aspect: ....

Code	Description	Code	Description
C	Crest	M	Mid-Slope
D	Closed Depression	P	Plateau
F	Flat	R	Ridge
G	Gully	U	Upper-Slope
H	Hillock	V	Open Depression
L	Lower-Slope	W	Wetland

SITE PHOTOS:

Photo Numbers

Plot centre: North ☐ South ☐ East ☐ West ☐

Plot Origin: ☐

Other: ☐

Gen Hab survey num:...................

DISTURBANCE: Survey number:...................

Type	Mean fire scar ht (m)	Severity 0 (nil) - 3 (severe)	Last Event[1]	Obs Type[2]
Wildfire				
Prescribed Burn				
Logging				
Treatment				
Grazing				
Non-native plant cover				
Erosion				
Storm				
Other (specify):				

[1] Last Event(time since):A:<1yr, B:1-5yrs, C:5-10yrs, D:10-20yrs, E:>20yrs

2 Observation type: 1=visual, 2=records, 3=informant, 4=imagery/mapped

100 x 50m area

	Total
Tree spp. richness:..	

50 x 20m area: (record length of all debris >10cm diam and >0.5m long)

Coarse woody debris:

Length: ....

Site Total:

Per ha Total:

50 x 10m area **Native Plant Species Richness:**

	Total
Shrub spp. richness:	
Grass spp. richness:	
Forbs and others spp. richness:	

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BIOCONDITION REFERENCE cont....

1 x 1m plots **Ground Cover:**

Ground Cover type	1	2	3	4	5	Mean
Native perennial grass						
Native annual grass						
Native forbs and other species (non-grass)						
Native shrubs (<1m in height)						
Non-native grass						
Non-native forbs & shrubs						
Litter						
Rock						
Bare ground						
Cryptograms						
Total	100%	100%	100%	100%	100%	

100 x 50m area: **Large Trees:** Plot size: ☐ 100 x 50m ☐ 100 x 20m ☐ 100 x 10m

Species	Eucalypt (E) or Non-Eucalypt (N)	Diameter at Breast height (1.3m) (cm) (Measure all Eucalypts >30cm dbh and all Non-eucalypts >20cm)
Eucalypts:		Average DBH (threshold) = cm # of trees >= benchmark( ): # of trees >= benchmark per ha:
Non-eucalypts:		Average DBH (threshold) = cm # of trees >= benchmark( ): # of trees >= benchmark per ha:

100m transect: **Tree and Shrub Canopy Cover:** Type - C = canopy tree, SC = subcanopy tree, E = Emergent tree or S = shrub)

type	distance	total	type	distance	total	type	distance	total	type	distance	total	type	Distance	total
													Subcanopy total:	
													Canopy total:	
													Emergent total:	
													Shrub total:	

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Appendix 3 Taking Photos

Taking photographs of site features from a fixed point is a great way to keep a permanent visual record of how attributes have changed over time. Photographs can be the most reliable and useful record collected in any monitoring program, as they best represent how things were over time, in comparison to our memories which aren't as reliable as we think.

Two photo types are recommended to be taken at each reference site.

1. The Spot photo

This is a photo taken from head height looking nearly vertically down on a spot marked with a one square metre frame or quadrat, as shown in Figure 7. You can use the base of your plot centre marker, to relocate the same spot each time you visit. Spot photos provide a detailed picture of the ground cover, organic litter and plant species for a standard sized area. Commonly there is great variety in ground cover at any given site, so taking more spot photos will help record this variation. It is important to have a system that allows you to take the spot photos in the same place each time you do an assessment. For example, spot photos could be taken along the transect line where you are doing the ground and litter cover assessments (i.e. 35, 45, 55, 65 and 75 metres).

Figure 7: Taking the spot photo – try and keep feet out of the frame and angle the camera down as straight as possible

2. The Landscape photo

The landscape photos are taken of features in the intermediate distance or further to provide an overview of the entire site and its surrounds. They illustrate the general condition of the site, showing changes in tree, shrub and ground layers over time. These site specific landscape photos can also be used to record particular disturbance events such as flood levels and damage or the impacts of a bushfire.

The landscape photo is taken from the plot centre and the origin of the 100m centre line, holding your camera so that the image is taken with a 'landscape' perspective – that is where the picture is wider than it is high. Stand next to the plot centre marker (Figure 8), facing south (recommended direction – see 'photo tips'), and position the horizon so it cuts the photo frame in half (half above the horizon and half

below). Then take the photo focusing on infinity. Recording how the photo was lined up or simply taking a copy of the picture with you on future visits will make lining up the shot easier. Alternatively and preferentially, taking a series of plot centre landscape photos in a north, south, east and west direction (with the aid of a compass), allows you to pick up more of the variation across the site and is easy to replicate next time an assessment is done.

Figure 8: Taking the landscape photos – record the bearing or direction of the photo in order to assist replicate photos on subsequent visits.

Photo tips

Any type of camera from colour print film to a digital camera can be used to take these photos. Digital cameras are ideal, allowing instant review of an image for clarity and colour; making sure you always have a good photo for your records.

The best photos are generally taken on a clear day between 9am and 3pm. Before 9am and after 3pm will generally result in more shadowing and different colour cast which may conceal some important features. Overcast days are great for photography in closed communities such as rainforests, scrubs and thickets, as the even light removes much of the shadowing.

A common problem is too much light blanking out the colour and detail of the image. If you have control over your camera settings, this can be reduced by setting the exposure compensation to a negative setting; using the auto-exposure lock (AE lock); or by using spot metering. Your camera's user guide will explain how to use these functions on your particular camera – the troubleshooting section is often a good place to find these and other useful solutions.

You will always get a better photo by having the sun behind you with the sunlight shining on the landscape facing you. So, if you are only taking one photo it is best to be facing south, avoiding having the sun shining into your lens.

For each photograph record the relevant area, land type and site; the date the photo was taken; and the direction the photo was taken (N/S/E/W). The date stamp feature on your camera may be useful if it does not obscure important components of a photograph. Photos can be stored in a database (scanned if not digital) and/or printed and kept on file with the monitoring records.

Appendix 4 Stratifying Vegetation

The assessment of the tree height and tree canopy cover attributes require consideration of the distinct vegetation layers or strata that make up the community. In general, site-based assessment of vegetation uses structure (vertical and horizontal distribution of vegetation: its growth form, height, cover and strata) and floristics (dominant genera or species in various strata and characteristic species) (Hnatiuk et al. 2009). In Queensland, the structural and floristic characteristics of the vegetation are used in defining and describing REs. Details of the methods used to classify vegetation and regional ecosystems in Queensland are described in Neldner et al. (2017).

Determining the ecologically dominant layer

Once the vegetation community has been classified into strata (see Figure 9 when strata are not obvious), the determination of the ecologically dominant layer (EDL) is made. The EDL contains the greatest amount of above-ground vegetation biomass (Neldner 1984). In the majority of cases in wooded communities, it is the tallest layer that forms the most above-ground biomass, except in the case of widely scattered emergent trees. Therefore, in most cases only the EDL layer is assessed for the attributes tree canopy cover and height in BioCondition. Exceptions include rainforest canopies with emergent species and mixed genus woodlands (e.g. poplar box and mulga woodlands).

Example 1: EDL; RE 3.5.24, *Eucalyptus chlorophylla* open-woodland (EDL), Cape York Peninsula

Here the above-ground biomass of the trees is estimated to be larger than the grass layer, and is the EDL. Generally if the tree layer in these situations has a canopy cover of 8 per cent or more, then the trees will form the EDL.

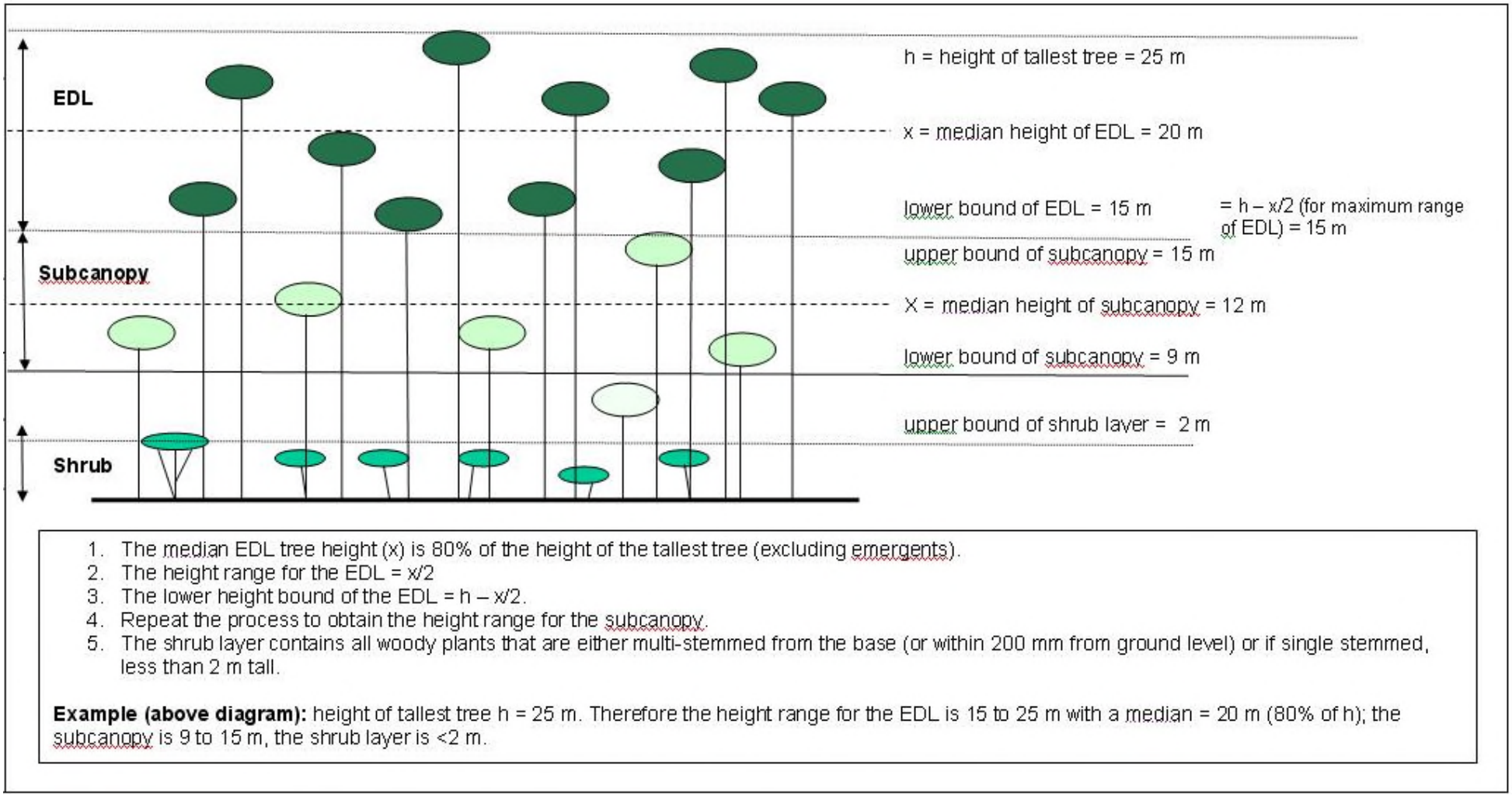

Figure 9: Method for determining vegetation strata, when not obvious

Example 2: Emergent layer and EDL; RE 5.7.2, *Acacia catenulata* low woodland (EDL) with emergent *Eucalyptus thozetiana*.

Example 3: EDL and shrub layer; RE 2.5.15, *Melaleuca viridiflora* low woodland (EDL) with a distinct shrub layer of *Petalostigma banksii* on western Cape York Peninsula.

Example 4: EDL and shrub layer; RE 2.5.12, *Eucalyptus pruinosa* low woodland (EDL) with low shrub layer of Acacia spp.

Example 5: Multi-layers: RE 8.5.1, coastal Corymbia spp. woodland (EDL) with a subcanopy layer of *Melaleuca viridiflora* and immature canopy trees. The layers in some forest communities can be relatively indistinct.

Example of benchmarks for REs with more than one strata layer

RE 6.5.3 *Eucalyptus populnea* woodland with *A. aneura* subcanopy.

- Canopy (EDL) of *Eucalyptus populnea*: Benchmark height = 15 m. Benchmark tree canopy cover = 18 %
- Subcanopy of *Acacia aneura*: Benchmark height = 8 m. Benchmark canopy cover = 30 %

Appendix 5 Measuring Tree Height

Clinometer Method (extracted from Abed and Stephens 2002)

The Suunto clinometer (clino) is a tool commonly used by foresters to measure tree heights and also slope angles. At the rear of the clino is a peephole, which shows a percentage scale and a horizontal line (see Figure 10).

1. First measure the horizontal distance between the base of the tree and the operator.
2. Looking through the peephole (see Figure 10 and 11), line up the horizontal line with the top of the tree (the highest part of the tree, usually foliage) and read off the corresponding number from the percentage scale, which is on the right hand side. The scale on the left is in degrees and should not be used.
3. Line up the horizontal line with the base of the tree and again read off the corresponding number from the percentage scale.
4. If the base of the tree is above you (i.e. you're on the downward slope) then subtract the number from step 3 from the number in step 2 and multiply by the horizontal distance to get a total tree height.
5. If the base of the tree is level with you or below you (i.e. you're on the upward slope) then add the numbers together and multiply by the horizontal distance to get a total tree height.
6. If the tree is leaning, stand at right angles to the lean so the tree isn't leaning towards or away from you. If the highest part of the tree is not directly above the trunk, then adjust the horizontal distance so that it relates directly to the highest part of the tree.

Hint: If you can't see the bottom of the tree because of branches or understorey, sight to a point up the stem that can be seen and treat this as the base of the tree and continue with the procedure as described above. Then add the height from the base to the point you could see to get your estimate of total height.

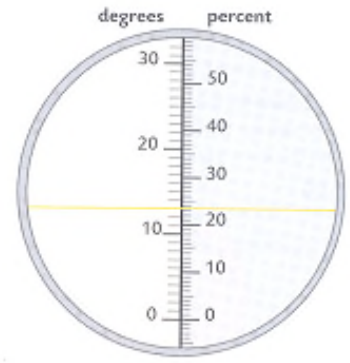

Figure 10: Looking through a clinometer

The heights of the crown can also be measured using a laser instrument called a hypsometer. Where the top of the tree is not directly above the base of the trunk, it is important to also measure the point directly below the highest point of the tree canopy to get an accurate crown height.

Appendix 6 Life-forms used in BioCondition

Code	Name	Description	BioCondition Category
T	**TREE**	Woody plants, more than 2 m tall with a single stem or branches well above the base	Tree
M	**TREE MALLEE**	Woody perennial plant usually of the genus Eucalyptus. Multi-stemmed with fewer than 5 trunks of which at least 3 exceed 10 cm diameter at breast height (DBH). Usually 8 m or more.	Tree
S	**SHRUB**	Woody plant multi-stemmed from the base (or within 200 mm from ground level) or if single stemmed, less than 2 m.	Shrub
Y	**MALLEE SHRUB**	Commonly less than 8 m tall, usually with 5 or more trunks, of which at least three of the largest do not exceed 10 cm DBH.	Shrub
Z	**HEATH SHRUB**	Shrub usually less than 2 m, commonly with ericoid leaves (nanophyll or smaller). Often a member of one of the following families: Ericaceae, Myrtaceae, Fabaceae and Proteaceae. Commonly occur on nutrient-poor substrates.	Shrub
C	**CHENOPOD SHRUB**	Single or multi-stemmed, semi-succulent shrub of the family Chenopodiaceae exhibiting drought and salt tolerance.	Shrub
U	**SAMPHIRE SHRUB**	Genera (of Tribe Salicornioideae, viz: Sarcocornia, and Tecticornia) with articulate branches, fleshy stems and reduced flowers within the Chenopodiaceae family, succulent chenopods. Also the genus Suaeda.	Shrub
G	**TUSSOCK GRASS**	Forms discrete but open tussocks usually with distinct individual shoots, or if not, then forming a hummock. These are the common agricultural grasses.	Grass
H	**HUMMOCK GRASS**	Coarse xeromorphic grass with a mound-like form often dead in the middle; genus Triodia	Grass
W	**OTHER GRASS**	Member of the family Poaceae, but having neither a distinctive tussock nor hummock appearance.	Grass
V	**SEDGE**	Herbaceous, usually perennial erect plant generally with a tufted habit and of the families Cyperaceae and Restionaceae.	Other
R	**RUSH**	Herbaceous, usually perennial erect plant. Rushes are grouped into families Juncaceae, Typhaceae, Restionaceae and the genera Lomandra and Dianella.	Other
F	**FORB**	Herbaceous or slightly woody, annual or sometimes perennial plant; not a grass, and including ground orchids.	Forbs

D	**TREE FERN**	Spirally arranged crowns on erect trunks several metres high (U.N.E 1989), characterised by large and usually branched leaves (fronds), arborescent and terrestrial; spores in sporangia on the leaves.	Shrubs
E	**FERNS AND FERN ALLIES**	Characterised by large and usually branched leaves (fronds), herbaceous to arborescent and terrestrial to aquatic; spores in sporangia on the leaves.	Other
B	**BRYOPHYTE**	Mosses and Liverworts. Mosses are small plants usually with a slender leaf-bearing stem with no true vascular tissue. Liverworts are often moss-like in appearance or consisting of a flat, ribbon-like green thallus.	Other
N	**LICHEN**	Composite plant consisting of a fungus living symbiotically with algae; without true roots, stems or leaves.	Other
K	**EPIPHYTE**	Epiphytes (including orchids), mistletoes and parasites. Plant with roots attached to the aerial portions of other plants. Often could also be another growth form, such as fern or forb.	Other
L	**VINE**	Climbing, twining, winding or sprawling plants usually with a woody stem.	Other
P	**PALM**	Palms and other arborescent monocotyledons. Members of the Arecaceae family or the genus Pandanus. (Pandanus is often multi-stemmed).	Trees
X	**XANTHORRHOEA**	Australian grass trees. Members of the family Xanthorrhoeaceae.	Shrubs
A	**CYCAD**	Members of the families Cycadaceae and Zamiaceae	Shrubs
J	**SEAGRASS**	Flowering angiosperms forming sparse to dense mats of material at the subtidal and down to 30m below MSL. Occasionally exposed.	Grass
Q	**AQUATIC**	Plant growing in a waterway or wetland with the majority of its biomass under water for most of the year. Fresh, saline or brackish water.	Other
O	**LOWER PLANT**	Alga, fungus.	Other
UNK	**UNKNOWN**		Other