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Historical forest survey data from *Eucalyptus–Callitris* forests: a valuable resource for long-term vegetation studies

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Abstract. Quantitative information about historical changes in natural ecosystems is important for guiding management interventions. However, few accurate data sources are available for documenting long-term vegetation changes. In this paper, we describe a neglected source of quantitative information on historical forest structure: forest inventory strip surveys, which were widely used in eastern Australia from 1915 to the 1940s. Strip surveys provide quantitative information on the species composition, stem density, basal area, stem form and size class distributions of dominant tree species. Such information is not available from other widespread data sources. Strip surveys usually surveyed 10% of the total forest area. In this paper, we describe the original survey methods, demonstrate how to decode data-book entries, and analyse a sample dataset from the Pilliga State Forests in northern New South Wales to illustrate the information that can be obtained from this material. Strip survey data-books are poorly archived. Many books exist for *Eucalyptus–Callitris* forests in northern and central NSW, and additional books may exist for many other forest types in eastern Australia. Strip surveys provide a valuable data source for studying long-term vegetation changes in forest ecosystems. We urge forest managers to search for and preserve this precious archival material.

Introduction

Understanding historical vegetation changes enhances our ability to predict ecosystem responses to disturbances and to conserve biodiversity in dynamic ecosystems (Clark 1990; Swetnam *et al*. 1999; Foster 2000; Lunt 2002), particularly where disturbance regimes have changed greatly since European colonisation. Accurate historical reference data are critical in assessing vegetation change over long periods, and aerial photographs and satellite images are commonly used as historical references for assessing landscape changes (e.g. Zheng *et al*. 1997; Miller *et al*. 1998; Kouki *et al*. 2001; Fensham and Fairfax 2002). However, stand-level assessments require images at scales larger than 1 : 20 000, which are not always available (Fensham and Fairfax 2002). Unfortunately, other data sources are usually sparse and fragmentary.

Because of the scarcity of data, researchers have used many novel sources to document long-term changes in vegetation structure, including documentary and environmental proxy records. Documentary sources include explorer's notes, historical photographs and land survey records (Gruell 2001; Cogbill *et al*. 2002; Fensham 2008). Environmental proxy records include tree-stump density and size-class distributions, tree-ring chronologies, palynology, pack-rat middens and carbon isotope ratios (Swetnam *et al*. 1999; Lunt *et al*. 2001; 2006; Witt 2002). While each method has strengths and limitations, data availability usually presents an over-riding constraint (Clark 1990; Swetnam *et al*. 1999; Lunt 2002).

Forest inventory surveys, originally conducted to assess the quantity of available timber, can provide detailed information on vegetation structure during the period of modern industrial management. Historical forest inventories have been used to assess vegetation changes in North America and Europe (Andersson and Östlund 2004; Etheridge *et al*. 2005; Montes *et al*. 2005; Lorimer 2008; Trofymow *et al*. 2008), but have not been used in Australian forests. Strip or cruise-line surveys were standard practice in the USA, Canada, Sweden and Australia during the early twentieth century (Frayer and Furnival 1999; Dargavel and Kowald 2001; Andersson and Östlund 2004; Etheridge *et al*. 2005) and have also been used in India (D'Arcy 1898). Parallel transects were systematically surveyed across large forest areas, with plots at regular intervals (Frayer and Furnival 1999). In Australia, they were called strip surveys, as plots were measured continuously along each transect (Forestry Commission of NSW 1915). Strip surveys were carried out in forests as diverse as *Eucalyptus regnans* F. Muell. forests in Victoria (Dargavel and McRae 1997), *Eucalyptus camaldulensis* Dehnh. forests along the Murray River (Lindsay 1967), *Eucalyptus–Callitris* forests in central NSW (this study), and rainforests in northern Queensland (Dargavel and Moloney 1997). In Australia, strip surveys commonly sampled 10% of the entire forest area (Lindsay 1946; Dargavel and Moloney 1997), which is an enormous sample size by today's standards. Strip surveys went out of fashion in the late 1950s as aerial photography and statistical

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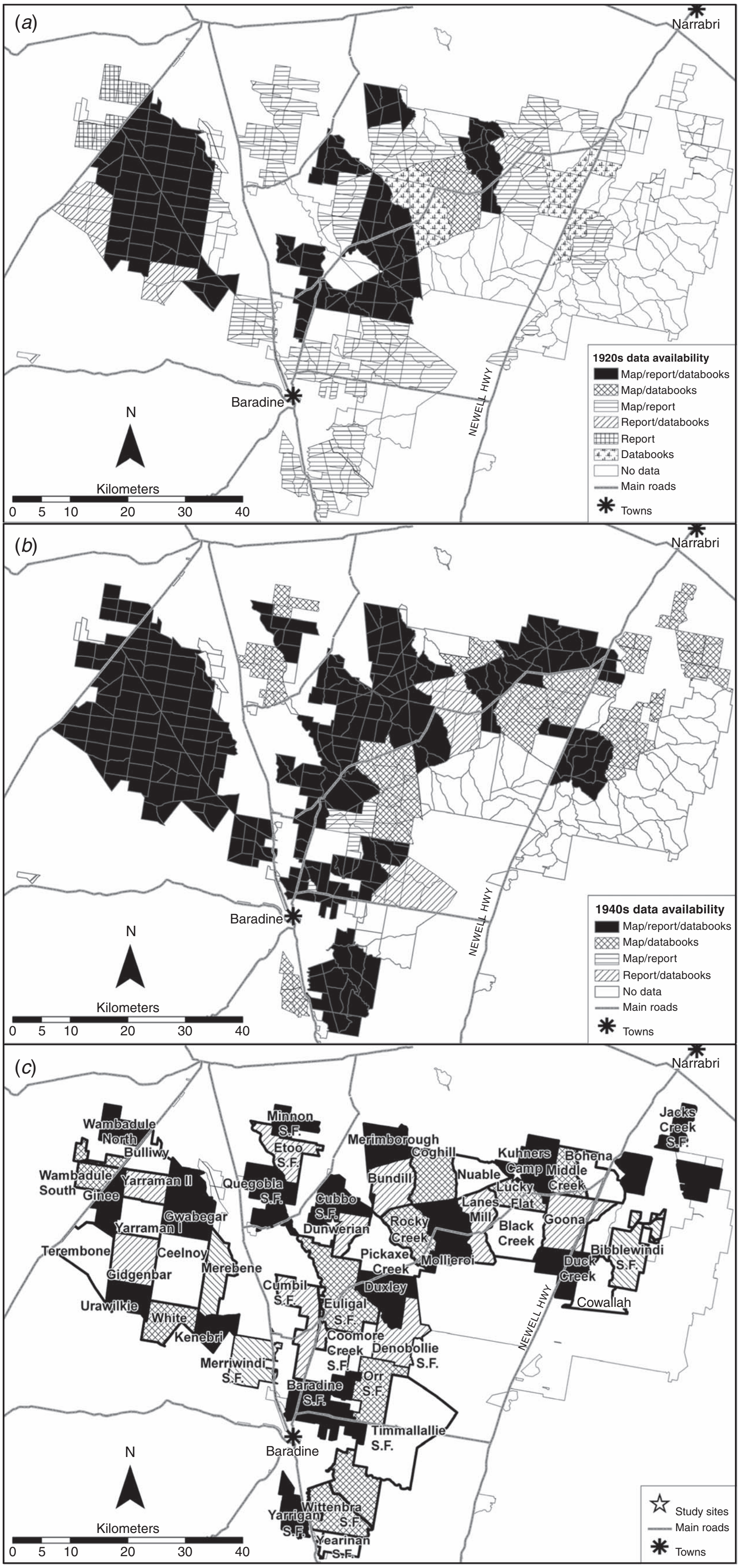


Fig. 1. Availability of (*a*) Priestman (1920s) and (*b*) Lindsay (1940s) survey data in the Pilliga State Forests, in comparison to (*c*) State Forest and State Forest Section boundaries in the 1940s. Data availability is adapted from Turner (2004), and is mapped according to modern compartment boundaries, but boundaries have changed since the 1920s and 1940s, and coverage is indicative only. Data was collected by State Forest or by Section, but Section names are no longer in common usage, so map (*c*) provides a reference for locating the data relevant to a selected study site. White stars in (*c*) indicate the location of study sites.

techniques such as stratified random sampling provided greater efficiencies (Dargavel and Moloney 1997; Frayer and Furnival 1999).

Unfortunately, strip survey data are difficult for modern ecologists to use as data-books are not properly stored or indexed, descriptions of survey methods are difficult to obtain,

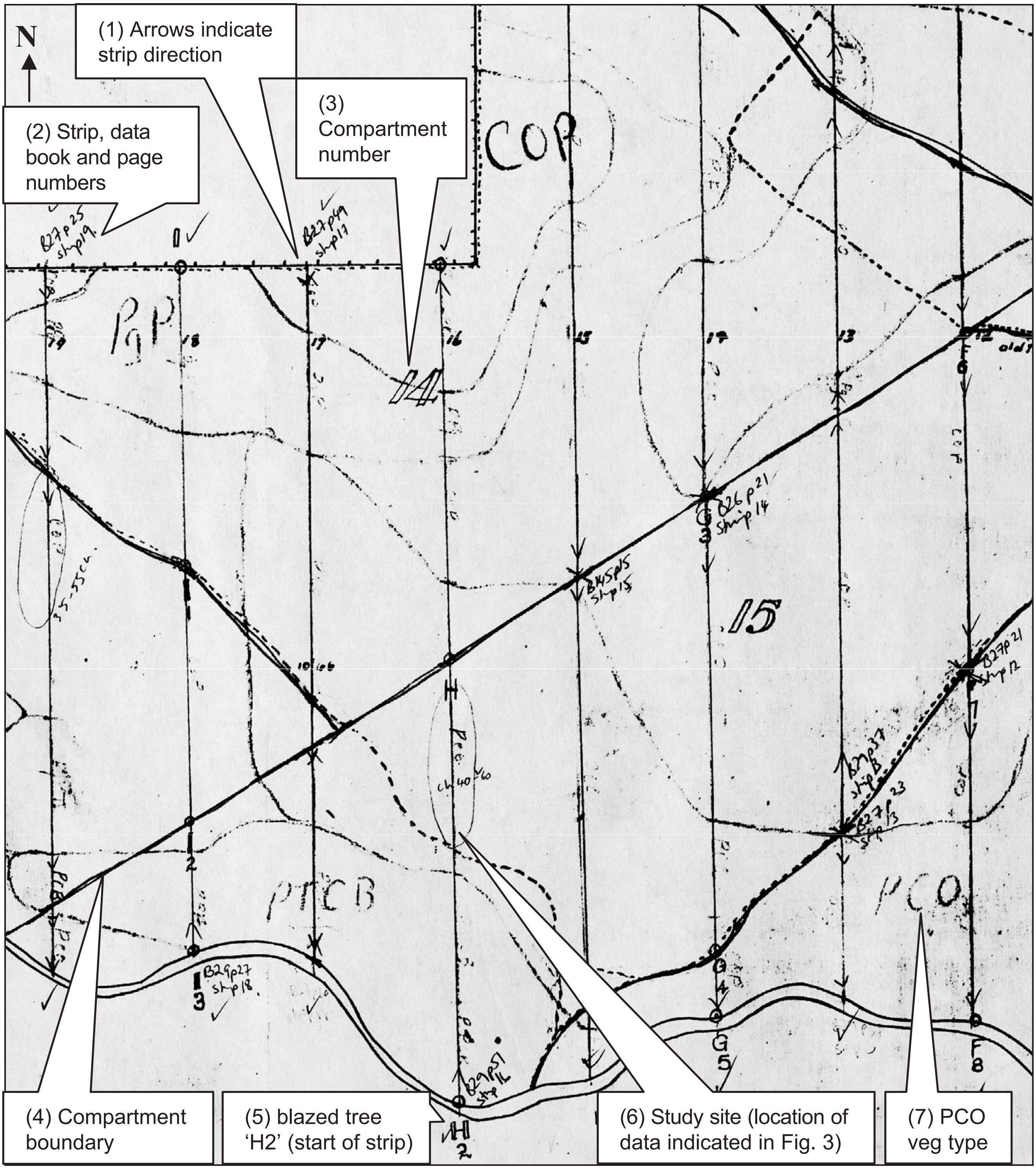


Fig. 2. Detail from a 1940s forest survey map of Kuhner's Camp Section in Pilliga East State Forest used to provide a spatial reference for forest survey data. Survey strips are represented as vertical lines. The location of the data book section illustrated in Fig. 3 is indicated (this fig. note 6). The compass bearing on this strip is 360° (N), as indicated in Fig. 3 note 4. Strip numbers (this fig. note 2) and direction of transects (note 1) have been overlain on a copy of the original base map by the current authors, based on cross-references from the data books.

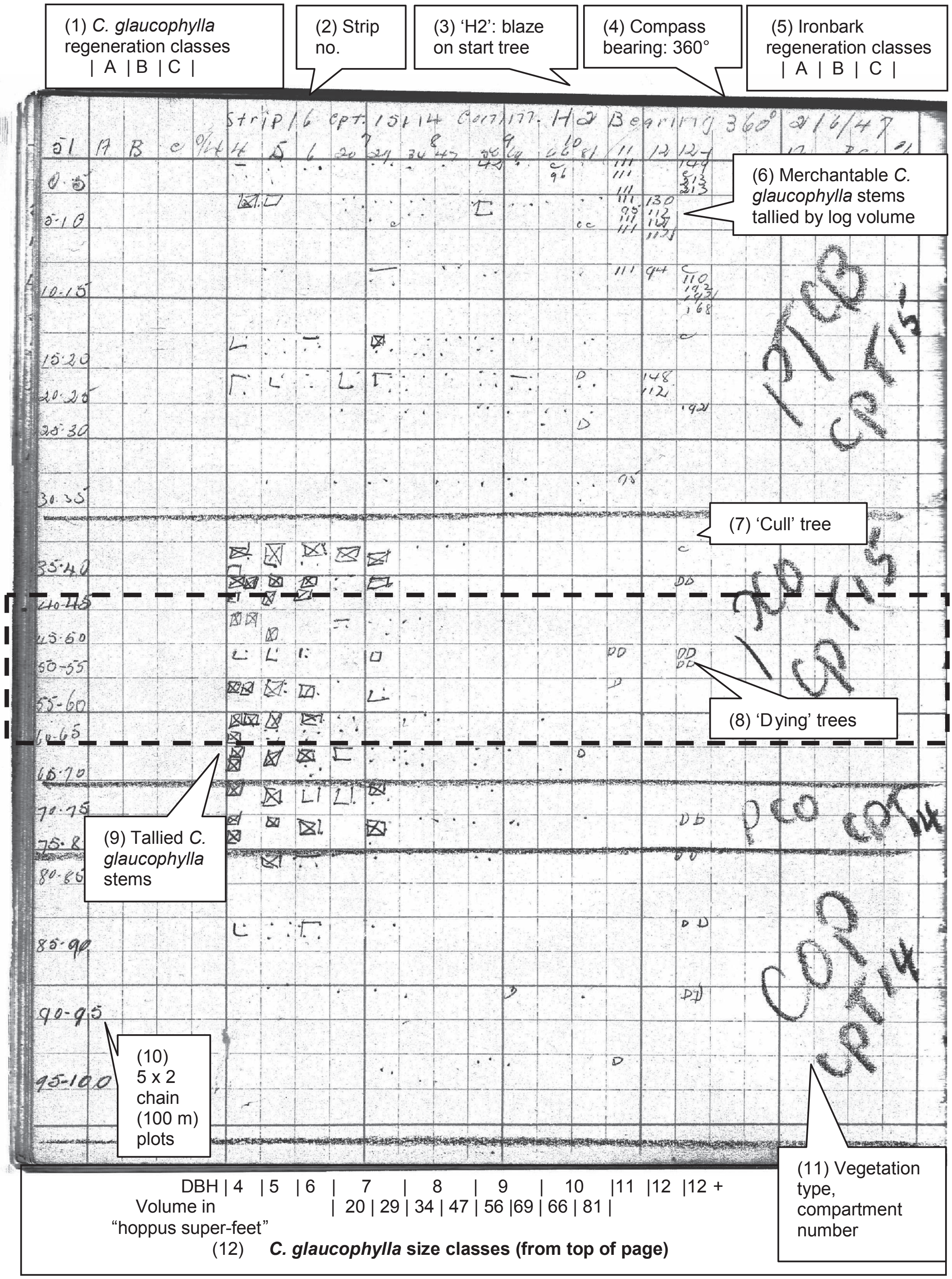
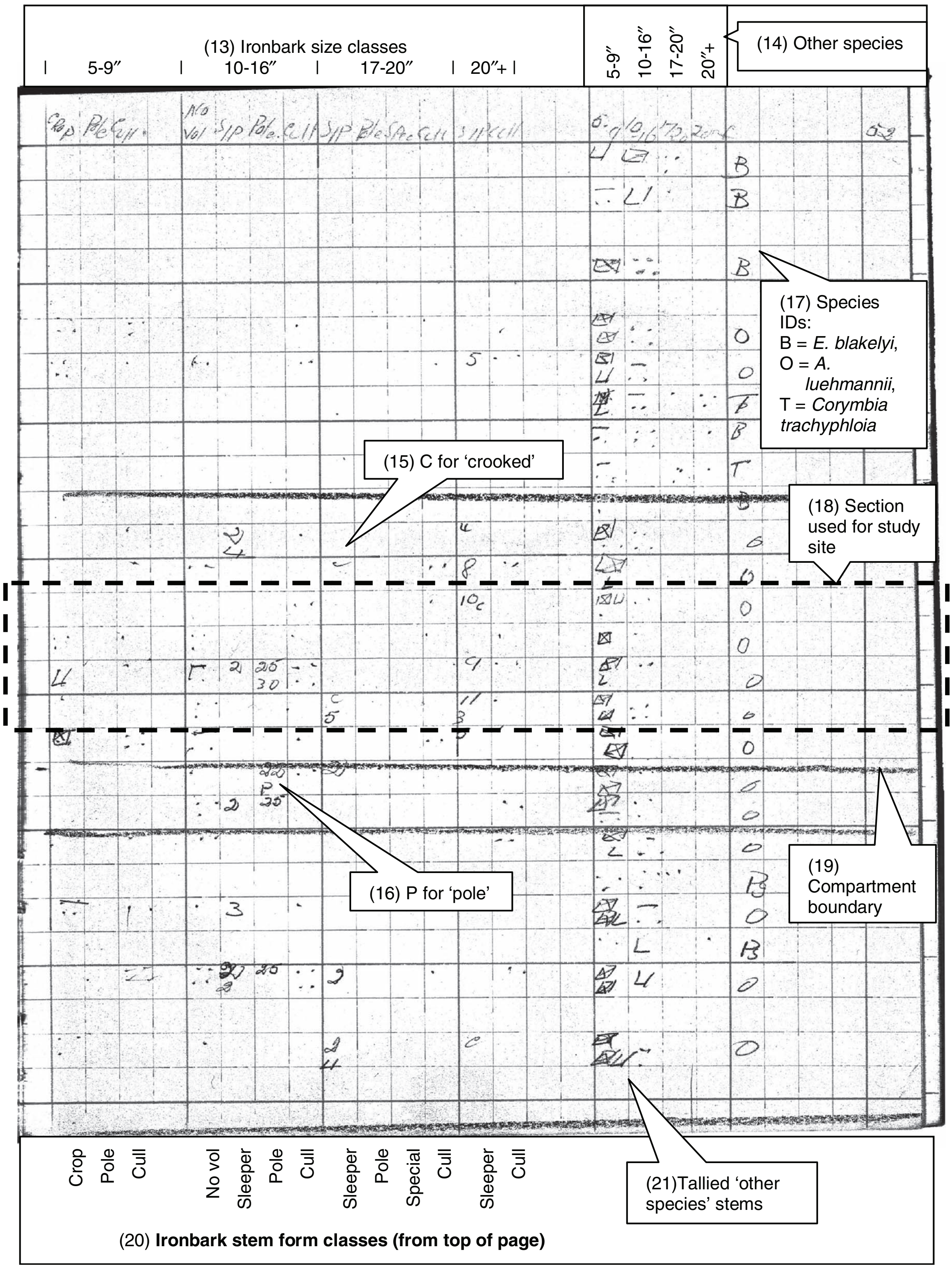


Fig. 3. A full double page from a 1940s data book from Kuhner's Camp section, Pilliga East SF. The first page shows tallied *C. glaucophylla* stems. *Callitris glaucophylla* size class headings are written out at the bottom of the page for clarity. The four recording units indicated by the dashed rectangles (note 18) correspond with the data recorded for the study site shown on the map in Fig. 2 (note 6). Codes indicating the identity of 'other species' (this fig. note 17) are as presented in Table 3. Image shown slightly smaller than actual size (graph paper is ruled in inch/quarter-inch squares). The second page shows ironbark



Continued, (principally *E. crebra*) and a column containing tallied stems of other species. For ironbark, entries in columns headed 'slp' indicate how many potential railway sleepers each tree was estimated to contain. Entries in columns headed 'Pole' indicate the length of pole each tree was estimated to contain. 'No vol' and 'crop' mean trees below merchantable size of good form that should eventually be merchantable, while 'cull' means trees of a form not suitable for either sleepers or poles. 'Sp' ('special') indicates an especially large pole or girder.

and the data-books contain reams of obscure 'hieroglyphics' which resist interpretation. In this paper we aim to provide a 'Rosetta Stone' to overcome these impediments. We outline the original survey methods in *Eucalyptus–Callitris* forests, describe how to decode data-book entries, and then analyse a sample dataset from the Pilliga State Forests in northern NSW to illustrate the information obtainable from this invaluable archive. These methods will assist future researchers to document the effects of management and disturbance on long-term vegetation changes.

Materials and methods

Development of forest strip surveys in Eucalypt–Callitris *forests*

In NSW, strip survey protocols were adopted from established methods such as those outlined by D'Arcy (1898), and further developed in the Pilliga State Forests near Coonabarabran (Swain *et al*. 1971; FCNSW 1915). These survey protocols were then implemented in other cypress forests across central NSW after each of the World Wars.

Two strip surveys were undertaken in the Pilliga: the 'Priestman survey' took place from 1926–34 and the 'Lindsay survey' from 1946–51 (Lindsay 1967; FCNSW 1986; original unpublished survey reports). These surveys sampled 10% of ≈252 000 ha of State Forest; thus 25 200 ha was directly measured (Lindsay 1967). The two surveys sampled the same transects but used slightly different methods. The main difference between the Priestman and Lindsay surveys is that the earlier maps were subjective and descriptive, while the maps produced from the Lindsay survey were true forest type maps based on a formal classification. Surviving records from both surveys include: (a) the original field data-books; (b) vegetation maps drawn from the survey data; and (c) a series of summary reports based on survey data and maps. In addition, an incomplete set of large aerial photo-mosaics on which forest type boundaries were drawn exists from the 1940s survey. However, records (stored in forest offices at Baradine and Dubbo) are incomplete, particularly for the earlier survey (Fig. 1*a*, *b*). This article focuses on the 1940s Lindsay survey, as the data and supporting instructions, maps and reports survive in a more complete form.

Lindsay methods

The methods described in this paper are based on the original 'Instructions for Forest Estimators' (Lindsay 1946). Only a few copies of the Instructions exist, and these are not catalogued in any library database. Lindsay's (1946) communiqué instructed foresters to survey forests along continuous strip transects, each 2 chains (40.2 m) wide. Successive parallel transects were placed 20 chains (402 m) apart, so that 10% of the entire forest area was sampled (Lindsay 1946). Data were recorded in small field notebooks (hereafter referred to as 'data-books'), from which forest type maps were drawn and management plans written.

Cross-referencing maps and data books

The Pilliga comprises several State Forests that form a more-or-less contiguous block. At the time of the 1940s forest surveys, maps were drawn for each individual State Forest or for Sections of the two of the larger State Forests. These Sections are critical to cross-referencing maps and data-books, but are no longer used by modern foresters, so their names and locations are shown in Fig. 1*c*.

Maps show lines of blazed trees carved with identifying letters and numbers, which were located at 40-chain (804 m) intervals along roads, streams or compartment boundaries. Survey strips began either at a blazed tree or at a point equidistant between two blazed trees. Many blazed trees have since disappeared, but their locations were marked in data-books and on maps. (e.g. blazed tree 'H2' in Fig. 2 note 5 and Fig. 3 note 3). This allowed us to match data-book entries to transects for each map. Forest types were classified in the 1940s based on the relative abundance of dominant trees (as described in the section on forest type classification, below), and were also marked on both maps and data-books (Fig. 2 note 7 and Fig. 3 note 11). We checked matches between transects on maps and in data-books using these forest-type boundaries.

Data-book entries

Within each 2-chain-wide (40.2 m) strip, foresters tallied trees in 5-chain (100.5 m) units (Fig. 3 note 10), with each unit corresponding to a 1-acre (0.404 ha) plot. Each unit was labelled according to the distance of its start- and end-points from the beginning of the strip. The two main commercial species, *Callitris glaucophylla* J. Thompson & L. Johnson, and *Eucalyptus crebra* F. Muell., were recorded in considerable detail in their own sections of each page (Fig. 3 notes 1, 5, 9, 12, 13 and 20), while all other species were recorded together in a third, smaller section (Fig. 3 note 14). The dot-tally system used to count stems in the Priestman and Lindsay data-books (Fig. 4) had been used in NSW since strip-survey techniques were introduced in 1915 (FCNSW 1915).

Callitris glaucophylla entries

Surveyors tallied all *C. glaucophylla* stems > 3.5 inches (8.9 cm) diameter at breast height (DBH) in one-inch classes, rounded to the nearest whole inch (Fig. 3 note 12). The largest class was > 12″ (>31.8 cm) DBH. The most common merchantable and near-merchantable size classes (7–10″ DBH) were recorded in two columns each (Fig. 3 note 12), based on the two most common standard log-lengths for each size class. In the data-books, the column sub-headings (Fig. 3 note 12) refer to predicted log volume in hoppus-superfeet, an old English Imperial measure

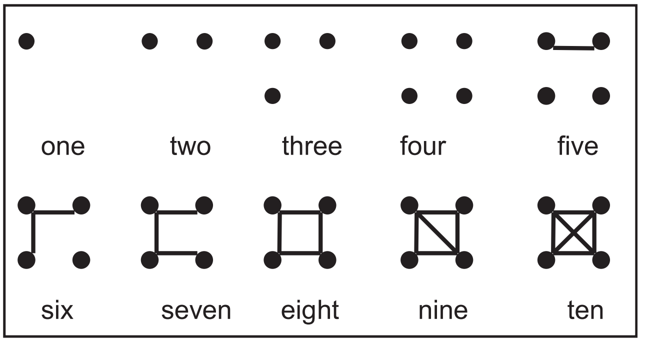


Fig. 4. Dot-tally system used in data books (FCNSW, 1915). See Fig. 3 (notes 9 and 21) for examples of use.

of log volume (100 hoppus-superfeet = 0.305 m^3; Dargavel 2002). Minimum small-end diameter for logs was 5″ (12.7 cm) over bark, and log length was estimated to the nearest 5 feet. For example, the most common recorded heights of 10-inch logs were 25 and 30 feet, corresponding to 66 and 81 hoppus super-feet (0.20 and 0.25 m^3), respectively (Lindsay 1946) (Fig. 3 note 12).

Lindsay's (1946) formal instructions were updated numerous times as methods evolved, and consequently page entries often vary slightly. Some pages include column headings for both size-class and volume-class, while others only show the volume headings (as for *E. crebra* in Fig. 3, note 13). Second, log volumes larger or smaller than the two most common standard lengths were usually recorded in Arabic numerals rather than using the dot-tally system. For example, the entry '111' under the 11″ DBH size class (Fig. 3 note 6) refers to one tree with a log volume of 111 hoppus-superfeet (and length 35 feet), not 3 trees or 111 trees. The marking 'C' indicates a 'cull' tree – one deemed too crooked or branched to be useful as a timber tree (Fig. 3 note 7), while 'D' (Fig. 3 note 8) signifies a dying tree that is not expected to survive to grow into the next size class.

Eucalyptus crebra

Stems of *E. crebra* larger than 4.5″ were tallied in four DBH classes (Fig. 3 note 13), rounded to the nearest whole inch: 5–9″ (11.4–24.0 cm), 10–16″ (24.1–41.8 cm), 17–20″ (41.9–52.1 cm) and 20″+ (>52.1 cm). Within each DBH class, *E. crebra* stems were generally described in terms of whether or not railway sleepers or poles could be cut from them, and were recorded in one of six tree-form categories (Table 1). Foresters always used the tree-form category headings when recording *E. crebra* stems, but did not always include size-class headings (e.g. Fig. 3 note 13). However, size class can be inferred from the order of the category headings; for example size class 10–16″ almost invariably begins with 'No. vol', and 'cull' is usually the last category listed per size class (Fig. 3 note 20).

Slight variations on this system were used with greater detail on better-quality sites. In particular, letters of the alphabet were occasionally used to denote individual trees of particular forms on better sites (Table 2).

Small stems

Surveyors in the 1940s did not tally *C. glaucophylla* stems < 3.5″ (8.9 cm) or *E. crebra* < 4.5″ (11.4 cm) DBH individually, but instead recorded the number of 1/40th acre (100 m^2) units that were 'effectively stocked' within a 5-chain (1 acre, 0.404 ha) tally section. (Such regeneration stocking assessments were not done elsewhere in cypress forests in NSW due to a lack of regeneration at that time.) Stems of other species < 4.5″ DBH were not recorded at all. Surveyors further classified each stocked unit in one of three classes (A, B or C; Fig. 3 notes 1, 5) according to the predominant size of small stems. For *C. glaucophylla*, these diameter classes were: A: < 2.5 cm; B: 2.6–< 5.1 cm; C: 5.1–<8.9 cm; while for *E. crebra* they were: A: < 3.8 cm; B: 3.8–<7.6 cm; C: 5.1–<11.4 cm.

The definition of 'effectively stocked' related to a 1/40th acre (100 m^2) unit having greater than a minimum acceptable stand density. This subjective decision was left to the discretion of forest assessors, although Lindsay (1946) advised that, 'in thinned stands, 12–16-foot spacing is classified as stocked'. This spacing corresponds with a minimum density of 420–748 stems/ha, or 4–7 stems in a stocked unit. However, there was no estimate of maximum density, as foresters were only interested in the distinction between 'enough' and 'not enough' small stems.

Stocked units of small stems were not recorded at all sites in the 1940s, and it was often unclear whether the lack of a recorded number of stocked units represented 'no small stems' or 'not recorded' (as in Fig. 3). At some sites, only a qualitative estimate of the abundance of small stems was available (S, M, D, for sparse, medium, dense). Sometimes both the number of stocked units and a qualitative estimate of the density of small stems were recorded, but there was no consistent correlation between them.

Forest type classification

A standardised forest type classification was developed in the 1940s for use in *Eucalyptus–Callitris* forests across NSW (Lindsay 1967). This system is still in use (Baur 1988; Resource and Conservation Assessment Council 2002). Each tree species was represented by a 1–2 letter code (Table 3), and

Table 1. Column headings for ironbark size- and merchantability-classes, as used in the 1940s data-books

Category	Applicable size-classes	Recorded using	Description
Crop	5–9″ class only	Dot-tally	A tree of good form expected to survive to produce at least one railway sleeper.
No. volume (No. vol.)	6–10″ class only	Dot-tally	Similar to 'crop' – a stem of good form not yet of merchantable size, expected to eventually produce at least one railway sleeper. Distinction is based on the fact that some other stems in this size-class were already of merchantable size 14″ DBH (35.6 cm) (Lindsay 1948).
Sleeper (Slp)	All except 5–9″ class	Estimated number of sleepers/tree	All trees potentially containing at least two railway sleepers, e.g. a tree estimated to contain 3 railway sleepers is recorded as '3'.
Pole	All classes	Length of pole	'Solid trees with a minimum of 20 feet of straight length to 8″ top diameter under bark' (Lindsay 1946, p10). An especially well-formed tree too valuable to be cut for railway sleepers, e.g. tree recorded as '20' would produce a 20-foot (6 m) pole.
Special (Spec)	Larger classes only	Length of pole or 'p' for pole	An especially large, straight tree suitable for special uses including large poles or girders. 'Special' trees were sound (solid) and greater than 20 feet (6 m) in length.
Cull	All classes	Dot-tally	Trees too crooked or too hollow to produce railway sleepers, or small suppressed stems unlikely to survive to produce sleepers. Due to be culled from the stand to free up growing space.

Table 2. Letter codes sometimes entered in Ironbark columns in 1940s data-books, for which Lindsay (1946) provides an explanation

Code	Description
d	Dying and not likely to reach next size class (but is not crooked)
c	Crooked (< 1 sleeper length of straight timber) (e.g. Fig. 3 note 15)
t	Tub (tree too hollow for sleeper cutting)
p	Pole tree – especially straight, solid tree suitable for special uses (e.g. Fig. 3 note 16)
s	Short log – only one sleeper-length of straight timber, not two lengths as preferred
g	Girder tree: tall, straight tree of > 20″ DBH

each forest type was represented by a combination of codes, ordered by the relative basal area of the dominant species. Thus, forest type PCO (Fig. 2 note 7, Fig. 3 note 11) was dominated by *C. glaucophylla* (P), *E. crebra* (C) and *Allocasuarina luehmannii* (R. Baker) L. Johnson (O), in order of decreasing basal area. However, since *C. glaucophylla* is a very slender tree (and therefore its basal area was low relative to its commercial importance), it was listed first wherever it was dense enough to be managed as a commercial stand. A commercial stand was defined as ≥100 stems/ha of *C. glaucophylla* of 4″ inches (10 cm) DBH or larger, or an equivalent basal area of smaller stems (Lindsay 1967; Baur 1988).

Table 3. Letter codes used to represent tree and shrub species in 1940s vegetation typing system (after Lindsay 1967)

Letter code[A]	Scientific name[B]	Common name[C]
A	***A**ngophora floribunda*	Rough-barked apple
B	*Eucalyptus **b**lakelyi* s.l. (including *E. chloroclada*)[D]	Blakely's red gum (Baradine red gum)
Be	*Casuarina cristata*	**Be**lah
Bp	*Callitris endlicheri*	**B**lack **p**ine, black Cypress pine
Br, Broom	*Melaleuca uncinata*	**Br**oom
Brig	*Acacia harpophylla*	**Brig**alow
C	*Eucalyptus **c**rebra*	Narrow-leaved red ironbark
CC	None	**C**ut and **c**leared
Cn	*Eucalyptus **co**n**i**ca*	Fuzzy box, fussy box
D	*Eucalyptus **d**ealbata*	Tumbledown red gum
Dp	*Callitris preissii* ssp *verrucosa*	**D**esert **p**ine, Mallee pine
Dw	*Eucalyptus **dw**yeri*	**Dw**yer's red gum
H	*Eucalyptus albens* (closely resembles *E. moluccana* syn. *E. **h**emiphloia*)	White box
I	*Eucalyptus **i**ntertexta*	Gum coolibah
L	*Angophora costata* (syn. *A. **l**anceolata*)	Smooth-barked apple
Me	*Eucalyptus **me**lanophloia*	Silver-leaf ironbark, silver-leaved ironbark
My	*Acacia pendula*	**My**all
N	*Eucalyptus fibrosa* (syn. *E. **n**ubilis*)	Broad-leaved ironbark
Nd	*Hakea leucoptera* and *H. tephrosperma*	**N**ee**d**lewood
O	*Allocasuarina luehmannii*	Forest **o**ak, buloke
P	*Callitris glaucophylla*	White Cypress **p**ine, Cypress pine
PP	*Callitris glaucophylla*	White Cypress pine only (**p**ure **p**ine)
Pf	*Eucalyptus populnea* ssp. *bimbil* (syn. *E. **p**opuli**f**olia*)	Bimble box, poplar box
Pg	*Eucalyptus **p**illi**g**aensis*	Pilliga box
Sd (or S)	*Eucalyptus **s**i**d**eroxylon*	Mugga ironbark
T	*Corymbia **t**rachyphloia*	White bloodwood
Kurr	*Brachychiton populneus* ssp. *populneus*	**Kurr**ajong
Mall	*Eucalyptus* spp.	**Mall**ee eucalypts
Wattle	*Acacia* spp. (various)	**Wattle**
Heath	Various, especially *Epacridaceae*	**Heath**land
JUNGLE	Probably dense regeneration of tall *Acacia* spp. e.g. *A. cheelii*	Motherumbah, various
SCRUB	Unknown	Unknown, various
UNTYPED	None	Not surveyed
NOT SF	None	Not State Forest

[A]Underlined, bold letters indicate the derivation of the letter code.
[B]Taxonomy follows Harden (1991; 2000); synonyms included here were in use when vegetation typing system was developed.
[C]The first-listed common names are generally those used by Lindsay (1967). More recent names are taken from Harden (1991; 2000) and Brooker and Kleinig (1990).
[D]*E. chloroclada* was first described as a variety of *E. dealbata* in 1965, well after these surveys were completed (Blakely 1965). Both *E. chloroclada* and *E. blakelyi* s.s. are found in the Pilliga (Beckers and Binns 2000). 'B' for *E. blakelyi* was used to describe a combination of species in the Pilliga that now includes *E. blakelyi, E. camaldulensis*, *E. chloroclada* and intergrades of these.

Analyses

To illustrate the value of the 1940s Lindsay survey dataset for studies of long-term vegetation changes, we used it to estimate tree species composition, density, basal area and size-class structure for dominant tree species at the Kuhner's Camp study site in Pilliga East SF (Fig. 1). Data from four adjacent recording units (c. 400 m long) were used at each study site (Fig. 2 note 6, Fig. 3 note 18). Site data were then aggregated and converted to per hectare values. Basal area was calculated using the midpoint diameter of each DBH class, with 13″ (33 cm) being arbitrarily used for the largest (12″+) size class for *C. glaucophylla* and 22″ (55.9 cm) for the largest (20″+) class for eucalypt species. Only stems large enough to be tallied individually were included in this calculation: i.e. stems >8.9 cm DBH for *C. glaucophylla* and > 11.4 cm DBH for *E. crebra* and other species.

For small stems, Lindsay's (1946) guideline that 'in thinned stands, 12–16 foot spacing is classified as stocked' (see above) was used to calculate a minimum density of small stems. This spacing corresponds with a density of 420–748 stems/ha. To provide a crude estimate of the minimum density of small stems, we multiplied the proportion of units classed as 'effectively stocked' by 420 and 748 stems/ha. Since it was often unclear whether a lack of a recorded number of stocked units represented 'no small stems' or 'not recorded' we avoided the possibility of false negatives by calculating the number of small stems only when the number of 'effectively stocked' units was recorded at least once on the same data-book page.

Results

The 1940s survey provides valuable data on stem density, basal area, tree species and size-class composition. The Kuhner's Camp site was classified as containing PCO forest type, and the survey data show that species composition conformed closely to expectations based on Lindsay's (1967) description of that forest type. Thus, three tree species were recorded, *C. glaucophylla* (P), *E. crebra* (C) and *A. luehmannii* (O), and *C. glaucophylla* was 3–4 times as numerous as *E. crebra* or *A. luehmannii* (Fig. 5*a*). The site carried 124 *C. glaucophylla* stems/ha > 4 inches DBH – more than meeting the minimum specification of 100 stems/ha > 4″ DBH for a commercial *C. glaucophylla* stand and a forest type code beginning with 'P' for 'pine' (Lindsay 1967). However, *E. crebra* had the highest basal area, indicating that stems were much larger on average than *C. glaucophylla* (Fig. 5*b*). *Allocasuarina luehmannii* was similar in abundance to *E. crebra*, but had lower basal area than the other two species, confirming its place as the last-named species in the PCO code. Size class histograms show that most *C. glaucophylla* stems were <19 cm DBH, and most *E. crebra* stems were <42 cm DBH (Fig. 6). All *A. luehmannii* stems were < 42 cm DBH and most were <24 cm DBH. The *C. glaucophylla* size-class histogram drops off sharply at 19 cm DBH (Fig. 6*a*), the size at which they could be cut for timber. Similarly, the size-class distribution for *E. crebra* peaks in the 24.1–41.8 cm DBH size class and then drops off in the 41.9–52.0 cm DBH class. Some parts of this compartment were harvested for *C. glaucophylla* sawlogs in 1941 and 1946 while *E. crebra* poles, girders and sleepers were harvested in 1931 (Forests NSW, unpubl. data). This may explain the observed size distribution.

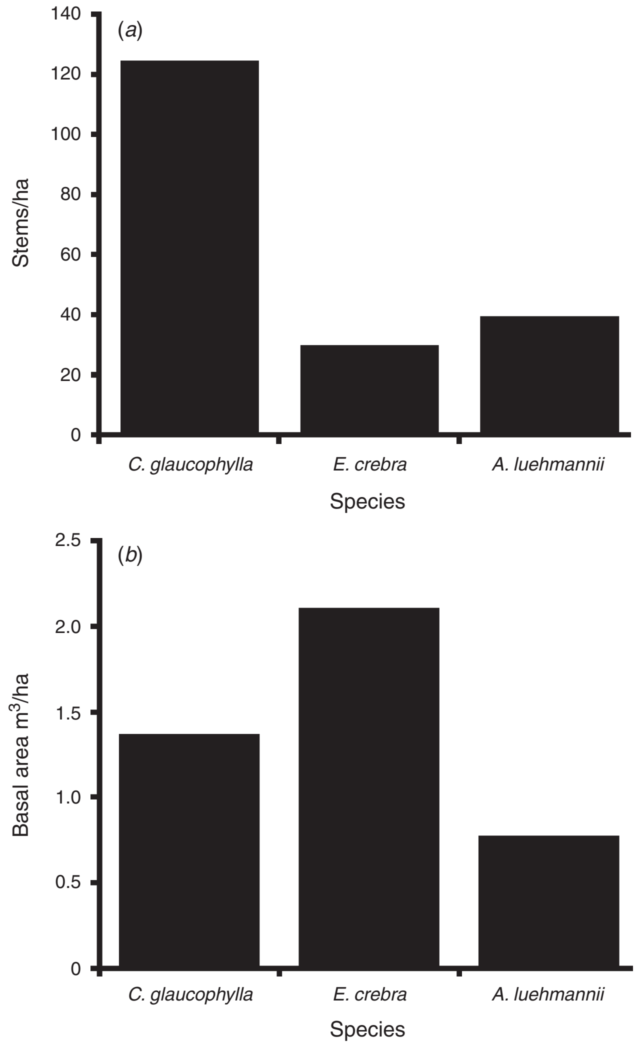


Fig. 5. (*a*) Stem density and (*b*) basal area of the three species (*C. glaucophylla*, *E. crebra* and *A. luehmannii*) at the Kuhner's Camp study site shown in Figs 3, 4.

The data-book provides additional detail on larger stems. For example, all *C. glaucophylla* stems > 10″ DBH at the study site were recorded as dying (D) (Fig. 3 note 8). Additionally, the density of large hollow-bearing eucalypts can be estimated from the number of 'cull' eucalypts large enough to support hollows. 'Cull' trees were those trees too hollow, crooked, branched or suppressed to produce sleepers or poles. In nearby Goonoo State Forest, the number of *Eucalyptus sideroxylon* A. Cunn. ex Woolls trees containing hollows increases dramatically above 40 cm DBH, and large hollows were found only in trees >47 cm DBH (Shelly 1998). This relationship holds strongly for all ironbark and box species in the Pilliga (Forests NSW, unpubl. data, from 21 144 trees > 10 cm DBH). It corresponds closely with the two largest size-classes of eucalypts recorded in the data-books. Within the 1.62 ha Kuhner's Camp study site, four of five *E. crebra* trees in the

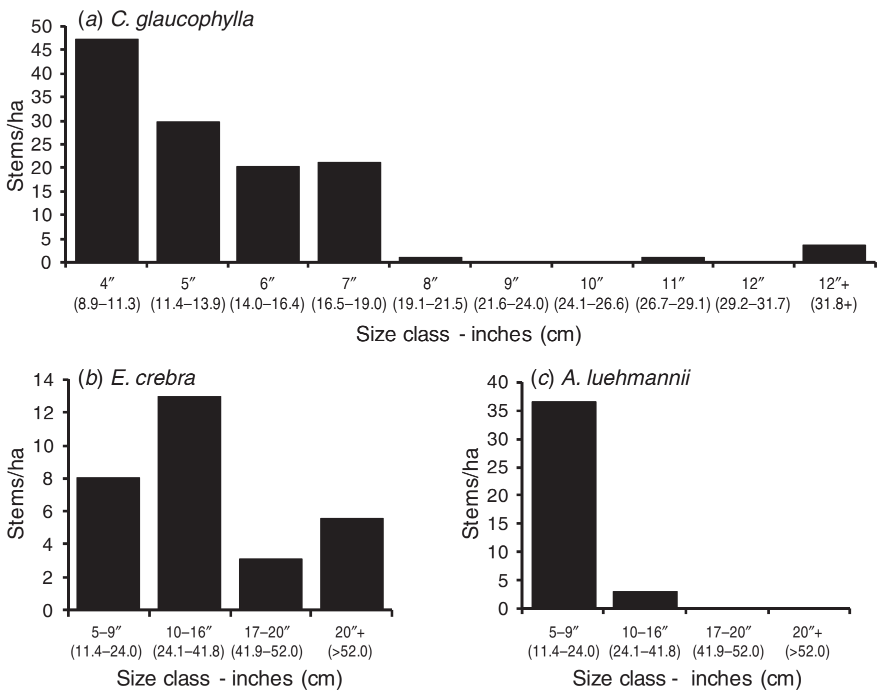


Fig. 6. Size class distribution of the three species at the Kuhner's Camp study site shown in Figs 3, 4.

17–20 inch-class (41.9–52 cm) and five of nine trees in the 20 + inch-class (> 52 cm) were described as 'cull' trees. Therefore nine (5.6 stems/ha) of 14 trees (8.7 stems/ha) large enough to potentially contain tree-hollows were designated as 'cull' trees; these trees are likely to have contained the most hollows. This is very close to the density of hollow trees recorded across the Pilliga during the Western Regional Assessment in 2000 (5.9 stems/ha: Forests NSW, unpubl. data).

There was no record of small stems of *C. glaucophylla* (<8.9 cm DBH) or *E. crebra* (< 11.4 cm DBH) at the Kuhner's Camp study site. This might mean that there were no such stems, that none were recorded, or that the stems present were not dense enough to comprise an 'effectively stocked' unit. Figure 7 provides an example from an area in Cubbo State Forest where many small *C. glaucophylla* stems were recorded. Regeneration entries were scattered down the page, which represents a 2.4-km survey strip. The four highlighted sections contained four 'effectively stocked' units, two stocked with stems 1–2″ (2.5–5.0 cm) in diameter, and two with stems 2.0–3.5″ (5.1–8.8 cm) in diameter. The minimum density of small stems in the four units was 6–8 stems/ha for each of the two size classes (total 12–16 stems/ha).

Discussion

The 1940s surveys provide a vast resource for assessing vegetation changes in many forests dominated by *Eucalyptus* and *Callitris* species (and perhaps other forest types) in NSW, and the methods described here allow future ecologists and foresters to exploit this resource. The data enable species composition, stem density, basal area, and size-class distributions to be calculated for trees > ~10 cm DBH, and provide crude information on the density of smaller *C. glaucophylla* and *E. crebra*. This detailed information is not available from any other data source. Other characteristics of the site and individual trees can also be deduced, such as merchantability and recent stand history. Elsewhere we have used this information to assess the effects of past timber harvesting and fires on current stand structure (Whipp 2009).

While merchantability characteristics were originally recorded in the Pilliga to allow foresters to estimate the volume of timber available for different product types, characteristics associated with non-merchantability also allow information about important habitat elements to be deduced. For example, large eucalypts are more likely to contain tree-hollows, a key resource for many animals including owls, parrots and arboreal mammals (Shelly 1998; Gibbons and Lindenmayer 2002). Ironbark and box eucalypts > 40 cm DBH contain considerably more hollows than smaller trees in both the Pilliga and the nearby Goonoo State Forest (Shelly 1998; Forests NSW, unpubl. data). Unmerchantable large stems recorded in the Pilliga in the 1940s are likely to have contained abundant large hollows.

The Pilliga is a particularly useful forest for which to have historical reference data of this kind. Increasing woody vegetation density in the area has long been controversial, especially following Rolls' (1981) claim that the Pilliga was predominantly a 'man-made' regrowth forest (see Norris *et al.* 1991; Benson and Redpath 1997; 1998; Flannery 1998; Rolls 2000; Jurskis 2000; Bowman 2001). More recent debates have focused on the sustainability of timber harvesting (Date *et al.* 2000; 2002; Western Conservation Alliance 2002; Owen 2004;

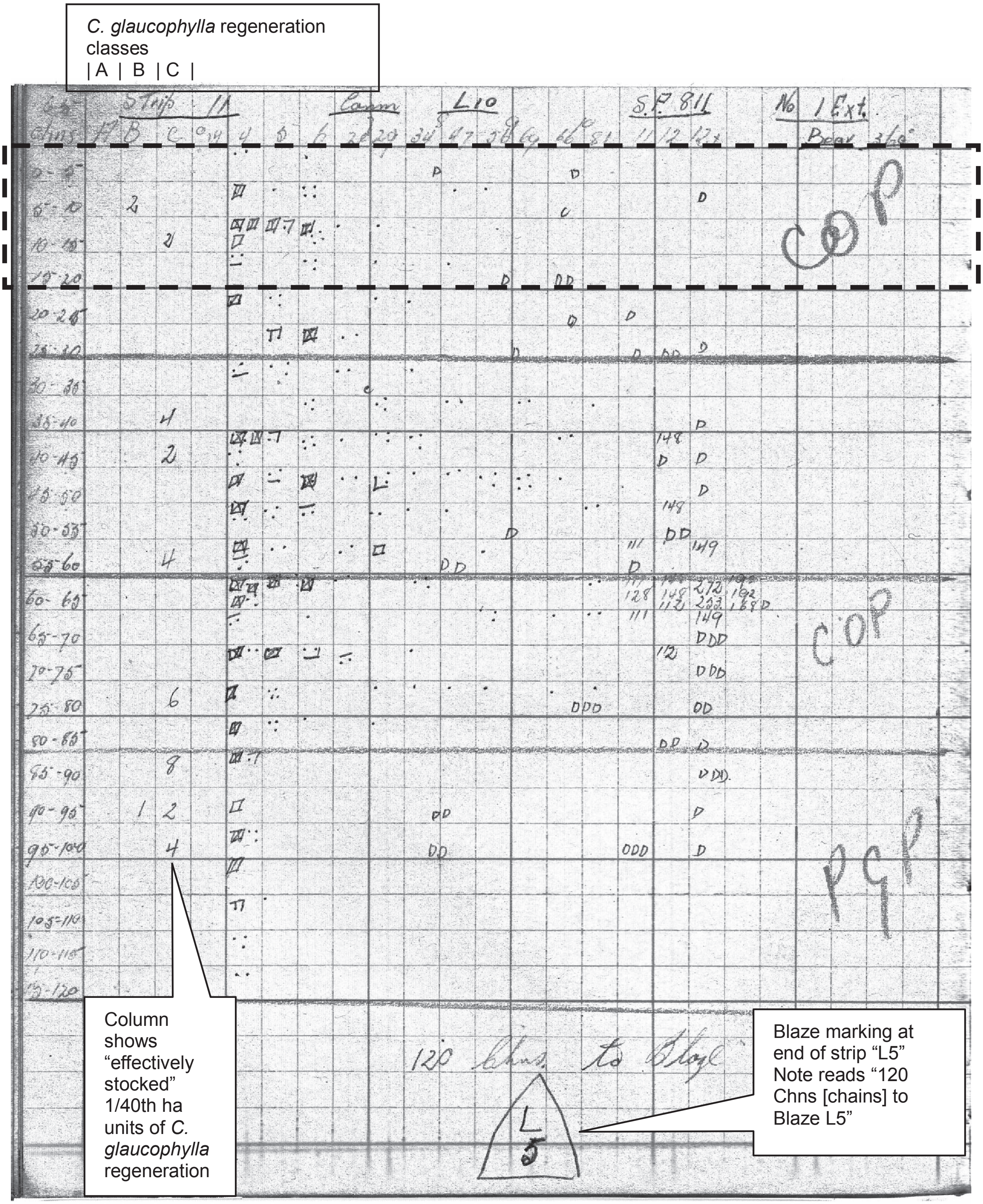


Fig. 7. A sample data page from Cubbo State Forest where small *C. glaucophylla* stems were recorded. Study site is indicated by dashed rectangle. Numbers in regeneration classes indicate the number of 1/40th acre-units (equivalent to 10×10 m squares) which were ‘effectively stocked’ with regeneration. Column headings ‘A, B, C’ indicate different size-classes of regeneration (see explanation in text). At the bottom of the page the assessor has drawn a diagram of a blazed tree (marking “L5”) and noted that there were a total of “120 Chains to Blaze L5” (i.e. survey strip was ~2.4 km in length).

Colless 2005; Marohasy 2005). Archival survey data, combined with information on subsequent disturbances and management activities, enable the relative effects of natural disturbances and human management on current forest structure to be quantified. For example, using the methods outlined in this paper, Whipp (2009) found that the density of stems < ~10 cm DBH increased 3-fold in the Pilliga forests between the 1940s and 2005. However, when this increase was analysed in the context of historical harvesting information, the direct effects of timber harvesting during that period contributed little to that change.

Table 4. Availability of strip survey data for other *Eucalyptus–Callitris* State Forests in NSW

Management area	Forest name	1917–19 assessment		Lindsay survey 1948–50			
		Summary report	Strip map	Summary report	Strip map	Field data book	Forest type map
Condobolin	Euglo South					**X**	**X**
Condobolin	Murda	**X**		**X**			
Condobolin	Taratta			**X**			
Condobolin	Nerang Cowal	**X (1930)**		**X**			**X**
Condobolin	Weelah	**X (1931)**	**X**	**X**			**X**
Forbes	Back Creek			**X (1954)**			**X**
Forbes	Back Yamma	**X**		**X**		**X**	**X**
Forbes	Barbingal			**X**		**X**	
Forbes	Bimbi	**X**		**X**		**X**	
Forbes	Blow Clear West			**X**		**X**	**X**
Forbes	Bogalong	**X (1931)**		**X**	inferred		
Forbes	Caragabal			**X**			**X**
Forbes	Carawandool	**X (1930)**		**X**		**X**	**X**
Forbes	Carraboblin					**X**	
Forbes	East Cookeys Plains	**X**		**X**		**X**	**X**
Forbes	Edols	**X (1930)**		**X**			
Forbes	Eurabba	**X**		**X**		**X**	**X**
Forbes	Gunning Gap					**X**	
Forbes	Gunningbland	**X**		**X**		**X**	**X**
Forbes	Lakeview			**X**			
Forbes	Limestone			**X**			
Forbes	Little Caragabal	**X**		**X**			
Forbes	Mandamah	**X (1931)**	**X**	**X**			
Forbes	Maudry	**X**	**X**	**X**			
Forbes	Monumea Gap	**X**		**X**		**X**	
Forbes	Mulyandry	**X**		**X**		**X**	**X**
Forbes	Priddle			**X**		**X**	
Forbes	Pullabooka	**X**		**X**		**X**	**X**
Forbes	Therabung			**X**			
Forbes	Tomanbil	**X**	**X**	**X**		**X**	**X**
Forbes	Ungarie			**X**			
Forbes	Warraderry	**X**		**X**		**X**	**X**
Forbes	Warregal	**X (1930)**		**X**		**X**	**X**
Forbes	Weddin	**X**		**X**		**X**	
Forbes	West Cookeys Plains					**X**	**X**
Forbes	Wilbertroy	**X**		**X**		**X**	**X**
Forbes	Wyrra			**X (1954)**			
Gilgandra	Bidden					**X**	**X**
Griffith	Binya			**X**			
Narrandera	Ardlethan	**X**					
Narrandera	Banandra			**X**			
Narrandera	Boona			**X**			
Narrandera	Bretts			**X**			
Narrandera	Bunganbil			**X**			
Narrandera	Ganmain	**X**		**X**			
Narrandera	Gillenbah			**X**			
Narrandera	Kockibitoo			**X**			
Narrandera	Kulki			**X**			
Narrandera	Lester			**X**			
Narrandera	Matong			**X**			
Narrandera	Mejum			**X**			
Narrandera	Ugobit			**X**			

Others have used similar survey information to assess species composition, stand density and size composition change in response to fire and timber management in Canada, Sweden and the USA (Axelsson *et al*. 2002; Andersson and Östlund 2004; Etheridge *et al*. 2006; Lorimer 2008). In Canada, historical forest survey results have also been used to help calculate a carbon budget for the conversion from old-growth to managed forests (Trofymow *et al*. 2008).

Availability and utility of data from other forests

Table 4 lists various data books and support materials for various cypress forests outside the Pilliga forests. The list of Lindsay data-books in Table 4 is the full list of those still known to exist; however, the list of summary reports and maps is not exhaustive and more remain to be identified. Data books for the Narrandera, Griffith, Dubbo, Gilgandra and Gulargambone Management Areas are believed to be lost. No search for data-books and support documents has yet been made for the Inverell and Gunnedah Management Areas.

If data-books exist then strip locations can usually be deduced even if the strip map is lost, provided the forest type map exists, and sometimes even if it is missing. If data books have been lost then re-sampling specific sites is not possible, but the summary reports list stocking and basal area by species and forest type. This enables broad comparisons of historical changes in vegetation structure at the stand and compartment scale.

Summary reports can also be used to re-create Lindsay forest type maps in areas where the types are relatively simple; for example, cypress areas in central and southern NSW. Such a project was started for forests of the Narrandera and Griffith Management Areas but has not been completed. Early summary reports (~1900 to 1930) for most of the forests of NSW are listed in FCNSW (1957).

Despite their potential value, historical forest inventory data are not formally archived in Australia. Thus it is impossible to determine how much information exists for forest types other than *Eucalyptus–Callitris* forests, either in NSW or in other states. Given that strip surveys were a standard survey technique for 40–50 years in Australia (Dargavel and Kowald 2001), data may well survive from other forest types. Strip survey techniques were also used in Canada, the USA, Sweden and India, (D'Arcy 1898; Frayer and Furnival 1999; Dargavel and Kowald 2001; Andersson and Östlund 2004; Etheridge *et al*. 2005) and possibly in other countries as well. While some forest inventory survey data have already been used to assess historical vegetation change in Scandinavia and North America, more resources may still await discovery. We encourage forest managers, historians and ecologists to uncover these resources.

In the meantime, the archival value of the 1920s and 1940s data-books, maps, reports and aerial photograph mosaics from the Pilliga and other forests in central NSW cannot be overstated. We implore data custodians to lodge such items in secure, curated institutions such as Australia's State and National Libraries.

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