Conservation and Society 12(1): 54-64, 2014

Article

Weeds and Wildlife: Perceptions and Practices of Weed Managers

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Abstract

Negative impacts of invasive plants or weeds on biodiversity have been well established yet their role in providing key habitats and resources for wildlife has been little understood. Weed removal thus has the potential to adversely affect wildlife but whether this is considered during weed management is poorly known. To determine the extent of this knowledge, we examined the perceptions of weed managers regarding wildlife and weed management in Victoria, Australia. We surveyed 81 weed managers of varying levels of experience from different types of organisations, including state and local government, community groups and private companies. We found 90% of managers had observed wildlife-weed interactions and that most (70%) adjusted management programmes to accommodate wildlife. Despite this, few (19%) had adopted the recommended practice of combining gradual weed removal with re-vegetation. While management programmes included monitoring of native vegetation, consideration of wildlife monitoring in weed management was rare. This highlights the need for management to better understand and respond to wildlife-weed relationships. If the improvement of wildlife habitat is included in the objectives of weed programmes, as it should be, then wildlife should also be incorporated in project monitoring. This would lead to a greater understanding of the role weeds and their management have in each situation and, ultimately, more informed decision making.

Keywords: weeds, wildlife, weed managers, perceptions, habitat, monitoring

INTRODUCTION

Weeds are unwanted plants that can have detrimental effects on both the economy and environment (Richardson et al. 2000; NRMMC 2006). They invade agricultural, urban and natural systems (Richardson et al. 2000). They have a wide range of ecological effects but best documented are their negative effects on native plants, such as reduction of their abundance, diversity, recruitment, pollination and species survival (Randall 1996; Gibson 2010). Weeds also detrimentally affect wildlife (vertebrates and invertebrates) (Bailey et al. 2001; Fulton and Ford 2001; Jellinek et al. 2004; Valentine et al. 2007), important ecological processes such as fire regimes (Shafroth et al. 2005) and water flows (Griffin et al. 1989), and can also change soil properties (Neira et al. 2007). Worldwide, weeds are considered to be one of the most important threats to biodiversity conservation (Hobbs and Humphries 1995; Rodriguez 2006; Bremner and Park 2007; Funk and Vitousek 2007) and so extensive resources have been allocated to their management (Ewel and Putz 2004; Sinden et al. 2004; Pimentel et al. 2005).

Despite their negative effects, globally, there is growing evidence that weeds benefit wildlife under certain circumstances. Weeds may represent a food source (Lawrie 2002); provide habitat for breeding (Nias 1986), roosting and perching (Fisher and Goldney 1997); and refuge from predators (Brown et al. 1991; Sanderson and Kraehenbuehl 2006). Weeds become particularly important for wildlife when alternative native habitat is limited (Sutter et al. 1995; Graves and Shapiro 2003), especially for threatened species (Date et al. 1996; Sanderson and Kraehenbuehl 2006; Schmidt et al. 2009). For example, in areas of southern Australia, weeds characterise

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	DOI: 10.4103/0972-4923.132131

key habitat of the threatened southern brown bandicoot *Isoodon obesulus obesulus* (Schmidt et al. 2009). It is therefore evident that removal of these weeds could adversely impact the bandicoots (Schmidt et al. 2009), yet weed management is required by law in these areas (Sindel 2000). In California, USA, weeds provide some butterflies with vital resources so that unplanned weed management would result in the disappearance of the butterflies (Graves and Shapiro 2003). Thus, managers face complex decisions as to when and how to manage weeds.

Covering more than 200,000 sq. km, the state of Victoria, Australia, represents a jurisdiction where weeds, such as African boxthorn *Lycium ferocissimum* Miers., are a significant management issue. Expenditure on weed management is among the highest in the continent (CES 2008). The primary objective of managing weeds in the natural environment of Victoria is to maintain or promote indigenous biodiversity (EWWG 2007). Government guidelines developed to monitor biodiversity changes associated with weed invasion (Ainsworth et al. 2008) involve monitoring native vegetation but overlooks the wildlife component. Wildlife is a prominent component of biodiversity and often attains iconic status among the general public (Martin-Lopez et al. 2007). An understanding of how their needs are incorporated in weed management planning and implementation is, therefore, desirable. To assist with this, it is important to consider the types of weeds and methods of management that are undertaken so we can better understand and assess any interactions and impacts involving wildlife.

Practitioner and stakeholder perceptions of weeds and their management are available for parts of Europe, the Mediterranean and Australia (Bardsley and Edwards-Jones 2006; Bremner and Park 2007; King 2007; Garcia-Llorente et al. 2008; Andreu et al. 2009; Reid et al. 2009) but this has not involved the effects of weeds or their management on wildlife. We assess whether weed managers in Victoria consider wildlife during weed management programmes by addressing the following five key questions. 1) Is weed management carried out for biodiversity, social or economic objectives? 2) Is there an awareness of the significance of weeds for wildlife? 3) What are the attitudes towards the idea that weeds potentially provide habitat for wildlife? 4) How is consideration for wildlife incorporated in weed management programmes? 5) Are positive outcomes for wildlife incorporated into weed management objectives and are these outcomes measured when assessing project success?

METHODS

We defined weed managers as organisational representatives who had some substantial role in the management of weeds in Victoria. Those surveyed (n=81 respondents) worked in different regions of Victoria and many had been involved in weed management in multiple regions of the state. Most (72%) had worked on weed management in the Port Phillip and Westernport region that surrounds Melbourne. Weed managers from federal, state, and local governments, community groups, non-government organisations (NGOs), and private companies were targeted with the expectation that they were likely to be guided by the objective of promoting indigenous biodiversity. These groups, therefore, were also expected to have greater experience in management of weeds in the natural environment (environmental weeds). Those who had experience in managing weeds in the agricultural industry (agricultural weeds) were not specifically targeted as biodiversity conservation was not expected to be their primary motivation.

Questionnaires (Appendix) were sent to potential respondents in each group, and the snowball effect used to recruit further participants (Heckathorn 2002; Salganik and Heckathorn 2004; Walker and Brammer 2009). This means that response rates are unavailable, but respondents were well spread across the different target groups. Our overall sample size of 81 respondents was comparable to what was achieved in previous research studies (e.g., Bardsley and Edwards-Jones 2006; Andreu et al. 2009). For individual survey questions, sample size varied as not every respondent answered every question.

The questionnaire was piloted and potential problems (e.g., ambiguities) rectified. The final questionnaire, with 13 pages and 29 questions, was distributed to participants (in 2009); with the option of participating in a random draw for a prize (~AUD 100). The questionnaire consisted of three sections (Appendix). The first explored demographics and experience in weed management. The second section investigated the types of the weeds managed, the management techniques employed, the objectives of weed management, and the success in attaining the objectives. The third section documented observations made of wildlife-weed interactions, knowledge of the role of weeds as wildlife habitat, and whether adjustments were made during weed management projects to accommodate wildlife. The questionnaire consisted of closed-ended (87%) and open-ended questions. Some (34%) closed-ended questions involved a five point Likert scale (from one [never] to five [always]) to examine observations, or a four point Likert scale (from one [very unimportant] to four [very important]) to examine attitudes. An option for 'unknown' was included in both Likert scales.

A composite variable 'experience' was created by combining two ordinal variables (the length of time that a respondent had been involved in weed management [<1 year, 1–5, 6–10, 11–15, 16–20, >20 years] and the frequency that they were involved in weed management at the time [Never, Annually, Monthly, Weekly, Daily]; after Manning and Munro 2006). These categories were changed to ranks (with the lowest numbers for categories representing least experience, i.e., <1 year and Never). The ranks for each question were then summed to indicate overall experience. Higher scores indicated greater experience in weed management.

The term 'weed' was used broadly throughout the questionnaire, reflecting the Australian usage of the word, which incorporates all contexts. When location or origin of the weed was important, the context of the weed was specified as: agricultural weed (invasive and harmful in agricultural environments); environmental weed (invasive and harmful

in natural environments); native weed (originating from Australia); exotic weed (originating outside Australia). The terms native and non-native also were used to categorise wildlife, describing their origin in relation to Australia.

Statistical analysis

Standard non-parametric statistical analyses were used throughout to reflect the ordinal nature of the data (Quinn and Keough 2002) using SPSS (v. 17.0, SPSS Inc., Chicago). Unless stated otherwise, analyses excluded all 'unknown' responses. On occasion, we present means and confidence intervals (±95%) to clarify differences between variables, even though statistical tests were conducted on ranks or medians. Analysis of Similarities using Bray-Curtis resemblance matrices and Similarity Percentages were performed using PRIMER 5 (Plymouth Marine Laboratory, UK) as appropriate (excluding outliers) and these results were confirmed with Non-metric Multi-dimensional Scaling.

RESULTS

Most respondents (n=81) were from state government organisations (36%) while others were from contracting (19%), NGO (14%), community groups (12%), local governments (11%) and private landholders (6%). Consultancy (1%) and federal government (1%) organisation types were excluded from analysis due to inadequate sample sizes. Most respondents were male (67%) and were aged 18–25 years (16%), 26–35 (22%), 36–45 (25%), 46–55 (25%), and >55 years (12%). Experience varied between respondents (experience score 3–11, median=7), and did not differ with organisation type (comparison 1 in Table 1).

Respondents had been involved more frequently in the management of environmental rather than agricultural weeds (comparison 2 in Table 1), a product of our sampling. They had more frequently managed exotic rather than native weeds; shrubs were the most frequently managed weed type compared with trees, forbs, vines and grasses; and, large weed infestations were managed less often than medium and small infestations (comparison 2 in Table 1). Respondents had been involved more frequently in weed management projects where cutting and painting of weeds or manual methods were conducted compared with other weed management techniques (Table 2 and comparison 3 in Table 1).

Environmental weeds were considered more important to manage than agricultural weeds, and exotic weeds more important to manage than native weeds (comparison 4 in Table 1). Trees were considered less important to manage than shrubs, forbs, grasses and vines and there was no difference in the perceived importance of the management of infestations of different sizes (comparison 4 in Table 1).

Objectives and success of weed management

Weed management projects were conducted more often for environmental/biodiversity objectives (3.6±0.2) compared to social (2.4±0.2) and economic objectives (2.9±0.3; comparison 14 in Table 1). Objectives did not differ between organisation types (comparison 15 in Table 1). Respondents held different views in relation to the relative success of attaining different objectives (comparison 16 in Table 1). Projects with environmental/biodiversity or economic objectives were considered successful (3.3±0.2; 3.3±0.3) more often than those with social objectives (3.1±0.3). Views of the relative success of attaining these objectives were similar between organisation types (comparison 17 in Table 1).

Observations of wildlife-weed relationships

Most respondents had observed wildlife using weeds before (90%) and after (73%) management of the weed had been undertaken. The proportion of respondents observing the use of weeds by wildlife did not differ between organisation type (comparisons 5 and 6 in Table 1), but those who noted wildlife using weeds were significantly more experienced than those who did not (comparison 7 in Table 1). Wildlife seen using weeds included birds (92%), reptiles (55%), mammals (48%), invertebrates (36%), and amphibians (22%) (n=67). Weeds were used for sheltering/roosting (97%), movement pathways (81%), breeding (77%), and feeding (75%) (n=67). Respondents observed non-native wildlife using exotic weeds more often than they used native weeds, a pattern not evident for native wildlife (comparisons 8 and 9 in Table 1; Figure 1). Both native and non-native wildlife were observed in shrubs more frequently than trees, grasses, vines and forbs and native wildlife more often were noted using environmental rather than agricultural weeds. There was no difference in the frequency that native wildlife were observed in different sized weed infestations; but non-native wildlife were observed using small weed infestations less often than medium or large infestations (comparisons 8 and 9 in Table 1).

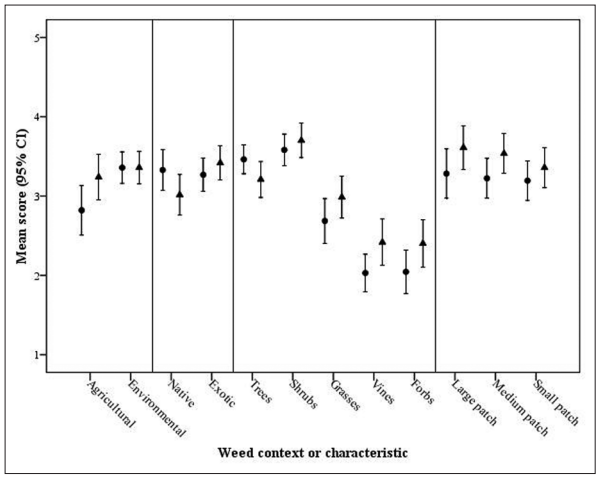

Figure 1
Mean scale scores (±95% CI) of the ranked frequency at which respondents (n=67) observed native (circles) and non-native (triangles) wildlife using weeds of different characteristics and in different contexts. Higher scale scores reflect higher frequencies of usage.

Table 1

Statistical comparisons performed throughout the study and their test statistics

Response	Predictor	Test	Test statistic	df/%
1. Level of experience in weed management[81]	Organisation type (state government vs contractors vs NGO vs community groups vs local government vs private landholders)	$^{K\text{-}W}\chi^2$	3.921	5
2. Frequency of involvement in weed management[79]	Weed location (environmental vs agricultural weeds)	z	**-5.498**	1
	Weed origin (exotic vs native weeds)	z	**-5.402**	1
	Weed growth form (shrubs vs trees vs forbs vs vines vs grasses)	χ^2	**34.374**	4
	Infestation size (large vs medium vs small infestation)	χ^2	**56.520**	2
3. Frequency of involvement in weed management[81]	Weed management techniques (cutting and painting vs manual vs mechanical vs grazing vs chemical vs biological control vs shading/solarising vs fire vs prevention)	χ^2	**271.956**	8
4. Perceived importance of weed management[79]	Weed location (environmental vs agricultural weeds)	z	**-5.811**	1
	Weed origin (exotic vs native weeds)	z	**-5.452**	1
	Weed growth form (shrubs vs trees vs forbs vs vines vs grasses)	χ^2	**18.439**	4
	Infestation size (large vs medium vs small infestation)	χ^2	2.198	2
5. Proportion of managers that observed wildlife using weeds *before* management of the weed had been undertaken[74]	Organisation type (state government vs contractors vs NGO vs community groups vs local government vs private landholders)	χ^2	6.218	4
6. Proportion of managers that observed wildlife using weeds *after* management of the weed had been undertaken[65]	Organisation type (state government vs contractors vs NGO vs community groups vs local government vs private landholders)	χ^2	7.879	4
7. Proportion of managers that observed wildlife using weeds[74]	Level of experience (3-11)	$^{M\text{-}W}z$	**99.000**	73
8. Frequency of weed use by *non-native* wildlife[67]	Weed location (environmental vs agricultural weeds)	z	**-3.517**	1
	Weed origin (exotic vs native weeds)	z	**-0.886**	1
	Weed growth form (shrubs vs trees vs forbs vs vines vs grasses)	χ^2	**109.194**	4
	Infestation size (large vs medium vs small infestation)	χ^2	**9.361**	2
9. Frequency of weed use by *native* wildlife[67]	Weed location (environmental vs agricultural weeds)	z	**-0.131**	1
	Weed origin (exotic vs native weeds)	z	**5.725**	1
	Weed growth form (shrubs vs trees vs forbs vs vines vs grasses)	χ^2	**159.141**	4
	Infestation size (large vs medium vs small infestation)	χ^2	0.282	2
10. Number of 'unknown' responses in regard to the perceived importance of weeds as habitat[73]	Wildlife groups (native birds vs native mammals vs native amphibians vs native reptiles vs native invertebrates vs non-native birds vs non-native mammals vs non-native amphibians vs non-native reptiles vs non-native invertebrates)	χ^2	**73.480**	9
11. Perceived importance of weeds as habitat[73]	Wildlife groups (native birds vs native mammals vs native amphibians vs native reptiles vs native invertebrates vs non-native birds vs non-native mammals)	χ^2	**89.381**	6
12. Perceived importance of adjusting weed management to accommodate wildlife[73]	Level of experience (3-11)	$^{K\text{-}W}\chi^2$	3.505	3
13. Proportion of managers adjusting weed management to accommodate wildlife[73]	Level of experience (3-11)	$^{M\text{-}W}z$	**326.500**	72
	Organisation type (state government vs contractors vs NGO vs community groups vs local government vs private landholders)	χ^2	4.288	4
14. Frequency weed projects were conducted[78]	Project objectives (environmental/biodiversity vs social vs economic)	χ^2	**62.493**	2
15. Frequency weed projects were conducted for particular objectives[75]	Organisation type (state government vs contractors vs NGO vs community groups vs local government vs private landholders)	R	**0.162**	16.97-20.76
16. Frequency that managers considered weed projects successful[78]	Project objectives (environmental/biodiversity vs social vs economic)	χ^2	**6.759**	2
17. Frequency that managers considered weed projects with particular objectives were successful[75]	Organisation type (state government vs contractors vs NGO vs community groups vs local government vs private landholders)	R	**0.121**	18.45-26.85

Contd...

Table 1
Contd...

Response	Predictor	Test	Test statistic	df/%
18. Frequency weed project success was determined[75]	Indicators (biodiversity attributes vs weed attributes vs targeted programmes vs anthropogenic measures)	χ^2	**9.362**	3
	Biodiversity indicators (wildlife presence vs native plant presence)	χ^2	**75.200**	3
19. Frequency weed project success was determined by particular indicators[75]	Organisation type (state government vs contractors vs NGO vs community groups vs local government vs private landholders)	R	0.012	16.09-20.86

Note: Comparisons are numbered, the response variables described, and the levels across which comparisons were made (predictor) are listed in parentheses. Statistical tests were based on Kruskal Wallis ($^{K-W}\chi 2$), Wilcoxon Signed Rank (z), Friedman (χ^2), Mann-Whitney (^{M-W}z) or Analysis of Similarities (Global R). Test statistics in bold indicate that tests were significantly different ($P<0.05$). A small Global R statistic suggests any affect is minimal (Clarke 1993) and, possibly, cannot be regarded as a true measure. Degrees of freedom (df where relevant) or the range of average dissimilarity (% where relevant) and sample sizes (in subscript and parentheses) are listed.

Table 2
Frequency of weed management techniques used by managers in Victoria, Australia (n=81), with mean (±95% CI) scale scores

Management technique	Mean scale score (1=never to 5=always)
Cutting and painting	3.9±0.2
Manual methods	3.6±0.2
Mechanical methods	3.4±0.2
Grazing	3.0±0.2
Chemical methods	2.9±0.2
Biological control	2.3±0.2
Shading/solarising	2.1±0.2
Fire	1.8±0.2
Prevention	1.7±0.1

Table 3
Beliefs cited by respondents (n=62) to justify their view that weeds provide important habitat to wildlife

Beliefs	Percentage of respondents citing belief
Alternative native habitat not available	32
Weed provides resource/s to wildlife	27
Species of wildlife using the weed is under threat	16
Overall threat status of the weed is low	8
Potential for replacement of weed with suitable native species is low	8
Other	7

Attitudes towards wildlife-weed relationships

When respondents indicated how important weeds were as habitat for wildlife, there were more 'unknown' responses for questions regarding non-native amphibians, reptiles and invertebrates, compared with other taxa (comparison 10 in Table 1), so these taxa were excluded from further analyses. There was a significant difference in the perceived importance of weeds as habitat for different wildlife groups (comparison 11 in Table 1). Most respondents considered weeds to be more important for native birds (78%), non-native birds (83%) and non-native mammals (78%) compared with native mammals (60%), reptiles (52%), invertebrates (49%), and amphibians (41%). The reasons respondents believed that weeds were important habitat for wildlife fell into six categories (Table 3).

Adaptive weed management for wildlife

Most respondents (84%) considered adjusting weed management to accommodate wildlife as 'important' or 'very important' regardless of their experience (comparison 12 in Table 1). Most (71%) also indicated they adjusted weed management in some way to accommodate wildlife, especially the more experienced respondents (comparison 13 in Table 1). There was no difference in the number who adjusted weed management projects between organisation types (comparison 13 in Table 1). A variety of adjustments were reported, for example, re-vegetation and changing the timing of management (Table 4). Some (38%) reported a combination of adjustments such as combining re-vegetation with the gradual removal of weeds. Of those who had observed wildlife using weeds, 19% cited this particular combination.

Evaluation of weed management projects

A variety of indicators were used to measure the success of weed management projects. These were categorised into biodiversity attributes (measuring native vegetation or wildlife populations), weed attributes (measuring number, cover or area of weeds), targeted programmes (implementation of monitoring or follow up programmes) and anthropogenic measures (amount of money or time spent on project). Anthropogenic measures were used less often (2.8±0.3) to measure weed project success compared to biodiversity (3.4±0.2) and weed (3.2±0.2) attributes and targeted programmes (3.2±0.2; comparison 18 in Table 1). This did not differ between organisation types (comparison 19 in Table 1). When assessing only biodiversity attributes, wildlife presence was measured less frequently (2.6±0.2) to gauge management success than was the presence of native plant species (comparison 18 in Table 1).

DISCUSSION

Weed management projects: purpose, perceptions and practice

The promotion of biodiversity (including wildlife) through weed management is a worldwide phenomenon (Randall

Table 4
Type of adjustments made by managers in order to better accommodate wildlife in weed management

Type of adjustment for weed management	Percentage of respondents making adjustments
Revegetation/replacement with native vegetation	34
Changing the timing of management (including avoiding animal breeding seasons)	32
Staging the removal of weeds	32
Retaining weed structure	26
Avoiding removal of important weeds	22
Herbicide selection or avoidance	20
Using an alternative weed management method	12
Pre-treatment monitoring	6
Reducing noise	2

Note: Total 93 responses from 50 respondents

1996; D'Antonio and Meyerson 2002; Reid et al. 2009). In our study, biodiversity conservation was a key objective of weed management, regardless of the organisation conducting the weed management. While we had targeted our research towards managers whom we expected to be guided by the objective of promoting indigenous biodiversity, the organisations we sampled varied in capacity and role with regard to weed management. For example, NGOs are often limited by funding (McNeely and Weatherly 1996) but have an abundance of labour via volunteers (Weston et al. 2003). Arguably, their strategies and project planning may be more limited when compared to better funded entities (Curtis and Lockwood 2000). Yet we observed similar objectives, perceptions of success and project evaluation across organisations of all types. This may result from the influence of widespread devolved government funding for weed management, associated with mandated project management standards as well as being guided by government strategies (e.g., NRMMC 2006).

A very different result may have occurred had we captured the views of those more experienced in agricultural weed management. Given that the effects of weeds in agricultural systems are widely referred to in terms of economic losses (van der Meulen et al. 2007), we would expect this to be reflected in their management objectives. Thus, the views of those more involved in agricultural environments are an important direction for future research.

The more frequent use of selective management methods (cutting and painting, manual methods; Muyt 2001) may be due to more respondents being involved in management of environmental weeds (Table 1). These lower impact management methods are more suitable in natural environments where non-target impacts on biodiversity are a concern (Muyt 2001), compared to more general chemical methods. That wildlife is a potential non-target impact is highlighted by respondents who had adjusted their weed management projects to accommodate wildlife by better selecting or avoiding herbicides. Internationally, the use of lower impact methods are common (Andreu et al. 2009), but just how often considerations around wildlife influence choice of management remains unknown.

A range of other factors also influence the choice of weed management methods. These include weed species, location and infestation size (Sindel 2000). Throughout the rest of Australia, herbicide is primarily used to manage Weeds of National Significance (WoNS), which threaten both agricultural and natural environments (Reid et al. 2009). In such cases, and particularly in an agricultural setting, more broad scale techniques are evidently more applicable. Given the large areas that can be managed with such techniques (Reid et al. 2009), it is unlikely that wildlife would remain completely unaffected; however, without their inclusion in project evaluation, this will go unnoticed.

Appropriate evaluation and monitoring of weed management projects is critical to refine programmes and to permit adaptive management (Reid et al. 2009). It is now generally accepted that outcome-orientated evaluation is preferable to output-orientated evaluation (Downey 2011). In our study, managers more often used measures of biodiversity (outcome-orientated reporting) to assess the success of a project, yet output-orientated reporting (that included measuring weed attributes and implementation of targeted programmes) was also used. Such a mix of reporting modes is to be expected given the need for transparency in project management; however, when managing weeds for biodiversity objectives, a greater emphasis on outcome-orientated evaluation could also contribute to further understanding wildlife-weed relationships.

Weeding for wildlife

Social research suggests that direct experience with a situation strongly influences intentions to engage in certain behaviours (Regan and Fazio 1977; Homer and Kahle 1988; Fulton et al. 1996). Our research demonstrated that more experienced weed managers frequently observed wildlife using weeds and made adjustments during weed management projects to accommodate wildlife. Additionally, some respondents based their attitudes regarding the importance of weeds for wildlife on whether alternative native habitat was available (32%) and/or whether the weed was providing resources to wildlife (27%); both of which require prior observation or information. This implies that the managers sampled here rely on their own observations and experience to guide their decisions regarding whether or not to adapt weed management to safeguard wildlife. Unfortunately, there are potential problems with this—firstly, managers may inadvertently manage only for conspicuous wildlife, such as birds and mammals (which they most frequently observed). Secondly, the types and complexity of interactions between wildlife and weeds may be underappreciated. Understanding nature of these interactions would improve the understanding managers have of the impacts of weed management. This also emphasises the need for ecologists worldwide to better document and communicate what is known about wildlife-weed interactions.

Current biodiversity monitoring guidelines in Victoria include quantitative and systematic measurements of vegetation and its

attributes (Ainsworth et al. 2008). A similar systematic approach to measuring wildlife attributes would also account for wildlife-weed interactions. Our study also suggests the presence or absence of alternative native habitat is a criterion often used by managers as the basis to decide whether or not adjustment to the weed management programme is needed. This approach disregards the deleterious effects associated with displacement of wildlife (Wolff et al. 1998) as it assumes there is adequate recognition of the importance of a given habitat, and is generally 'assumption rich'. Given the experience-attitude-behaviour link and the global prevalence of weeds, it is likely that these types of assumptions are being made outside Victoria when a wildlife-weed interaction is recognised.

A good understanding of the impacts of weed management on wildlife is essential for managers to plan the most appropriate strategies. This has been highlighted in South-western United States where management of *Tamarix* species is largely influenced by native breeding birds that use the weed as habitat (Sogge et al. 2008). For example, the endangered southwestern willow flycatcher *Empidonax traillii extimus* is negatively impacted by biological control of *Tamarix*, which causes high levels of defoliation of the plant and renders it unsuitable for nesting. In these circumstances, smaller scale herbicide application or mechanical removal has been recommended (Sogge et al. 2008).

There is a clear need for more studies concerning weed management and its impacts on wildlife, including specific studies of techniques which may mitigate any impacts. Indeed, little is known about what wildlife particularly may be dependent upon weeds, and what life history attributes render them vulnerable or resilient to weed management. Currently, a combination of re-vegetation and gradual weed removal in response to the presence of a wildlife-weed relationship is recommended (Gosper and Vivian-Smith 2006; Sogge et al. 2008; Carlos and Gibson 2010). This is to account for the time lag that occurs before re-vegetation sufficiently allows for replacement of weed resources. Time lags can be substantial; for example, five year old re-vegetation does not support the same richness or abundance of birds as adjacent weed vegetation (Carlos and Gibson 2010). Thus, weed management projects that include re-vegetation would need to be conducted over considerable time periods. A lack of long term funding and support could help to explain why, in our study, only 19% of managers had combined the two practices or, for example, why restoration occurs in only 29% of previously invaded sites in Spain (Andreu et al. 2009). Alternatively, if the experience-attitude-behaviour link applies, this practice may be infrequent merely due to the lack of proper assessment of potential wildlife-weed interactions.

The very process of weed management may itself reveal hitherto unknown species of wildlife relying on weeds as habitat. Thus, it would be prudent to include wildlife in an adaptive management paradigm that incorporates post weed management monitoring (Reid et al. 2009; Downey 2011). While funding for weed management is already limiting (Downey 2011), the suggestion to incorporate another element into the management process may not appeal. It is clear, however, that most managers are aware of wildlife-weed relationships and many already are taking steps to adjust their management approach despite the finding that there is significantly less formal monitoring of wildlife compared to native vegetation. By conducting 'fauna-inclusive' monitoring, adaptive management could be better informed, avoiding any unintended deleterious outcomes. Alternatively, the objectives of weed management may need to be reassessed so that they recognise conservation of floral diversity as a priority, rather than the objective to conserve biodiversity more broadly.

ACKNOWLEDGEMENTS

We thank all respondents and those involved in the pilot survey. The Holsworth Wildlife Research Endowment, BirdLife Australia (Victoria), M.A. Ingram Trust, and Deakin University scholarships provided funding. This research was conducted under a Human Research Ethics Committee permit (reference: STEC-16-2008-CARLOS). Our sincere thanks go to the two anonymous reviewers, whose comments improved this manuscript.

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Received: January 2012; **Accepted:** March 2013

APPENDIX

Structure and content of questionnaire sent to respondents. Questions asked are numbered and respondents were asked to either: select the most appropriate option (indicated as[(1)] with options listed in italics); select as many options as apply (indicated as[(#)] with options listed in italics); select how often they had observed the listed items, from 1-5 or 'unknown' on a Likert scale (indicated as[(1-5)] with items listed in italics); select how important they believed the listed items to be, from 1-4 or unknown on a Likert scale (indicated as[(1-4)] with items listed in italics); write a response (indicated as ⌵).

General information

1. What is your age?[(1)]
   18-25; 26-35; 36-45; 46-55; >55

2. Are you:[(1)]
   Male; Female

3. What type of organisation are you primarily involved with when managing weeds?[(1)]
   Local government; State government; Federal government; Community group; Contractor; Consultancy; Private land holder; Non-Government Organisation; Other

4. What best describes your role/s in the above organisation?[(#)]
   Planner; Manager; Ground crew; Advisor; Volunteer; Other

5. How long have you been involved in weed management?[(1)]
   <1 year; 1-5 years; 6-10 years; 11-15 years; 16-20 years; >20 years

6. Overall, what scale best describes the area over which you are most often involved in weed management? [(1)]
   <10 ha; 10-100 ha; 101-500 ha; Regional level; State level

7. How often are you involved in weed management in your current position?[(1)]
   Daily; Weekly; Monthly; Annually; Never

Section 1: Weed management

8. Where across Victoria have you been involved in managing weeds?[(#; a map was provided)]
   Mallee; Wimmera; Glenelg Hopkins; North Central; Corangamite; Goulburn Broken; North East; East Gippsland; West Gippsland; Port Phillip and Western Port

9. In what vegetation types have you managed weeds?[(#)]
   Agricultural; Pastoral; Rainforest; Dry forest; Heathlands; Wet forest; Woodland; Alpine; Grasslands; Coastal; Wetland; Riparian; Other

10. Based on the weed management projects that you have been involved in, how often are the following types of weed management strategies conducted?[(1-5)]
    Manual control (by hand)
    Mechanical control (with aid of machinery)
    Chemical control
    Cutting and painting
    Shading/Solarising
    Release of biological control
    Fire
    Grazing
    Prevention
    Other

11. Based on the weed management projects you have been involved in, how often have the following weed categories been managed?[(1-5)]

Agricultural weeds
Environmental weeds
Native weeds
Exotic weeds
Trees (e.g., pittosporum, pine)
Shrubs (e.g., gorse, blackberry)
Grasses (e.g., pasture grasses, serrated tussock)
Vines (e.g., Japanese honeysuckle)
Forbs (e.g., Patterson's curse, dandelion)
Large infestations (covering >1 ha)
Medium infestations (cover 0.25-1 ha)
Small infestations (cover <0.25 ha)

12. Based on their negative impacts, from your accumulated knowledge or direct experience, how important do you think it is to manage the weed categories listed in question 11?[1-4]

13. Based on your accumulated knowledge or direct experience, indicate how often you think management is carried out for each of the reasons listed below.[1-5]
To prevent the spread of a weed
To eradicate a weed
To help conserve biodiversity
To improve growth of native vegetation
To improve habitat quality for wildlife
To improve ecosystem function
To enable flow of water
To help remove refuges for pest animals (e.g., foxes)
To reduce fire fuel loads
To decrease snake numbers
To improve aesthetics
To improve a view
To be a good neighbour
To improve recreation
To have a social event
To improve yields/economic values
To meet requirements of the policy of your organisation
To access available funding
To project an image of environmental responsibility for your organisation or property
To qualify for government accreditation (e.g., Land for Wildlife) or funding
To provide activities for your staff or volunteers
Other
14. Based on your accumulated knowledge or direct experience, indicate how often you think that projects with the objectives listed in question 13 have been successful?[1-5]
15. In your opinion what makes a weed project successful?
16. Based on the projects you have been involved in, how often is the success of weed management measured from the following?[1-5]
From the presence of non weed plant species
From the presence of specific animal species
From a targeted monitoring project
When the cover of the target weed has reached a pre-determined level
From the success of the naturally regenerating native plants
From the success of a revegetation programme
When a follow up programme has been implemented
When a certain amount of time has been spent in an area
When the project funds have been used
When the weed has been eradicated from an area
When a pre-determined area of weeds have been removed or treated

When a set number of plants have been removed or treated
Photo point monitoring
When the weed no longer looks like a problem
Other

17. Based on the weed management projects you have been involved, in how often is 'follow up' work carried out?[(1-5)]

Section: Wildlife and weeds

18. Have you ever observed wildlife using weeds that have not had any management applied to them?[(1)]
Yes; No

19. Have you ever observed wildlife using these weeds after weed management has been applied? For example, weeds that have been sprayed or piles of removed weeds?[(1)]
Yes; No

20. What wildlife have you observed using the weeds you have been managing?[(#)]
Mammals; Birds; Amphibians; Reptiles; Invertebrates; Feral (non-native) animals; Others

21. How often have you seen native wildlife use the weed categories listed in question 11?[(1-5)]
22. How often have you seen non-native wildlife use the weed categories in question 11?[(1-5)]

23. What have you observed wildlife doing on or within weeds?[(#)]
Feeding; Sheltering/roosting; Nesting; Moving through; Other

24. Have you ever adjusted your weed management programmes because of wildlife? If yes, how and why?[(_)]

25. How important do you think weeds are as habitat for the following wildlife?[(1–4)]
Native birds
Native mammals
Native amphibians
Native reptiles
Native invertebrates
Non-native birds
Non-native mammals
Non-native amphibians
Non-native reptiles
Non-native invertebrates

26. What are your main reasons for deciding how important weeds are as habitat?[(_)]
27. Overall how important do you think it is to adjust weed management to accommodate wildlife?[(1-4)]
28. What is your main reason/s for deciding how important it is to adjust weed management to accommodate wildlife?[(_)]

29. What have you observed after weed removal in terms of wildlife changes?[(#)]
Loss of a native species; Loss of a non-native species; Gain of a native species; Gain of a non-native species; Increase in abundance of native species; Increase in abundance of non-native species; Decrease in abundance of native species; Decrease in abundance of non-native species; No change