The importance of seasonality in the timing of flora surveys in the South and Central Western Slopes of New South Wales

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Abstract: Semi-permanent quadrats, located in the South and Central Western Slopes botanical regions of New South Wales, were assessed to indicate suitable periods of the year to conduct surveys of botanical diversity. The quadrats were located in woodland communities with a generally herbaceous understorey, and subject to a wide range of domestic stock grazing intensities. In the mid to western South Western Slopes (SWS) the greatest number of species was generally recorded in an October survey. The main exception was in degraded areas (low species diversity, high proportion of annual weed species), where similar results were recorded in September and October. In the cooler and wetter eastern SWS a relatively high proportion of species were recorded in October to early December surveys. However, when compared to species totals compiled from multiple assessments in all seasons, or from August to November, a single optimal survey usually recorded only 60–75% of the plant species at a site. Surveys in mid to late summer, autumn and early winter usually recorded less than 50% of the plant species present. The results reflect the prevailing Mediterranean-type climate, and that the ground layer vegetation (primarily comprised of annuals and herbaceous perennials) dominates the species diversity.

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Introduction

Vegetation and flora surveys to assess plant species diversity can involve many variables, including whether to use quadrats or random searches, expertise of personnel, plot size, number of plots, time of survey and preceding weather conditions (Kirby et al. 1986, Scott & Hallam 2002, Barnett & Stohlgren 2003, Kercher et al. 2003, Kéry & Gregg 2003). When and how often to sample often depend on personnel availability, budget constraints and an appreciation of the seasonality of the flora under investigation (Ristau et al. 2001, Tremblay & Larocque 2001). Understanding the seasonality of vegetation is important both when designing effective sampling schemes, and when interpreting the diversity reported in previous assessments. The South Western Slopes (SWS) botanical region of New South Wales (NSW) experiences a Mediterranean-type climate (cool, moist winters and hot, dry summers). At Wagga Wagga (average annual rainfall 583 mm), average monthly precipitation is relatively constant through the year, but there is a high degree of variability on a monthly basis, especially from December to May, as indicated by the differences between mean and median rainfall and a variability index (Table 1). Only in June and July does average precipitation exceed evaporation, while in December, January and February average evaporation is at least 6 times the average rainfall (Table 1). A similar pattern has been recorded for much of the SWS (Moore 1953).

The distinct seasonal differences in the ratio of rainfall to evaporation are reflected in the proportion of growth forms in the vegetation. Moore (1953), in an assessment of the South Eastern Riverina, found the life-form spectrum was dominated by cryptophytes and hemicryptophytes (usually herbaceous perennials) and therophytes (annuals). Burrows (1999) found that, of 658 taxa recorded in areas of remnant vegetation in the SWS, 31% were annuals or biennials, 45% perennial herbs and 24% trees or shrubs. Trees and shrubs may be recognised in any season, although identification to species level may be difficult without flowers and/or fruits. In contrast herbaceous species (annuals and herbaceous perennials) may not be recognisable for extended periods of the year. During summer the annuals are present as seeds and the majority of the herbaceous perennials are present, primarily as below-ground bulbs, corms and other specialised rootstocks. Only a few herbaceous perennials remain in leaf over summer e.g. *Lomandra* and *Dianella* species. Almost all of the rare or threatened species recorded for the SWS are perennial herbs or annuals (Burrows 1998).

Methods for conducting vegetation surveys have been extensively developed (Ristau et al. 2001, Barnett & Stohlgren 2003). For example, the NSW National Parks & Wildlife Service (now part of the NSW Department of Environment & Conservation) provide detailed survey forms, to be used on a state-wide basis. However, no guidelines or stipulations are specified as to the timing of surveys. It is possible that surveys might be conducted at less than optimal times of the year for reasons such as a lack of appreciation of species' growth patterns, to purposely avoid finding vulnerable or endangered species, or to expend funds by the end of the financial year. The author and other environmental consultants in the region are disturbed by the continuing requests for surveys from mid summer to mid winter. The aim of compiling this seasonality data is to suggest suitable

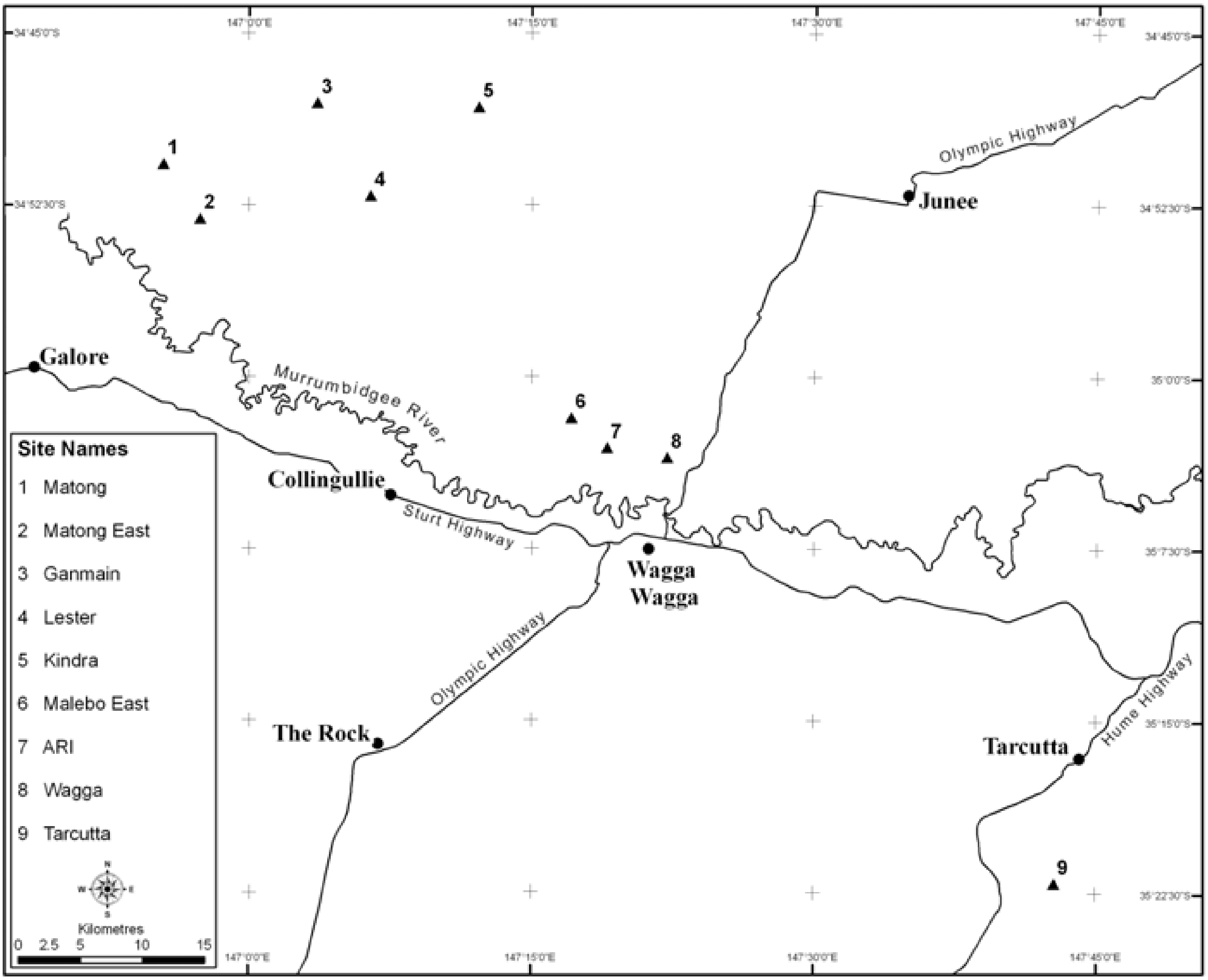

Fig. 1. The location of the nine study sites in the SWS botanical region.

sampling times and, perhaps even more importantly, to quantify what percentage of the flora might be missed at sub-optimal times.

Materials and methods

Data for this assessment of seasonality was from four separate surveys conducted between 1996 and 2005. Three were in the SWS botanical region and one was in the CWS botanical region of NSW. All four were in the NSW South Western Slopes (IBRA) biogeographical region. Figure 1 shows the location of the SWS botanical region study sites. Species were recorded as present on the basis of vegetative, reproductive or dead material. Each quadrat was assessed 'blind' i.e. without reference to previous survey records, and the same assessor was involved in the assessment of each quadrat, and for all the species identifications. For the 2001–2003 assessments a species' developmental stage was also recorded (vegetative, flower buds present, flowering, fruiting, dead). Average annual rainfall varies from c. 450 mm around Matong to 800–850 mm in the Tarcutta Hills region (Fig. 1). Various monthly climatic averages for Wagga Wagga and Wyalong are given in Table 1.

White Cypress Pine woodlands

During 1996, seven sites, 10–50 km NW of Wagga Wagga with a *Callitris glaucophylla* overstorey, were assessed (Fig. 1). These sites had three levels of domestic stock grazing intensity: low (Kindra State Forest [SF] and Ganmain SF), moderate (Lester SF and Matong SF, and a private property on the eastern side of Malebo Range) and high (a property on the eastern border of Matong SF, and a paddock managed by the NSW Agricultural Research Institute [ARI] at Wagga Wagga). At each site 15 randomly located 10 × 10 m semi-permanent quadrats were established; each quadrat was assessed 4 times, at roughly monthly intervals (August, September, October, November). Rainfall for Wagga Wagga was average or above average for June, July, August, September and November 1996 and 69% of average in October.

Table 1. Average monthly rainfall (mm), median rainfall (mm), rainfall variability (decile 9 minus decile 1 then divided by decile 5) and average monthly evaporation (mm) figures for Wagga Wagga 1941–2002 and Wyalong Post Office 1895–2001.

	J	F	M	A	M	J	J	A	S	O	N	D	Total
Wagga Wagga													
Average rainfall	41	40	43	44	54	50	56	53	51	62	44	45	583
Median rainfall	31	26	26	29	41	47	55	55	48	51	35	34	
Rainfall variability	2.7	3.4	4.2	2.7	2.8	1.7	1.4	1.5	1.5	2.0	2.2	2.6	
Average evaporation	307	255	211	117	62	36	37	59	84	146	210	295	1819
West Wyalong													
Average rainfall	45	36	38	37	41	42	42	40	37	47	37	43	485
Median rainfall	28	21	23	27	32	36	39	41	30	38	31	31	
Rainfall variability	3.8	4.3	4.3	3.0	2.9	1.8	1.7	1.3	2.3	2.3	2.4	3.3	

Lake Cowal

On the edge of Lake Cowal, c. 35 km NW of West Wyalong in the CWS, forty-one 10 × 10 m quadrats were established within a 3 × 5 km site on private property during 1997. Seven quadrats were located on the treeless, seasonally inundated, lake bed, while the remainder were in cleared paddocks or open woodland (remnant overstorey species of *Acacia pendula*, *Casuarina cristata*, *Callitris glaucophylla*, *Eucalyptus camaldulensis*, *Eucalyptus dwyeri*, *Eucalyptus populnea* and *Geijera parviflora*). All areas were grazed by domestic stock, with intensity ranging from moderate to high. The quadrats were assessed on September 23/24 and again three and half weeks later on October 18/19. At the first survey the surface soil was moist and the gilgai depressions were almost full of water, while by the second survey the upper soil layers were dry and the smaller gilgais empty. At the Wyalong Post Office c. 60 mm of rainfall was recorded in 6 rain days in the three weeks before the first survey, while 21 mm of rain was recorded on one rain day between the surveys. Rainfall for West Wyalong was average or above average in May, June and August 1997 and 55% of average in July.

Charles Sturt University (Wagga Wagga Campus)

During 2001, five 10 × 10 m quadrats were established in a straight line, with 10 m between each quadrat, on a lightly grazed paddock with a *Eucalyptus melliodora* overstorey on the Wagga Wagga campus of CSU. The quadrats were assessed 18 times between July 2001 and November 2002, and twice in October 2003. The 2002 growth period (April–October) was the sixth driest since records began in 1898 (Anon. 2003). Monthly rainfall data for the main study period is given in Figure 3.

Tarcutta Hills Reserve

During 2003 six 10 × 10 m quadrats were established in the Australian Bush Heritage Fund's Tarcutta Hills Reserve. Three quadrats were on ridges with an overstorey of *Eucalyptus macrorhyncha*, *Eucalyptus rossii* and *Eucalyptus sideroxylon* and three quadrats were in the intervening gully areas with an overstorey of *Eucalyptus goniocalyx*, *Eucalyptus macrorhyncha* and *Eucalyptus polyanthemos*. The quadrats were surveyed at roughly monthly intervals from November 2003 to January 2005. Monthly rainfall data for the study period is given in Figure 4.

Combining all the surveys the study is based on 670 assessments of 157 quadrats. The number of plant species in each quadrat at each assessment was counted. The total number of plant species recorded in a quadrat was determined for the full period for which assessments were made. For each assessment the percentage of species recorded, in relation to the total number of species found in that quadrat over all assessments, was calculated. As most quadrats at a site produced a similar seasonal trend (e.g. Fig. 2) data was averaged across quadrats at a site (Table 4, Figs 3, 4).

Results

Growth form

The proportion of growth forms (annual/biennial, herbaceous perennial, shrub, tree) was calculated for the plant species recorded at each of the study sites (Table 2). At all sites shrubs and trees constituted fewer than 8% of the species recorded, except at Ganmain and Tarcutta Hills, where they constituted between 12 and 17% (Table 2). The annuals/biennials and perennial herbs made up, on average, 53% and 40% of the recorded species respectively (Table 2). Most of the annuals (average 69%) were introduced species, and almost all of the perennial herbs (average 90%) were native (Table 2). Almost all annuals were dead and undetectable by early to mid summer (e.g. see Fig. 5). The majority of the herbaceous perennials had mesophytic leaves and the plants died back to underground bulbs, corms, tubers and other rootstocks during late spring to early summer. Thus, given the high proportion of annuals and herbaceous perennials in the surveyed floras, the mesophytic leaf types of these species and Mediterranean-type climate, it could be expected that a high percentage of species would not be recordable during summer and autumn.

Seasonality

The 1996 and 2001/2002 studies in the mid to western SWS assessments in October recorded the highest number and percentages of species (Tables 3, 4, Fig. 3); however in the more heavily grazed sites (Matong E and ARI), the total number of species was low, a high proportion of these

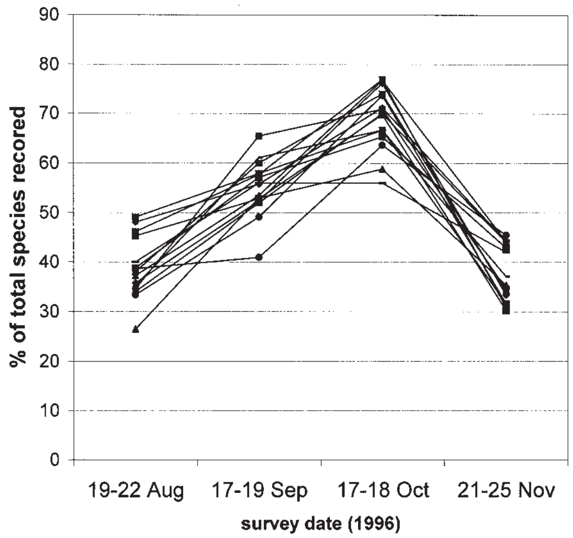

Fig. 2. The percentage of total species recorded over 4 months in 1996, in each of 15, 10 × 10 m quadrats, at Lester State Forest. The figure indicates the percentage of the quadrat total recorded at each assessment for each of the 15 quadrats.

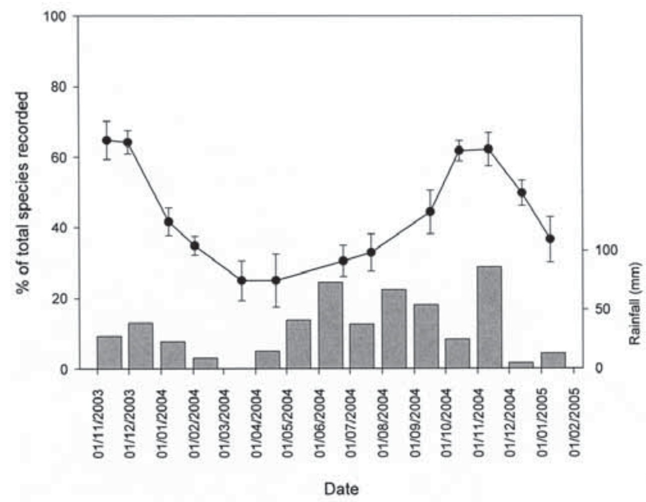

Fig. 4. The percentage of total species recorded over 15 months in 2003–2005, averaged over 6, 10 × 10 m quadrats, at Tarcutta Hills Reserve. The figure indicates the percentage of the mean quadrat total (95% CI) recorded at each sampling period. The monthly rainfall data is for Wagga Wagga.

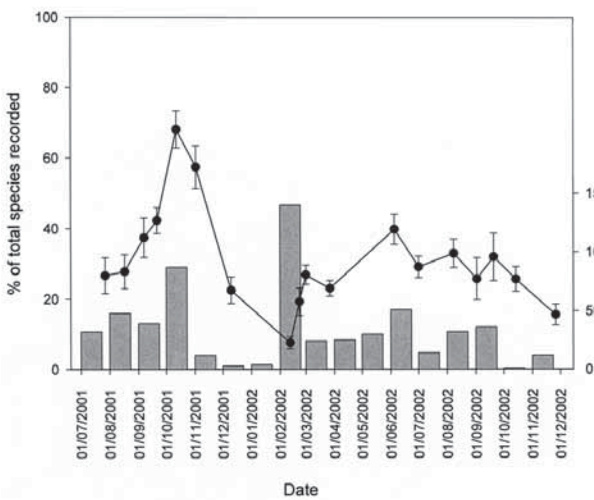

Fig. 3. The percentage of total species recorded over 17 months in 2001 and 2002, averaged over 5, 10 × 10 m quadrats, at Charles Sturt University. The figure indicates the percentage of the mean quadrat total (95% CI) recorded at each sampling period. The monthly rainfall data is for Wagga Wagga.

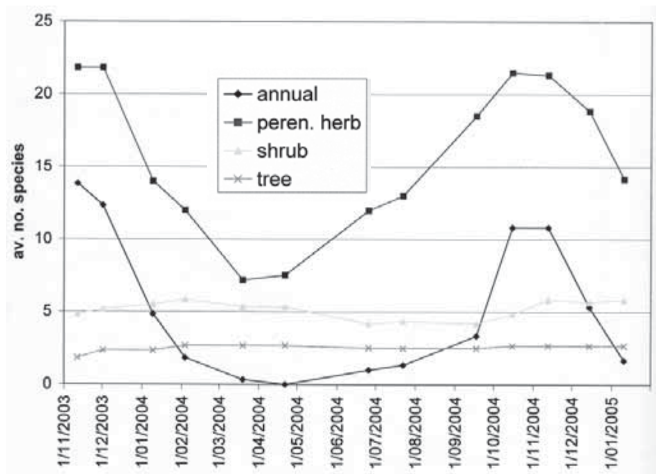

Fig. 5. Average numbers of annuals, perennial herbs, shrubs and trees for 6, 10 × 10 m quadrats at the Tarcutta Hills Reserve study site over a period of 15 months.

species were introduced (Tables 2,5), and species composition remained relatively stable from August to October (Tables 3,4). At the cooler and wetter Tarcutta Hills there was a more extended period (October to early December) when a high proportion of species were recorded (Fig. 4). The 1996 study, based on surveys in August, September, October and November, found that October assessments recorded the highest number and proportion of species, but if only a single survey was conducted in this period then only about 65–75% of the total species present at a site would have been recorded (Table 4). Likewise, in the CSU and Tarcutta Hills studies optimally timed surveys only recorded 60–70% of the species present (Figs 3,4). In the 2001–2002 study, for July to September 2001 and the 7 months from December 2001 to June 2002 less than 50% of the total species were recorded (Fig. 3). In the 2003/2005 study less than 50% of recorded species were detected from January to September (Fig. 4).

The seasonality of the various growth forms was examined for the Tarcutta Hills site (Fig. 5). The shrubs and trees were consistently recorded throughout the year. The annuals displayed a distinct seasonal trend and were recorded in very low numbers during late summer and a very dry autumn. The herbaceous perennials showed a similar yearly trend to the annuals, but only dropped to about 33% of their late spring numbers. In late autumn and winter it appeared that the herbaceous perennials resprouted earlier than the annuals began to germinate (Fig. 5). Given that the annuals were largely (68%) weeds and the herbaceous perennials were largely (93%) native (Table 2) there would be no great difference in optimal survey time if exotics or weeds were being specifically targeted.

The drought conditions of 2002 meant that a peak in species recordings did not occur in October at the CSU study site (Fig. 3). In 2003, after several months of above average or close to average rainfall (except for September), the site was surveyed again in early and mid October. Results were similar to October 2001 with 68% and 81% of total species recorded.

The Lake Cowal survey was based on two assessments in 1997 of 41 quadrats. The September and October assessments recorded, on average, 20 and 25 species respectively (Table 3). When the recordings of these two assessments were combined an average of 31 species per quadrat was found (Table 5), or expressed another way, on average, the first assessment missed 11 species per quadrat that were found in the second assessment and the second missed 6 species found in the first. This illustrates the advantages of multiple assessments and the rapid change in the detection of some species as the growing season progresses.

Relative species diversity

A wide range in the average number of species per quadrat (23–66) was recorded at the various sites (Table 5). An even wider range (6–50) was recorded for the average number of native species recorded per quadrat at the various sites (Table 5). Several sites had an average of over 50 species per quadrat and 15 quadrats had over 60 species. A relatively high species diversity was recorded in most quadrats when assessed several times between August and November or over a full year (Table 5), even though there was often lower apparent species diversity in these quadrats between December to June/July (Figs 3,4).

Table 2. Growth form information for the study sites.

A: percentages of various growth forms (annuals/biennials, herbaceous perennials, shrubs, trees). **B:** the percentage of native species for the growth form.

Site	Annual/ biennial		Herbaceous perennial		Shrub		Tree	
	A	B	A	B	A	B	A	B
Kindra	47	36	48	94	4	100	1	100
Ganmain	41	43	47	90	11	92	1	100
Lester	56	31	39	92	2	100	3	100
Matong	53	36	41	89	4	100	2	100
Malebo E	70	22	28	86	1	100	1	100
Matong E	67	26	27	89	3	100	3	100
ARI	75	18	23	85	2	100	0	–
Lake Cowal	53	43	40	96	5	100	2	100
Wagga 2001–3	42	25	55	88	3	100	0	–
Tarcutta Hills 2003–5	30	32	53	93	13	100	4	100
Average	**53**	**31**	**40**	**90**	**5**	**99**	**2**	**100**

Table 3. Average numbers of plant species for 10 × 10 m quadrats (with Standard Error) recorded at various sites in the SWS and CWS during August to November. The month columns record the average number of species recorded per quadrat at a site for that month.

Site	August	September	October	November
Kindra	28 (1.1)	33 (0.9)	42 (1.1)	21 (1.3)
Ganmain	28 (1.0)	27 (1.1)	32 (1.2)	16 (0.6)
Lester	19 (1.2)	27 (1.3)	34 (1.5)	18 (0.8)
Matong	22 (1.0)	28 (1.1)	35 (1.7)	19 (1.3)
Malebo E	17 (1.6)	20 (1.8)	23 (2.0)	10 (1.1)
Matong E	14 (0.6)	21 (0.9)	22 (1.4)	11 (0.6)
ARI	15 (0.5)	15 (0.5)	15 (0.6)	07 (0.6)
Lake Cowal		20 (1.4)	25 (1.6)	

Table 4. Average percentage of the total plant species recorded in quadrats (with Standard Error) at various sites in the SWS and CWS during August to November. The month averages are based on the number of species recorded in a quadrat at an assessment in relation to the total number of species recorded for that quadrat.

Site	August	September	October	November
Kindra	51 (1.4)	60 (2.1)	77 (1.3)	39 (1.8)
Ganmain	64 (1.6)	61 (1.0)	72 (1.3)	37 (1.6)
Lester	39 (1.6)	55 (1.5)	69 (1.6)	37 (1.5)
Matong	43 (2.2)	54 (1.6)	67 (2.4)	36 (1.6)
Malebo E	53 (2.3)	63 (2.4)	70 (2.2)	30 (2.8)
Matong E	44 (1.7)	65 (1.9)	66 (2.3)	35 (1.8)
ARI	65 (2.4)	68 (1.8)	64 (2.4)	32 (2.9)
Lake Cowal		64 (1.8)	81 (1.3)	

Table 5. Average numbers and ranges of overall and native species diversity at the survey sites. (Averages followed by Standard Error).

Site	Av. no. spp./quad	Range: no. spp./quad	Av. no. native spp./quad	Range: no. native spp./quad
Kindra	55 (1.5)	43–67	39 (1.5)	25–46
Ganmain	44 (1.5)	34–55	36 (1.4)	27–43
Lester	50 (1.6)	34–57	28 (2.1)	14–45
Matong	52 (2.2)	35–66	32 (1.5)	20–40
Malebo E	33 (2.8)	11–52	12 (1.3)	2–22
Matong E	33 (1.4)	24–44	15 (0.8)	11–20
ARI	23 (1.0)	16–29	6 (0.6)	3–10
Lake Cowal	31 (2.0)	9–56	16 (1.4)	1–34
Wagga 2001–3	37 (1.6)	34–41	23 (1.3)	20–27
Tarcutta Hills	66 (2.3)	59–71	50 (1.1)	48–54

Discussion

Few, if any, guidelines are available regarding optimal vegetation sampling times in south eastern Australia. Groves (1965), working in a *Themeda* grassland 15 km west of Melbourne (annual rainfall c. 520 mm), recorded flowering patterns of 101 species (37 introduced) on a monthly basis from October 1962 to January 1964. Groves recorded a distinct peak in flowering in October for introduced species and October/November for native species. Of the studied species, approximately 83% and 70% were recorded as flowering in October and November respectively, while in all other months less than 35% of species were in flower. Assuming that Groves' flowering records are equivalent to the presence/absence records of the present study, then the results of the two studies are very similar.

For the years 1949–1953 Williams (1961) made monthly notes on the vegetative and reproductive status of about 60 species in an ungrazed *Danthonia caespitosa* grassland, near Deniliquin (c. 220 km W of Wagga Wagga, average annual rainfall c. 400 mm). His results show that almost all species with a single bloom period per year flowered in September or October. The results also indicate that many species show a distinct variability in the timing and length of flowering, both year to year and within a year. This indicates that it is difficult to stipulate a single optimal time of sampling.

Morgan (1999), working in grasslands in 'western Victoria', described the regeneration of perennial species after annual summer fires. In a similar pattern to the present study his results show a peak in species richness in October, followed by a rapid decline as plants died back to their protected basal buds.

The site assessments and overall experimental design used in this study were not specifically aimed to determine an optimal sampling time in the SWS; however a wide diversity of quadrats were subject to multiple sampling, all quadrats were of equal size, and the same assessor was involved in all sampling and species identifications. Some limitations of the study are: (i) the different sites were surveyed in different years and thus different climatic conditions, (ii) not all surveys extended across a full year and different numbers of assessments were carried out at the various sites, (iii) sampling was not always at equal intervals, (iv) some surveying was conducted in drought conditions, and (v) quadrat layout differed from random to linear transect.

Some useful observations for woodland vegetation in the SWS can be made: (i) mid to late spring is probably the best time to survey to record the greatest number of plant species, (ii) there are several months of the year (December or January to July or August) where a single assessment will probably record less than 50% of the species at the site, (iii) a single assessment, even at the optimal time of year, will only record about 60–75% of the species at a site, and (iv) multiple assessments through time are needed to record a higher percentage of the plant species diversity.

While surveys conducted in mid to late spring to early summer have given the highest recordings of plant species richness, the timing of a survey within this broad period will probably be influenced by factors such as: (i) whether the survey is conducted in early, mid or late in this period, (ii) the preceding weather conditions, especially rainfall, (iii) the location of the site, east to west, within the SWS, and (iv) the vegetation at the site. Rainfall is probably the most important variable influencing plant diversity recordings in the SWS. Rainfall in the SWS is highly variable on a yearly and monthly basis (Anon. 2003, Table 1). Any recommended or stipulated optimal time for a single diversity assessment should be implemented with an appreciation of the interaction between rainfall and detection of species diversity. The results of flora surveys in the SWS should be accompanied by rainfall data for at least the previous 2 to 3 months for the site or the surrounding area and an indication of how this compares to the long-term average. This information will allow an informed assessment of plant diversity survey data. The unusually wet and cool conditions of February 2002 led to an increase in the number of species recorded (Fig. 3), while below average rainfall during the 2002 growth period led to a much reduced number of species recordings (Fig. 3). These findings would be difficult to interpret without rainfall data. Austin et al. (1981), in a study extending from 1949 to 1968 and based at Deniliquin (c. 220 km west of Wagga Wagga), showed that differences in seasonal climatic conditions have an important bearing on vegetation dynamics between years, as well as within a year.

Autumn surveys, commissioned by both private companies and government agencies, are relatively common in the SWS (pers. ob.). This may be related to stable, moderate weather conditions, a lack of appreciation of growth patterns, and/or the requirement to use allocated funding by the end of the financial year. If such studies are considered essential, then their limitations should be clearly expressed. Goodfellow and Peterken (1981), working in British woodlands, employed correction factors. They increased the number of species recorded by 10% for each of the following: (i) woodland visited once only and no previous records available, or (ii) woodland assessed outside the main growth period. Similar correction factors are unlikely to be useful in the SWS owing to the high rainfall variability, especially during summer and autumn (Table 1).

Trémont (1995) noted that native forbs make a major contribution to species richness in temperate grassy communities and provided phenological information for six native forbs (3 annual, 3 perennial) over a 17 month period. Her study showed distinct seasonal differences in processes such as vegetative growth, flowering and senescence between these species. These differences then influence whether a species would be recorded at various times of the year.

Twenty two rare or threatened plant species are listed for the SWS (Burrows 1998). Of these 4 (18%) are annuals, 16 (73%) perennial herbs and 2 (9%) shrubs. Thus about 90% of the plant species for which there are specific legislative responsibilities will probably only be recordable during mid to late-spring and/or early summer in years with near average or above average rainfall throughout the growing season. Flora surveys for environmental impact assessments should be conducted in mid to late spring, both for recording maximum diversity and optimising the likelihood of recording rare or threatened species. Surveys for threatened species should target those seasons (and years) where the species is likely to be observable above ground.

The results of this study indicate that surveys in mid to late spring will record the highest percentage of the plant species present at a site in the SWS of NSW. A single, optimally-timed survey, conducted after near- or above-average rainfall in the two or three months preceding the survey, will record about 65–75% of the species present. For much of summer, autumn and early winter a single survey or even multiple surveys will record less than 50% of the species present.

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