A survey of *Senecio madagascariensis* Poir. (fireweed) density in pastures of coastal New South Wales

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Summary

A survey of *Senecio madagascariensis* Poir. (fireweed) density in coastal New South Wales was undertaken to quantify infestations observed in previous surveys. Fields of pasture were selected at random within Local Government Areas from four coastal regions, and fireweed density rated on a scale of 7 to 0 (high to low). Associated pasture and grazing species were also recorded. Fireweed densities were found to be unevenly distributed in New South Wales, the major centres of infestation concentrated on the Far North Coast, the Lower North Coast and Hunter Valley, Western Sydney, and the Upper South Coast. Conversely low densities were found on the Mid North Coast, the Upper Hunter, and the South Coast. Significant relationships were found between fireweed density and pasture/grazing species, however, these factors overall explained less than half of the variation observed. Results are compared with previous surveys and discussed in relation to continuing spread, factors which influence density, and economic impacts on grazing industries.

Introduction

In a survey of farmers from coastal New South Wales, 43% of dairy and pastoral producers considered *Senecio madagascariensis* Poir. (fireweed) their worst weed (Sindel and Michael 1988). An introduced species from southern Africa (Michael 1981), it has spread exponentially from the first recorded locality at Raymond Terrace (New South Wales Herbarium, Specimen No. 55556) to occupy most of the New South Wales coastal plains and parts of south-east Queensland (Sindel and Michael 1992a). Fireweed is toxic to cattle and horses causing fatalities and poor growth if ingested (Walker and Kirkland 1981, Kirkland *et al.* 1982, Watson *et al.* 1984), and is highly visible when flowering, leading to the perception that it competes with pasture and discourages stock from grazing amongst it (Sindel and Michael 1988). Fireweed has been estimated to cost the dairy industry alone in the order of $A10 million per annum in lost animal production and control expenses (Cousens personal communication).

No quantitative data are available on fireweed density in New South Wales. Two previous surveys of fireweed infestation were undertaken but these were qualitative, asking farmers and district weed inspectors for their assessments of its importance/significance (Dellow personal communication, Sindel and Michael 1988). Data are not available on densities of fireweed plants within pastures of New South Wales, frequency of infested pastures and area covered by infestations. Data are also lacking on relationships between fireweed density and pasture and grazing species associated with an infestation.

A survey of fireweed density was undertaken as part of an impact assessment for the proposed biological control of fireweed. The aims of the survey were:

i. to make direct comparisons between the severity of fireweed infestations in different parts of New South Wales using a standard density scale,
ii. to provide a semi-quantitative base from which to estimate economic losses through competition with pastures, and
iii. to provide data on pasture species associated with infestations.

Results will be compared with those of previous surveys to provide information on the stability of fireweed populations, and the continuing spread of this weed.

Methods

Sampling strategy

Sampling during this survey was based on New South Wales coastal Local Government Areas (LGAs), as in a previous survey of fireweed infestation (Watson *et al.* 1984, Dellow personal communication). LGAs were grouped into four regions to break the survey into stages, each taking up to one week to complete. Regions were:

- the North Coast (NC) which included 16 LGAs from Greater Taree to the Queensland border,
- the South Coast (SC) with 7 LGAs from the Victorian border to Wollongong and Wingecarrabee,
- the Hunter Valley (HV) including 14 LGAs extending from Gosford to Gloucester and inland to Singleton, and
- Western Sydney (WS) including Wollondilly, Penrith and Hawkesbury.

The survey route was travelled by car. Paddocks within LGAs were sampled at regular distances along pre-determined routes. Roads were chosen to allow representative samples of the maximum area of each LGA to be taken. Intervals between surveyed paddocks were 10 km for the NC region, 7 km for the SC, and 5 km for the HV and WS. These intervals were arbitrarily chosen to allow 20 paddocks to be sampled in each LGA. Only paddocks used for grazing were sampled. In the event that no paddock occurred at the chosen sampling interval, the next suitable paddock was assessed. Main roads and forested areas in each region (National Parks and State Forests) were avoided if alternate routes were available.

The survey was conducted by the same two workers throughout to reduce the likelihood of variation in estimates of density between regions and LGAs.

Field assessments

The density of fireweed plants was estimated in each paddock sampled by using a standardized scale of 7 to 0 (high to low). Grades of fireweed density were: 7 (fireweed plants <0.5 m apart), 6 (0.5–1 m), 5 (1–2 m), 4 (2–5 m), 3 (5–2 0 m), 2 (>20 m), 1 (occasional plants), and 0 (no fireweed). Scores were based on the average distance between the main stems of individual fireweed plants. Visual density assessments were made from one location at the edge of each paddock where plants could be clearly seen (i.e. up to 100 m in). Ground truthing of density estimations with 1 m quadrats was done during a trial, but not for the main survey.

The most common pasture species in each paddock sampled were recorded. Type of grazing animal was also identified by presence in paddocks, or by the type of manure present.

Notes were made of fireweed plants seen outside surveyed paddocks in otherwise 'clean' areas.

Timing of survey

The survey was conducted during four weeks from 14 September to 16 October 1992. Fireweed was flowering and highly visible throughout New South Wales in this period allowing consistent estimations of density between regions and LGAs.

Data analysis

A map of mean densities for coastal LGAs was produced to highlight regions of different intensities of fireweed infestation. Maps were produced using the MAP-INFO mapping package, and LGA boundaries reproduced with C-DATA 91 (Census data 1991) supplied courtesy of the Land Information Centre, Bathurst.

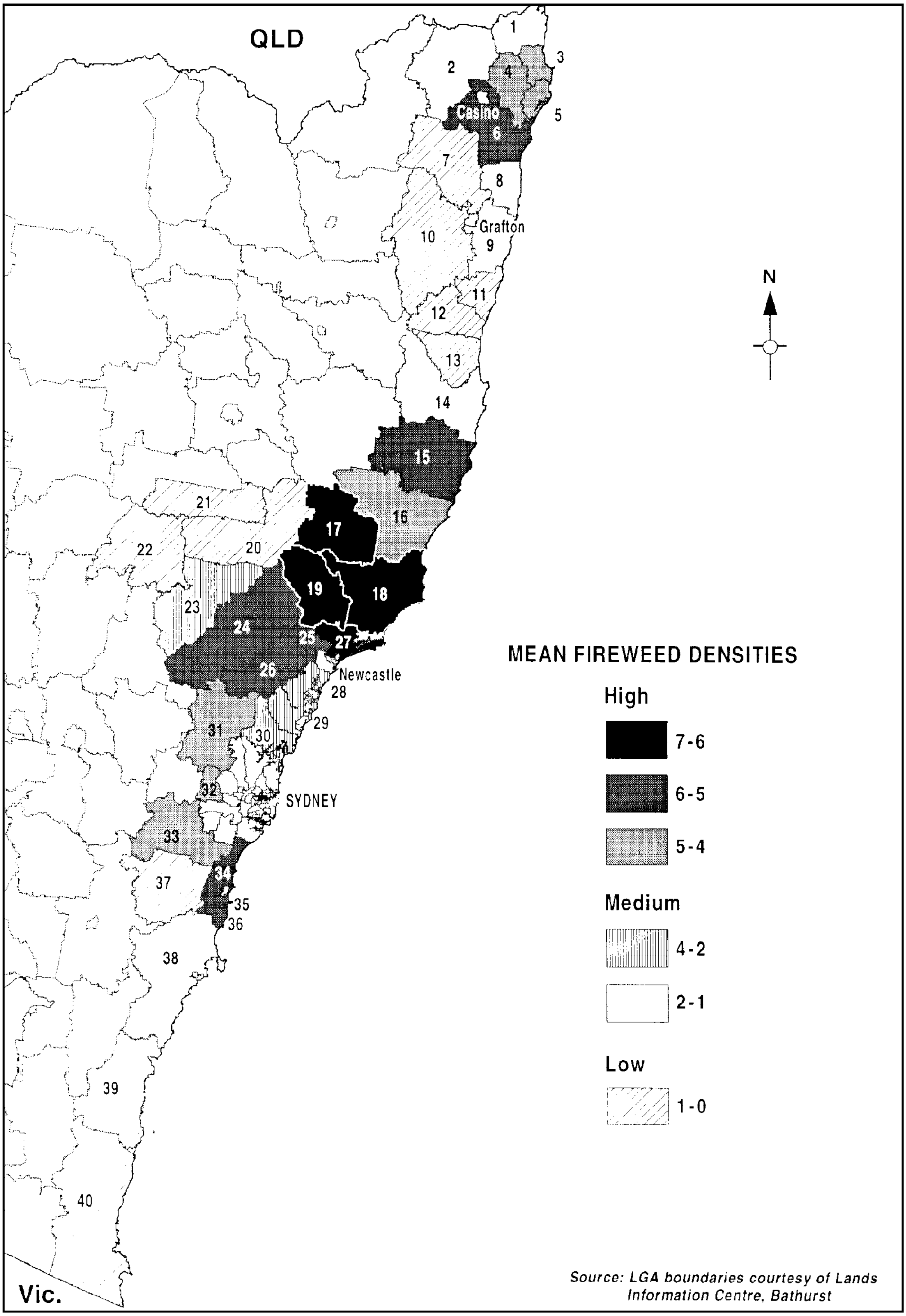

Figure 1. Mean fireweed densities in LGAs on the New South Wales Coastal Plains and adjoining Tablelands and Western Slopes. Density is indicated by shading as shown on the legend. The LGAs represented by the numbers shown on the map are: for the North Coast Region, 1. Tweed Heads, 2. Kyogle, 3. Byron, 4. Lismore, 5. Ballina, 6. Richmond River, 7. Copmanhurst, 8. Maclean, 9. Ulmarra, 10. Nymboida, 11. Coffs Harbour, 12. Bellingen, 13. Nambucca, 14. Kempsey, 15. Hastings, 16. Greater Taree; for the Hunter Valley, 17. Gloucester, 18. Great Lakes, 19. Dungog, 20. Scone, 21. Murrurundi, 22. Merriwa, 23. Muswellbrook, 24. Singleton, 25. Maitland, 26. Cessnock, 27. Port Stephens, 28. Lake Macquarie, 29. Wyong, 30. Gosford; for Western Sydney, 31. Hawkesbury, 32. Penrith, 33. Wollondilly; and for the South Coast, 34. Wollongong, 35. Shell Harbour, 36. Kiama, 37. Wingecarrabee, 38. Shoalhaven, 39. Eurobodalla, and 40. Bega Valley.

New South Wales pasture statistics (ABS Agstats 1991–1992) were used to calculate the percentages of coastal pasture, and percentages of cattle, horses, and sheep represented by fireweed densities.

Chi-squared analysis was used to test for significant relationships between density of fireweed and occurrence of common pasture species and grazing animals. Paddock data were pooled into three density categories for this analysis; high (7–5), medium/low (4–1) and zero fireweed (0). Pooled data were used because the small numbers of paddocks with densities from 4 to 1 would have reduced the effectiveness of chi squared tests.

Stepwise regressions were used to calculate the percentage of variation in fireweed density explained by pasture species and grazing animals, and to identify correlations between them. Regressions were performed for the total survey data set, and separately for each of the survey regions. Only species which accounted for 2% or greater of observed variation are included in the results.

Results

Fireweed density

All fireweed densities were represented during this survey. Of a total of 520 paddocks surveyed 16% had a density of 7, 17% had 6, 11% had 5, 6% had 4, 5% had 3, 2% had 2, 5% had 1, and 37% had 0.

Mean LGA densities in New South Wales are mapped in Figure 1. Mean densities ranged from 7 to 0 highlighting large differences in fireweed abundance among LGAs. Geographic patterns in distribution of high and low density LGAs can clearly be seen.

Mean fireweed density was high (7–4) in LGAs on the Far NC (Richmond River, Lismore, Ballina and Byron), on the Lower NC south of Hastings, in the Lower HV inland to Singleton, in WS, and on the northern SC (Wollongong, Shell Harbour and Kiama). More than 50% of paddocks in these areas had fireweed density of 6 or 7 (Figure 2a).

Medium mean densities (4–1), were found on various parts of the Far and Mid NC (Tweed Heads, Kyogle, Maclean, Ulmarra and Kempsey), in the Upper HV and Central Coast (Musswellbrook, Lake Macquarie, Wyong and Gosford), and the SC (Shoalhaven). These LGAs were characterized by a mixture of high, medium and low density paddocks (Figure 2b).

Low mean densities of fireweed (1-0) were found on the Mid NC (Nambucca, Bellingen, Coffs Harbour, Nymboida and Copmanhurst), in the Upper HV (Merriwa, Murrurundi and Scone), and most of the SC (Bega Valley, Eurobodalla and Wingecarrabee). Greater than 90% of paddocks in these LGAs had zero fireweed (Figure 2c). The LGAs of Murrurundi and Eurobodalla recorded zero fireweed in all paddocks surveyed, however fireweed plants were noted elsewhere in both.

Pasture and livestock abundance

Percentage of pasture area and livestock in high, medium and low density areas are shown in Table 1 (New South Wales pasture statistics, ABS Agstats 1991–1992). One third the area of pasture, and a third of cattle and horses occurred in LGAs of high fireweed density. Approximately one sixth of pasture, cattle, and horses occurred in areas of medium density. About 50% of pasture and 40% of cattle and horses occurred in regions of low fireweed density. Over 90% of sheep from coastal regions of New South Wales occurred in areas of low fireweed density.

Co-existing pasture species and grazing animals

A total of 69 pasture and weed species were identified as common components of pasture in surveyed paddocks. Of these, 16 species occurred in more than 10 paddocks sampled and have been included in further analyses. Kikuyu (*Pennisetum clandestinum* Hochst. ex Chiov) was the most common pasture species and occurred as a major component of pasture in 34% of fields; paspalum (*Paspalum dilatum* Poir.) occurred in 27%; white clover (*Trifolium repens* L.) in 19%; couch grass (*Cynodon dactylon* (L.) Pers.) in 13%; blady grass (*Imperata cylindrica* P. Beauv.) in 9%; speargrass (*Stipa* spp.) in 7%; ryegrass (*Lolium* spp.) in 6%; phalaris (*Phalaris aquatica* L.), bracken (*Pteridium* spp.) and native pastures in 5% each; kangaroo grass (*Themeda triandra* Forssk.), tussock grass (*Poa* spp.), parramatta grass (*Sporobolus indicus* (L.) R. Br. var. *capensis* Engl.), and whisky grass (*Andropogon verginicus* L.) in 4%; and barley grass (*Hordeum leporinum* Link) and rushes (*Juncus* spp.) in 3%. The three most common grazing animals were cattle (73%), horses (12%), and sheep/goats (4%). Other grazing animals included deer, camels, and pigs.

Significant relationships between fireweed density (high, medium/low and zero), and pasture species/grazing animal are found in chi-squared analyses in Table 2. Ten pasture species had statistically significant relationships with fireweed density (P≥0.05). There was a significant trend for higher fireweed densities to occur within pastures of kikuyu,

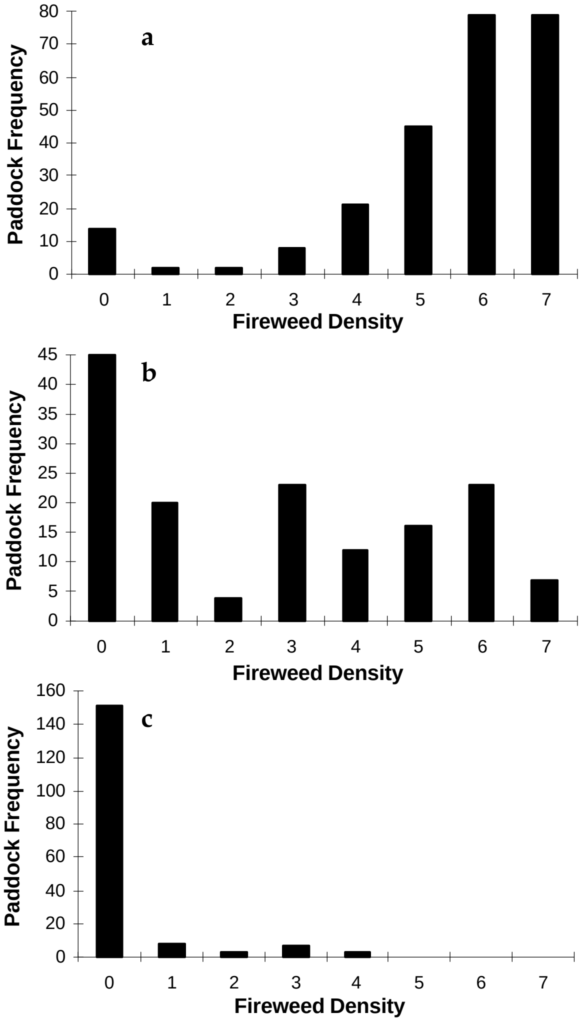

Figure 2. Frequency distribution of paddock fireweed densities in Local Government Areas (LGAs) with (a) high, (b) medium and (c) low mean fireweed density.
(a) High mean density LGAs were: 3. Byron, 4. Lismore, 5. Ballina, 6. Richmond River, 15. Hastings, 16. Greater Taree, 17. Gloucester, 18. Great Lakes, 19. Dungog, 24. Singleton, 25. Maitland, 26. Cessnock, 27. Port Stephens, 31. Hawkesbury, 32. Penrith, 33. Wollondilly, 34. Wollongong, 35. Shell Harbour, and 36. Kiama.
(b) Medium mean density LGAs were: 1. Tweed Heads, 2. Kyole, 8. Maclean, 9. Ulmarra, 14. Kempsey, 23. Muswellbrook, 28. Lake Macquarie, 29. Wyong, 30. Gosford and 38. Shoalhaven.
(c) Low mean density LGAs were: 7. Copmanhurst, 10. Nymboida, 11. Coffs Harbour, 12. Bellingen, 13. Nambucca, 20. Scone, 21. Murrurundi, 22. Merriwa, 37. Wingecarrabee, 39. Eurobodalla, and 40. Bega Valley.

white clover, couch and paspalum. The opposite trend was observed for fireweed found in ryegrass, native species, phalaris, speargrass, barley grass and bracken dominated pasture (i.e. fireweed was usually at low or zero density). No relationship was observed between fireweed density and other pasture species.

Significant relationships were also found between fireweed density and grazing animals (Table 2). Higher fireweed densities occurred in fields where cattle grazed, and lower densities in sheep/goat pasture. No relationship was identified between fireweed density and grazing of horses.

Stepwise regressions show that little of the observed variation in fireweed density was explained by occurrence of a particular pasture and species of grazing animal. Nine species accounted for only 23% of total variation in this survey. The maximum variation explained by a single species was 5% (couch). Results were similar for each survey region analysed separately. Within the NC survey region 15% of variation was explained by five species, a maximum of 4% being explained by the occurrence of bracken. Within the HV region 46% of variation in density was accounted for by five species. Most of this variation was explained by speargrass and barley grass (24% and 10% respectively). In WS a total of 31% of variation was explained by the occurrence of sheep/goats (19%) and ryegrass (12%). Kikuyu explained a total of 6% of variation found on the SC.

Discussion

Patterns of fireweed infestation identified during this survey were similar to those found during previous studies (Watson *et al.* 1984, Sindel and Michael 1988). The Far North Coast, Lower North Coast, Lower Hunter Valley, Western Sydney, and Upper South Coast were areas with the densest and most frequent fireweed infestations during this survey. A survey of district weed inspectors (Watson *et al.* 1984, J. Dellow personal communication) identified the same areas as having heavy to medium infestations in 1984. Again similar regional patterns were identified in a survey of farmers in 1985 (Sindel and Michael 1988). In a survey by Sindel and Michael (1988), more than half the farmers surveyed in Lismore district (Far NC), Taree and Gloucester (Lower NC), Hexham (Lower HV), and Cumberland (WS) believed that they had high to moderate fireweed infestations on their properties, while most farmers in Muswellbrook (Upper HV), Shoalhaven (SC) and Bega (SC) believed that they had little or none. Little change has occurred in fireweed distribution or abundance over the period from 1984 to 1992. This contrasts with the 10 years previous to 1984 which saw fireweed spread from the Hunter Valley and scattered infestations on the North Coast, to occupy most of the New South Wales coastal plains (Watson *et al.* 1984)

The similarity in the results of this and previous surveys indicates that fireweed is stable and persistent in regions once significant populations have become established. Comparisons with J. Dellow's survey (Watson *et al.* 1984) show that some local centres of high fireweed abundance have shifted between LGAs (e.g. Kyogle, Tweed, Copmanhurst and Kemsey) due perhaps to seasonal microclimatic differences between local districts. However the general pattern of distribution of densely infested LGAs in New South Wales remains unchanged. Further, it is likely that any LGA that has previously supported large fireweed populations has the potential to do so again under suitable conditions due to seed banks established in previous periods of abundance. There is little evidence in the results of this survey to indicate that attempts to control fireweed have had significant impacts on abundance on regional scales.

Comparisons with previous surveys indicate that fireweed continues to spread. Fireweed was observed in Coffs Harbour, Bellingen, Nambucca and Murrurundi, all of which had no fireweed in 1984 (Watson *et al.* 1984). With continued spread outside coastal New South Wales (Western Slopes, Tablelands and south-eastern Queensland), and the results of bio-climatic analysis of outlying fireweed localities (Sindel and Michael 1992a), there is little evidence that fireweed has yet reached its potential limits of distribution or abundance.

Areas of presently low density are urgent priorities for control and awareness campaigns. Once established fireweed populations are likely to remain persistent as seen from their stability at high densities. There is potential for significant increases in economic impacts in LGAs identified with low fireweed density, which represent almost half of all cattle and horse production on the New South Wales coast. BIOCLIM analysis indicates that these areas have the potential for fireweed to establish (Sindel and Michael 1992a).

The low percentages of variation in

Table 1. Percentage of pasture, cattle, horses and sheep in classes of mean LGA fireweed density (ABS Agstats, 1991–1992). LGAs within each mean density class are listed in Figure 1. The total area of pasture found in coastal LGAs of New South Wales was 1 417 789 ha, and the total number of cattle, horses, and sheep 1 365 243, 26 820, and 836 869 respectively.

Mean LGA fireweed density	No. of LGAs	Percentage of			
		pasture (%)	cattle (%)	horses (%)	sheep (%)
7–6	4	11.2	10.9	8.0	1.8
6–5	8	12.2	13.4	11.6	0.6
5–4	5	8.1	11.1	12.8	0.1
4–2	4	3.2	4.5	14.3	1.2
2–1	6	13.4	18.8	12.6	0.5
1–0	9	51.9	41.3	40.6	95.5

Table 2. Chi-squared tests for relationships between pasture species and fireweed density. Density categories are high (7–5), medium/low (4–1), and zero (0). The first five species were associated with higher fireweed densities, which can be seen by the greater percentage of paddocks in the high and medium/low densities compared to paddocks with zero fireweed. The remaining seven species were more frequently found with medium/low and zero densities than high fireweed density.

Pasture and grazing species	Percentage (%) paddocks at fireweed density			Statistical significance (P)
	high	medium/low	zero	
Kikuyu	39.2	30.9	28.3	0.050
Paspalum	33.2	28.9	18.3	0.003
White clover	25.0	12.4	13.6	0.003
Couch	21.1	7.2	6.3	0.000
Cattle	76.7	77.3	64.9	0.013
Speargrass	3.0	3.1	14.1	0.000
Ryegrass	3.0	9.3	7.3	0.011
Phalaris	0.9	1.0	11.0	0.000
Native pasture	2.1	9.3	5.7	0.017
Bracken	0.4	3.1	11.0	0.000
Barley grass	0.4	1.0	6.8	0.000
Sheep/goats	0.4	1.0	8.8	0.000

density of fireweed explained by associated species (stepwise regressions), despite significant statistical relationships (chi squared tests), indicate that other factors are also important. Such factors may include control, management, history of fireweed abundance, climate, microclimate, recent weather conditions, soil characteristics etc. It is likely that these factors interact to give different patterns of fireweed density between districts, farms and even paddocks. Data from this study reveals no information on how pasture species are distributed relative to these factors. Comprehensive studies of density, and associated pasture species and environmental factors, targeting specific districts are required to highlight the most important factors controlling fireweed numbers in the field.

In contrast to perceptions of farmers that these species were their best competitive controls for fireweed (Sindel and Michael 1988), improved pastures of kikuyu, paspalum, and white clover were more likely to have higher fireweed densities than other pasture species. This illustrates the importance of factors other than associated species in determining fireweed density. Improved pasture species may only be effective competitors under specific conditions. Factors such as irrigation, heavy grazing, soil fertility, may all influence the competitive performance of pasture species (Sindel 1986, Sindel and Michael 1992b). It seems from our results that in less optimal conditions improved pasture species are likely to encourage increased fireweed infestation, while other species such as ryegrass, speargrass, phalaris, and native pasture species seem to discourage fireweed. Use of improved pastures to control fireweed must therefore be accompanied by appropriate management.

This survey quantifies fireweed abundance and distribution in New South Wales using frequency of densities within LGAs. As such, this data may be used as a basis from which to estimate pasture production loss due to fireweed competition, and therefore economic losses to the grazing industries. Research is required to determine densities of fireweed at which losses in pasture production loss may occur, and the frequency and duration of such losses. Lethal cases of ingestion of fireweed by cattle are documented (Walker and Kirkland 1981, Kirkland *et al.* 1982) but more work is required to determine the rates of production and economic loss due to sub-lethal toxic effects on stock in areas of dense fireweed infestations.

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