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A model that will assist on-ground practitioners in their quest to protect biodiversity values in natural ecosystems

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Summary

There has been ongoing discussion around the necessity for quantitative models in ecology. The use of quantitative modeling is well established in some areas of endeavour, such as Before-After-Control-Impact (BACI) studies, but not in others, in particular the field of invasion ecology. In weed risk analysis, semi-quantitative models (scoring systems, with or without weighting procedures) help policy makers to assess the risk (hazard) posed by individual weed species. Such systems are available to assess weed risk management feasibility at larger geographic scales. However, nothing is available to assist on-ground practitioners in prioritising weed control at the individual site level. Interestingly, the fundamental problem of model choice was solved in the early 2000s by sociological researchers (Dana and Dawes 2004), who demonstrated that qualitative models actually **outperformed** quantitative models, as long as all of the important factors in the system had been identified. An earlier attempt to establish this finding in the weed invasion literature (Panetta and Cacho 2014) has not been successful. In this paper, I use the results from an ongoing project ("Future-proofing Australia's National Post-Border Weed Risk Management System") to develop a model that combines both qualitative and semi-quantitative approaches. This model should be fit-for-purpose by practitioners at the site level, as well as by policy makers charged with allocating scarce resources at larger geographic scales.

Keywords

Co-ordinated control, Maintenance control, Policy maker, Practitioner, Weed management feasibility

Introduction

The problem of allocating scarce resources (Cacho and Hester 2011) is endemic in the management of invasive plants. It is in the foreground in incursion management, as well as in determining which weeds to target in the protection of natural biodiversity. This problem can be addressed via one of three fundamental modelling approaches. Quantitative models are suitable where the analytic environment is data-rich, such as in biological (or physical) systems. Semiquantitative models find their place where some data are available. Where no data are available, but there is in an intuitive understanding of a system, qualitative models come into their own. Ironically, qualitative models can actually be **more** accurate than quantitative models, **providing that all of the important factors are identified** (Dana and Dawes 2004).

For weed risk assessment, semiquantitative models, such as scoring systems, have been used with a high degree of success. This has allowed policy makers to prioritise weeds for coordinated management programs (such as eradication) at larger (national or regional) geographic scales. However, at the smallest scale (e.g., managing weeds in individual biodiversity assets), there is no real assistance for practitioners. In most cases, a practitioner would not be amenable to, or capable of, adapting a scoring system for use on a site-by-site basis.

Panetta and Grigg (2021) presented a partial analysis of the weed risk management feasibility of the most impactful weeds in Christmas Island National Park (Christmas Island, Indian Ocean.) Two species-intrinsic factors, namely the time to reproduction and the nature of the dispersal vector suite (sensu Panetta and Cacho 2012) were utilised. This approach provides a land manager a means of prioritising the species that pose the greatest weed risk, i.e., "extreme"—equivalent to the concept of "transformer" (first elaborated by Richardson et al. 2001). These two factors are arguably the **most important** in determining management feasibility, but a thorough treatment would clearly need to take into consideration a number of additional factors (see Figure 1).

- Recruitment dynamics
- Life history characteristics
- Detectability
- Cost of control
- Control effectiveness
- Urgency

Figure 1. Factors to be taken into consideration in the determination of weed risk management feasibility

In the wake of the 2019/2020 Black Summer Bushfires and recent floods in Australia, on-ground practitioners have had to make decisions relating to the prioritisation of weed management in post-disturbance landscapes, while lacking the tools to support timely decision making. Thus, there is a critical need for decision support tools specifically designed to assist these operators in managing weeds after such massive disturbances.

The objectives of this study were:

1. To develop a full analysis of weed risk management feasibility;
2. To develop decision support tools for land managers by designing post-disturbance modules to allow on-the-ground decision making; and

The approach

Major fires and floods are singular disturbance events that present both risks and opportunities for weed management. The imperative for restricting the allocation of scare resources to management of the most damaging weeds will remain, but management feasibility will likely differ between species in the post-disturbance environment. Many changes in management feasibility, whether positive or negative, will act "across the board" in relation to the weed flora and hence will be of little use to their prioritisation for management. Availability of resources (including participation by volunteers) will influence whether or not weed management is undertaken in an asset, rather than which weeds are targeted for control. Accordingly, factors that will permit discrimination between weeds with regard to management feasibility are elaborated in this piece. Two categories of weeds are considered: high-impact transformer species (sensu Richardson et al. 2001) of restricted distribution that have previously been declared targets for coordinated management, (such as eradication/extirpation or containment); and transformers that are widespread and therefore beyond the stage of invasion at which coordinated management is a realistic goal. Management of the former group is a **weed-led** activity, whereas management of the latter is **site-led** (see Owen 1998), which will apply to most of the species to which the modules would be applied.

Prioritising weeds for control and deciding upon the type of control

Prioritising weeds for control and deciding upon the type of control and its associated investment are fundamental to weed management planning. Risk analysis is central to this process, combining the activities of risk assessment, risk management and risk communication. Risk assessment methodology is highly developed, but risk management has typically been a secondary matter, often overlooked. Some time ago, Virtue et al. (2001) listed the essential criteria for addressing the feasibility of managing weeds as: 1) stage of invasion; 2) weed biology; 3) means of control; 4) cost of weed control; and 5) motivation of land managers. In recent years there has been a move by invasion scientists and practitioners to develop scoring protocols for the assessment of weed management feasibility (Wilson et al. 2016, Booy et al. 2017,Vanderhoeven et al. 2017, Panetta and Grigg 2021).

Disturbance is a major factor affecting the invasion by, and consequent impact of, weeds in natural ecosystems (Hobbs and Humphries 1995). Human-induced disturbances such as fragmentation, nutrient enrichment, and changed grazing and fire regimes are important, as are natural disturbances such as major floods and catastrophic fires. The latter events are unique forms of disturbance that provide both risks and opportunities for weed management (Zimmer et al. 2012). The aim of this exercise is to develop modules that are specific to post-fire and post-flood conditions and can be used to assess management feasibility as a basis for prioritising weeds for control. In designing these modules, I have been conscious of the need for simplicity (while capturing essential features), so that modules will be easy to use at small (site) geographic scales.

Post-disturbance risks and opportunities

Management activities that may contribute to weed introduction, establishment and spread include soil disturbance associated with firebreak/fire containment lines, access track construction, and the use of potentially weed-contaminated heavy vehicles, such as bulldozers and other management vehicles. The introduction of fodder, for native or domestic animals can provide opportunities for weed seed introduction. Weeds may also be dispersed by animals farther than is usual in unburnt vegetation, as animals may travel farther than usual to find food, including onto open pasture (Zimmer et al. 2012). Similar pathways of weed introduction are likely to be active after major flood events.

Some weeds have highly persistent seed banks and germinate prolifically after fire. In the absence of targeted control efforts in the first few seasons post fire, they may increase in cover abundance locally, as well as spread further through the landscape. Timely post-fire management action is necessary to prevent both potential outcomes. Fire may cause high mortality in weeds that are not fire-adapted and may therefore create an opportunity for increased management impact. Control of weeds that are adversely affected by fire (i.e., where established plants are killed or reduced in size before they can reach the reproductive stage) presents an opportunity for changing the relative cover abundances of weeds vs native species in favour of the latter.

Improved access immediately after fires may provide new opportunities for control. This may apply especially in dense riparian vegetation or in wet forests, where the dense vegetation generally impedes access to weeds, or wherever the foliage of established weeds is beyond reach of standard foliar chemical methods. Finally, the relatively open conditions following a major fire event will provide an opportunity for enhanced weed surveillance that could permit the detection of new and emerging weeds (Zimmer et al. 2012). Similar opportunities may exist after floods, although in some cases the deposition of large amounts of debris may cause problems relating to accessibility and consequently weed detection and control.

Weed management strategies

Coordinated control and maintenance control are the two fundamental weed management strategies.

Coordinated control

Coordinated weed control strategies include eradication and containment. Eradication has been defined as the elimination of every single individual (including propagules) of a species from a defined area in which recolonisation is highly unlikely. Where recolonisation is possible, **extirpation** (the elimination of all individuals from an area in which the possibility of recolonisation cannot be ignored in practice; Wilson et al. 2016) could be the appropriate strategy for high value assets. This would be the case when such assets are isolated spatially and potential pathways of recolonisation are either inactive or can be managed effectively.

Containment can be either absolute (stopping spread) or relative (slowing spread), but the concept of absolute containment has limited application (Panetta and Cacho 2012), often restricted to a scenario combining species that naturally spread slowly with the existence of strong barriers. Slowing spread can provide substantial benefits, including 'buying time' while more effective control methods, such as biological control, are developed. However, this strategy requires an indefinite commitment of funding and other resources and has not proven attractive to policy makers.

Maintenance control

In most cases "maintenance management" (i.e., controlling a transformer to densities at which it can be tolerated) will be the most appropriate response. Where damage functions are non-linear, this would involve ensuring that invader densities lie below the impact threshold zone (Figure 2).

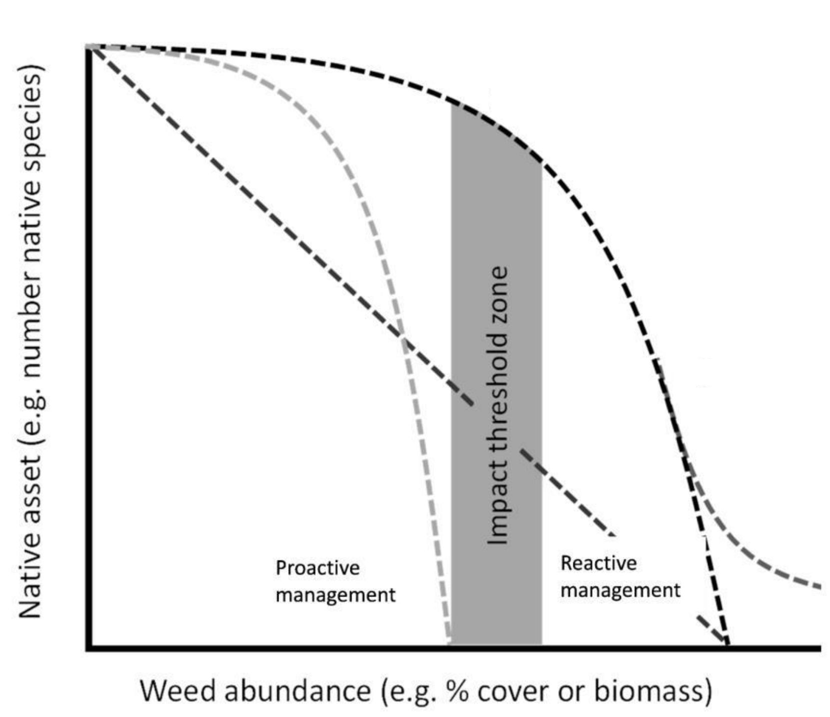

Figure 2. Weed impact threshold relationships can be defined as non-linear declines in one or more ecosystem properties with increasing weed abundance. For natural ecosystems, such properties as the number of native plant species or the occurrence of rare and threatened species will be of concern. The objective of maintenance control is to keep the cover abundance of transformers at levels sufficiently low to minimise their impacts on ecosystem values (from Panetta and Gooden 2017).

Setting the context

Post disturbance weed risk management (WRM) modules need to be applicable at a range of scales, from state to the regional and local (site) scales. Higher level (state and regional scales) will be appropriate for determining the gross allocation of funding and other resources following a catastrophic environmental event, whereas considerations at the site level will relate specifically to the prioritisation of weed species for on-ground management.

Small scale (state or regional) considerations: disturbance type and severity

Fire and flood are different disturbance types, requiring the design of different post-disturbance WRM modules. How such modules are applied will depend upon the category of weed, for example whether a species has a restricted distribution and has been targeted for coordinated control, is widespread and has significant impacts, or has been newly detected and is of unknown significance. This last category of weed will require weed risk assessment (WRA) and therefore falls outside the scope of the present exercise, whose focus is on the management of species for which the weed risk has already been determined. In addition to the availability of standard WRA procedures (see Pheloung et al. 1999 for a pre-border example), preliminary guidance is available for the assessment of weed risk based on field measurements (Blood et al. 2016, Panetta 2016).

The procedure for applying the post-disturbance WRM modules is similar for both disturbance types (Figure 3). Where the weed risk is unknown, however, it is doubtful as to whether WRA assessment could be undertaken quickly enough to for the modules to be applied.

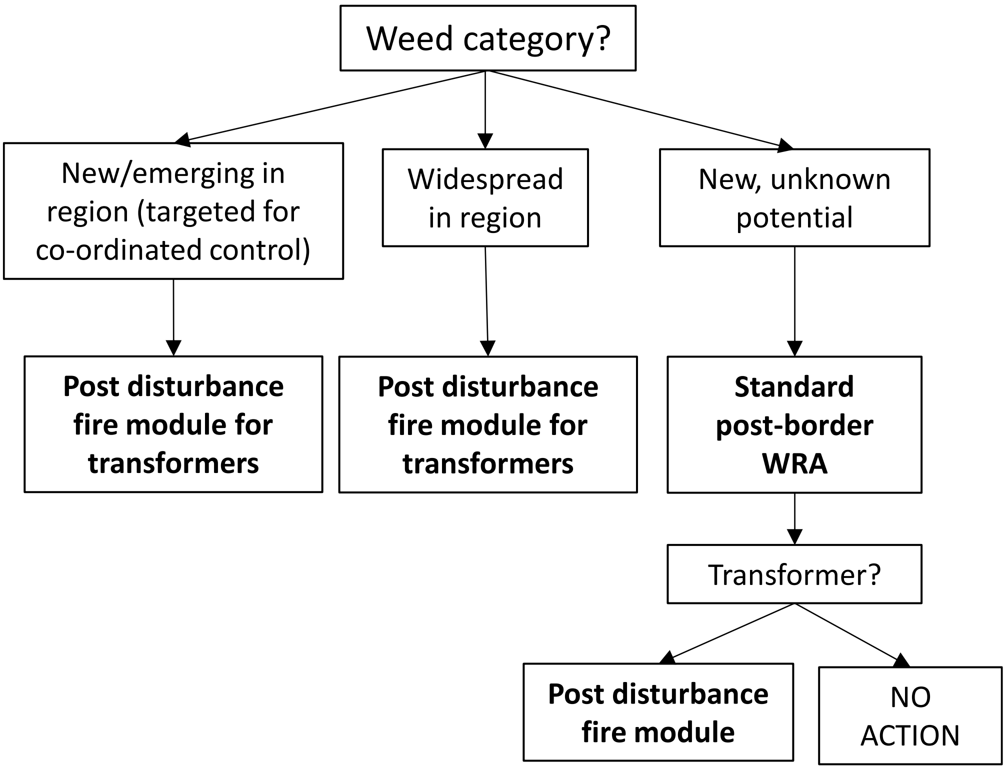

Figure 3. The decision making procedure is identical, whether the catastrophic event is a fire or flood.

The impact of a disturbance event upon ecosystem values will vary according to its severity. For fire events, this would be defined in terms of the intensity and areal extent of the fire and, for flood events, in terms of the depth and duration of flooding (Figure 4). For both disturbance types, post-disturbance WRM modules would be especially relevant to situations in which substantial mortality of desirable species had occurred.

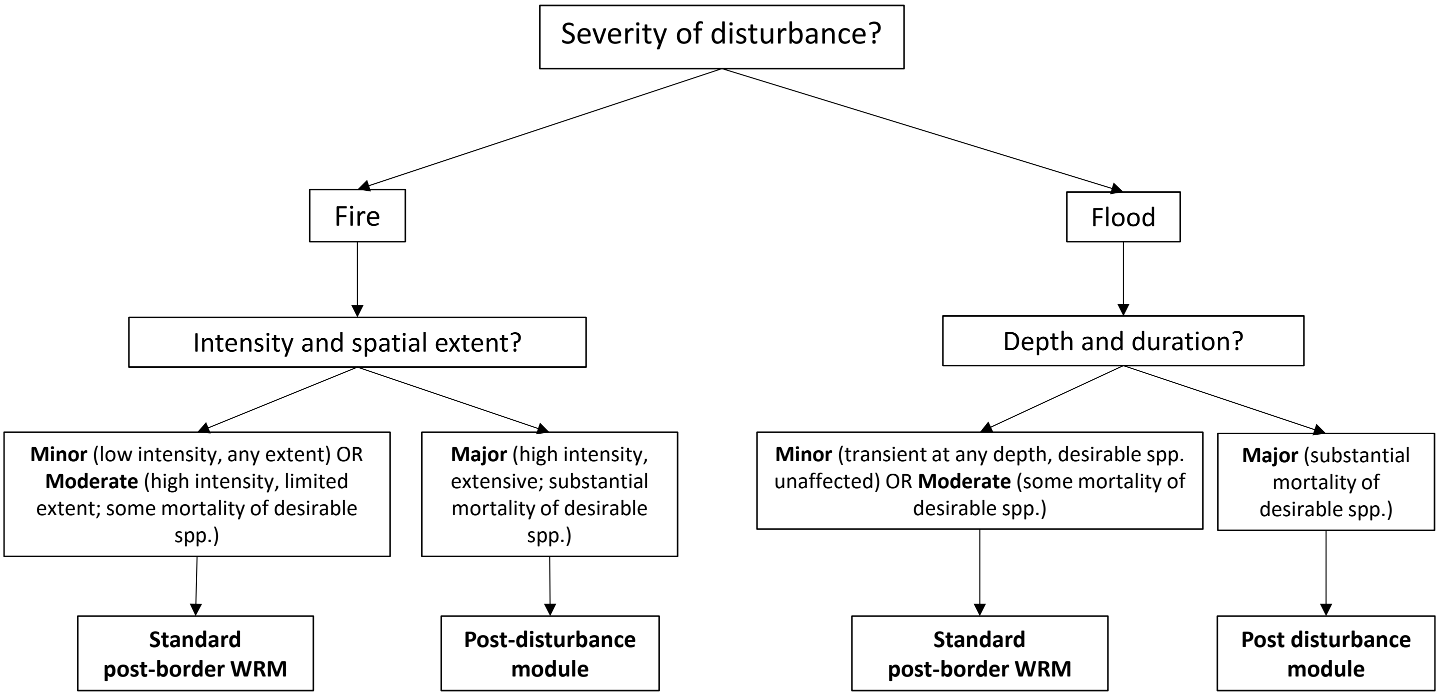

Figure 4. For both fires and floods, dedicated post-disturbance WRM modules would be most relevant to situations in which the disturbance was sufficient to cause substantial mortality of desirable species.

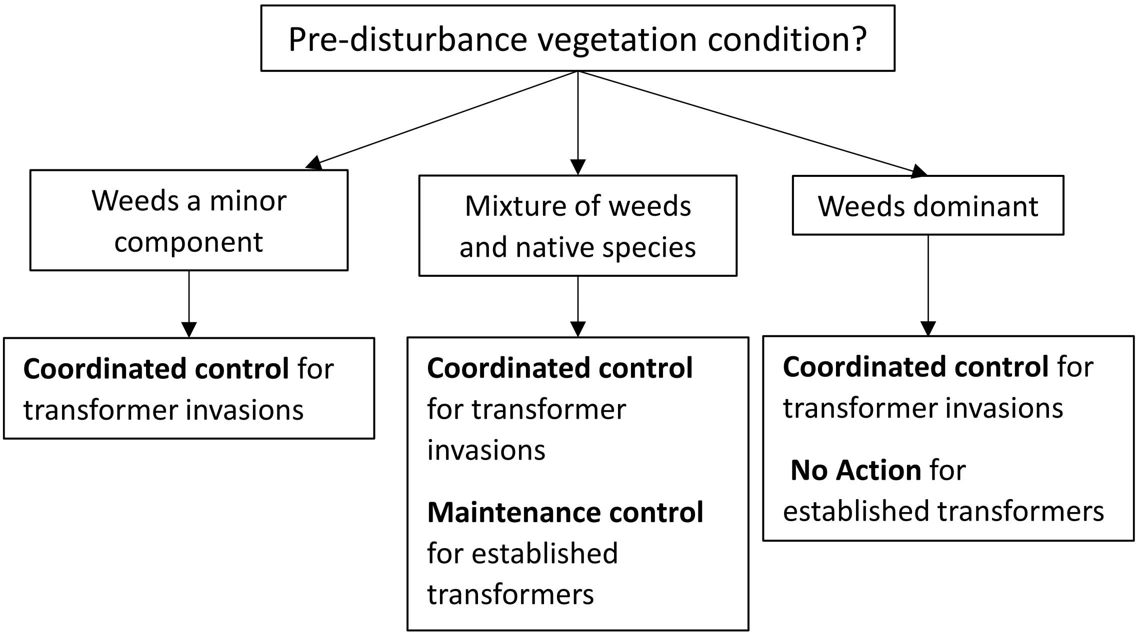

Figure 5. For natural ecosystems, strategic weed management goals will vary according to the pre-disturbance vegetation condition.

Large scale (site) considerations

Post-disturbance WRM modules will most immediately applicable at the site level. In Figure 5, different types of vegetation condition in a natural ecosystem are delineated, from one extreme where weeds are a minor component, to the other, where the plant community is a highly degraded type that is weed-dominated.

Feasibility of management

It could be anticipated that there would be at least some generic changes in the feasibility of management for all weeds post-disturbance, and that these changes would be specific to the type of disturbance. Such changes could be positive (i.e., increasing management feasibility) or negative (reducing management feasibility). By all appearances, a major fire event would, overall, increase management feasibility more than would a major flood, whose net effect would be negative (Tables 1 and 2).

Table 1. Generic change in weed management feasibility post fire in natural ecosystems. (Negative = reduced feasibility; mixed = neutral effect)

Factor	Net effect	Comments
Detectability pre-reproduction	Positive	The habitat should become more open as a result of removal of above ground biomass, markedly improving detectability.
Minimum time to reproduction	Negative	May be reduced owing to lack of competition.
Control effectiveness	Positive	For some resprouting species rapid growth in the first season post-fire may make a weed particularly susceptible to chemical control.

Accessibility	Mixed	Has two components: getting to a site (reduced owing to tree falls) and moving within the site (improved owing to reduction in above-ground biomass).
Control cost	Positive	Cost of labour reduced owing to increased ease of movement within a site
Land manager participation	Negative	Other actions (e.g., replacement of infrastructure) likely to be prioritised.
Volunteer participation	Positive	Individuals from unaffected areas may volunteer.
Potential for off-target damage	Positive	Improved targeting of control owing to reduction in above-ground biomass

Table 2. Generic change in weed management feasibility post flood in natural ecosystems. (Negative = reduced feasibility; mixed = neutral effect)

Factor	Net effect	Comments
Detectability pre-reproduction	Mixed	A site may become more open post flood, but reduced accessibility and presence of debris may hinder timely detection.
Minimum time to reproduction	Negative	May be reduced owing to lack of competition
Control effectiveness	Neutral	No change (once accessibility issues have been overcome)
Accessibility	Negative	The soil is likely to be boggy for a protracted period after a major flood event, preventing timely access for purposes of weed control. There may also be impedance issues owing to the deposition of debris.
Control cost	Neutral	No change (once accessibility issues have been overcome)
Land manager participation	Negative	Other actions (e.g., replacement of infrastructure) likely to be prioritised.
Volunteer participation	Positive	Individuals from unaffected areas may volunteer.
Potential for off-target damage	Neutral	No change because desirable spp. will have chance to regrow/re-establish while site dries out.

A scoring system for post-border weed risk management feasibility

Virtue (2010) provided a simple and transparent scoring system to prioritise weed species for strategic management at a range of spatial scales. In this system, there were two key considerations in prioritising weeds for coordinated control programs—**weed risk** and **feasibility of control**. Virtue's system was designed for use in South Australia and a derivative, complementary system for New South Wales was established by Johnson (2009)

In both of these systems, a score for 'Feasibility of Containment' was generated by multiplying separate scores (each ranging between 0 and 10) for the three criteria of 'Control Costs', 'Current Distribution' and 'Persistence'. Scores for each of these criteria were generated from a series of multiple-choice questions (whose possible answers were "high", "medium", or "low"), with accompanying definitions to aid in the consistency of assessments.

The high/medium/low options used in Virtue's system comprise a ternary structure (see Table 3). A system in which simple 'yes' and 'no' answers were generated would be binary. In both structures, scores can be readily converted into management feasibility ratings.

Table 3. Scores from management feasibility assessments can be converted into management feasibility ratings. Here, scores are positively related to management feasibility.

Question type	Scoring	Management feasibility rating
Binary	1	Lower
	2	Higher
Ternary	1	Lowest
	2	Moderate
	3	Highest

Post-disturbance weed management feasibility modules

For the present exercise, a series of questions relating to the factors influencing weed risk management feasibility was established. These questions are set out in Box 1 and are employed in Post-Fire and Post-Flood Weed Risk Management Feasibility Modules in Boxes 2 and 3 respectively.

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Box 1. Questions for Post-Disturbance Weed Management Feasibility Assessment. Critical questions for the on-ground practitioner are underlined.

Recruitment dynamics (RD)

RD1 What is the reproductive strategy of the weed following a flood?

RD2 If recruitment of the weed occurs from seed, what is the pattern of emergence?

Life history characteristics (LH)

LH1 For weeds recruiting from seed, what is the minimum time to the production of sexual or vegetative propagules?

LH2 For resprouting weeds, what is the minimum time to the production of sexual or vegetative propagules?

LH3 For weeds establishing from fragments, what is the minimum time to the production of sexual or vegetative propagules?

Detectability (D)

D1 Can weed identity be ascertained early (by the emergence of the seedling's first true leaves)**?**

D2 Can weed seedlings be readily distinguished from those of native species?

D3 Can the juvenile (sub-reproductive) growth of the weed be identified easily?

Other management factors

Cost of control (CC)

CC1 Might repeated control efforts be required to kill individual plants that have regenerated by resprouting?

CC2 Is the plant community likely to be subject to grazing pressure during its recovery from flood? If so, might the weed be palatable at any stage of its life cycle?

CC3 Does the weed growth form differ from the dominant ecosystem growth form(s) such that selectivity of control increases?

CC4 For Transformer species that are targeted for coordinated control and reproduce by fragmentation, will the search-and-control area increase as a result of dispersal by floodwaters?

Control effectiveness (CE)

CE1 Is the weed a resprouting species?

Urgency (U)

U1 What is the degree of urgency for weed control?

Box 2. Post Fire Disturbance Weed Management Feasibility Module.

This module is designed to assess weed management feasibility relative to that which would have existed before the fire. The objective is to identify species differences in management feasibility as a basis for prioritisation for weed control after a fire. Some generic changes in management feasibility factors can be anticipated after a major fire (see Table 2). There should be increased within-site accessibility and a reduced cost of control, plus a reduced potential for off-target herbicidal damage, resulting from a marked reduction in above-ground biomass—these factors will likely be of little value in the prioritisation process. Similarly, the availability of resources (such as labour, equipment, and fuel and chemicals) is something that will determine the capacity to manage an asset as a whole, rather than providing a basis for discriminating amongst the weeds that are present. Such discrimination needs to be based on biological and ecological features of the weeds and how these might influence the timing and effectiveness of control efforts.

MF = Management Feasibility

Y = Yes; N = No; DK = Don't Know

Answers to questions that are underlined *are critically site dependent.*

Biological factors

Some weeds have highly persistent seed banks and germinate prolifically after fire. In the absence of targeted control efforts, they may increase in cover abundance locally and spread further through the landscape. Control of weeds that are adversely affected by fire (e.g., where mature plants are killed or reduced in size before they can reach the reproductive stage) presents an opportunity for changing the relative cover abundances of weeds vs native species in favour of the latter.

Recruitment dynamics (RD)

RD1. What is the reproductive strategy of the weed following fire?

Mass emergence of seedlings may necessitate control over a larger area than if only resprouters are present. Seedlings will generally be easier to kill than resprouters but may be difficult to control without reducing recruitment of native species.

From seed bank (soil or above-ground) only	*Lower MF*
Resprouting plus from seed bank	*Lower MF*
Resprouting only	*Higher MF*

RD2. If recruitment of the weed occurs from seed, what is the pattern of emergence?

Highly synchronised (a flush of seedling emergence occurs within weeks of germination-stimulating rainfall)	*Higher MF*
Protracted	*Lower MF*
Don't know	*Lower MF*

Reproduction (R)

The time that must elapse before a plant can reproduce will determine how frequently control measures must be applied (and hence the total control effort) to prevent this. Weeds that have the capacity to survive a major fire will likely reproduce more quickly than those that must regenerate from seed.

R1. For weeds recruiting from seed, what is the minimum time to the production of sexual or vegetative propagules?

Less than 1 year 1 to 3 years	*Lowest MF*
More than 3 years	*Moderate MF*
Don't know	*Highest MF*

R2. For resprouting weeds, what is the minimum time to the production of sexual or vegetative propagules?

Less than 3 months	*Lowest MF*
More than 3 months	*Moderate MF*
Don't know	*Highest MF*

Detectability (D)

Seedlings of both weeds and native species may be present post fire, so weed control may need to be delayed until weed seedlings are readily distinguishable.

D1. Can weed identity be ascertained early (by the emergence of the seedling's first true leaves)? *Y = Higher MF; N= Lower MF*

D2. Can weed seedlings be readily distinguished from those of native species? *Y = Higher MF; N= Lower MF*

D3. Can the juvenile (sub-reproductive) growth of the weed be identified easily? *Y = Higher MF; N= Lower MF*

Other factors

Cost of control (CC)

CC1. Might repeated control efforts be required to kill individual plants that have regenerated by resprouting?

Y = Higher MF;
N= Lower MF;
DK= Lower MF

CC2. Is the plant community likely to be subject to grazing pressure during its recovery from flood? If so, might the weed be palatable at any stage of its life cycle?

Y = Higher MF;
N= Lower MF;
DK= Lower MF

CC3. Does the weed growth form differ from the dominant ecosystem growth form(s) such that selectivity of control increases? For example, where a woody weed may be invading an herbaceous wetland community.

Y = Higher MF;
N= Lower MF;
DK= Lower MF

CC4. For Priority 1 species that reproduce by fragmentation, will the search-and-control area increase as a result of dispersal by floodwaters?

Y = Higher MF;
N= Lower MF;
DK= Lower MF

Control effectiveness (CE)

For some resprouting species rapid increase in leaf area in the first season post-fire may make a weed particularly susceptible to foliar-applied herbicides.

CE1. Is the weed a resprouting species?

Y = Lower MF;
N= Higher MF

Urgency (U)

Urgency is defined as the increase in total control effort that would be required to achieve maintenance control should there be a delay in action. The generic increases in weed management feasibility that occur following a major fire will, by nature, be time limited. The duration of this "enhanced management feasibility window" will be determined by environmental factors, especially rainfall and temperature. A long spell without rainfall post fire could mean, for example, that land managers and volunteers can attend to other critical needs and thus be available to manage weeds in a timely manner once significant rainfall occurs. Unfortunately, it would be difficult to predict with confidence the occurrence of rainfall (both timing and amount) post fire. Even in the absence of rainfall, however, weeds that resprout after fire will have an advantage in regaining reproductive status.

What is the degree of urgency for weed control?

Lower MF —The juvenile period of the weed is less than 2 months.
Higher MF—The juvenile period of the weed is 2 months or more.

Box 3. Post Flood Disturbance Weed Management Feasibility Module.

This module is designed to assess weed management feasibility relative to that which would have existed before a major flood. The objective is to identify species differences in management feasibility as a basis for prioritisation for weed control post flood. The net effect feasibility as a basis for prioritisation for weed control after a fire. Some generic changes in management feasibility factors can be anticipated after a major fire (see Table 3). There should be increased within-site accessibility and a reduced cost Prioritisation of weeds that are present in an asset needs to be based on their biological and ecological features and how these might influence the timing and effectiveness of control efforts.

The effects of major floods will depend upon floodwater velocity, which can be expected to vary over both space and time. Where the velocity is very high, a significant part of the standing vegetation and its associated soil seed banks may be removed, meaning that the post-flood environment will present a relatively "clean slate". At the opposite extreme (such as in broad floodplains), where water velocity has been mostly low or close to negligible, soil and biomass deposition will occur, and deep standing water may persist for some time.

MF = Management Feasibility

Y = Yes; N = No; DK = Don't Know

Answers to questions that are *__underlined__* *are* critically *site dependent.*

__Biological factors__

Some weeds have highly persistent seed banks and may germinate prolifically after a flood. In the absence of targeted control efforts, they may increase in cover abundance locally and spread further through the landscape. If more weed than native plants are killed by flooding, this will present an opportunity for changing the relative cover abundances of weeds vs native species in favour of the latter.

Recruitment dynamics (RD)

RD1. What is the reproductive strategy of the weed following a flood?

Mass emergence of seedlings may necessitate control over a larger area than if only resprouters are present. Seedlings will generally be easier to kill than resprouters but may be difficult to control without reducing recruitment of native species.

From pre-existing seed bank or seed deposited from floodwaters	*Lower MF*
Resprouting only	*Higher MF*
Resprouting plus from seed	*Lower MF*
From fragments deposited from floodwaters	*Higher MF*

RD2. If recruitment of the weed occurs from seed, what is the pattern of emergence?

Highly synchronised (a flush of seedling emergence occurs within weeks of germination-stimulating rainfall) *Higher MF*
Protracted *Lower MF*
Don't know *Lower MF*

Reproduction (R)

R1. For weeds recruiting from seed, what is the minimum time to the production of sexual or vegetative propagules?
Less than 1 year 1 to 3 years *Lower MF*
More than 3 years *Higher MF*
Don't know *Lower MF*

R2. For resprouting weeds, what is the minimum time to the production of sexual or vegetative propagules?
Less than 3 months *Lower MF*
More than 3 months *Higher MF*
Don't know *Lower MF*

R3. For weeds establishing from fragments, what is the minimum time to the production of sexual or vegetative propagules?

Less than 3 months *Lower MF*
More than 3 months *Higher MF*
Don't know *Lower MF*

Detectability (D)

Seedlings of both weeds and desirable species may be present post flood, so weed control may need to be delayed until weed seedlings are readily distinguishable.

D1. Can weed identity be ascertained early (by the emergence of the seedling's first true leaves)? *Y = Higher MF*
N= Lower MF

D2. Can weed seedlings be readily distinguished from those of native species?
Y = Higher MF
N= Lower MF

D3. Can the juvenile (sub-reproductive) growth of the weed be identified easily?
Y = Higher MF
N= Lower MF

Other management factors

Cost of control (CC)

CC1. Might repeated control efforts be required to kill individual plants that have regenerated by resprouting?

Y = Higher MF;
N= Lower MF;
DK= Lower MF

CC2. Is the plant community likely to be subject to grazing pressure during its recovery from flood? If so, might the weed be palatable at any stage of its life cycle?

Y = Higher MF;
N= Lower MF;
DK= Lower MF

CC3. Does the weed growth form differ from the dominant ecosystem growth form(s) such that selectivity of control increases? For example, where a woody weed may be invading an herbaceous wetland community.

Y = Higher MF;
N= Lower MF;
DK= Lower MF

CC4. For Priority 1 species that reproduce by fragmentation, will the search-and-control area increase as a result of dispersal by floodwaters?

Y = Higher MF;
N= Lower MF;
DK= Lower MF

Control effectiveness (CE)

For some resprouting species rapid increase in leaf area in the first season post-fire may make a weed particularly susceptible to foliar-applied herbicides.

CE1. Is the weed a resprouting species?

Y = Lower MF;
N= Higher MF

Urgency (U)

Urgency is defined as the increase in total control effort that would be required to achieve maintenance control should there be a delay in action. An asset is likely to be boggy for a protracted period after a major flood event, delaying access for purposes of weed control. In contrast to the situation with fire, repeated flood events may occur that prolong (or renew) the period of low accessibility and potentially affect the regeneration of both weeds and native species. The "window of opportunity" for weed control in this situation will be determined by weed biological characteristics, especially the rate at which a weed can reach the reproductive stage. (It is assumed that soil moisture will be non-limiting for a substantial period after a major flood has receded.)

What is the degree of urgency for weed control?

Lower MF —The juvenile period of the weed is less than 2months.
Higher MF—The juvenile period of the weed is 2 months or more.

Discussion

The semi-quantitative models currently employed have been fit-for-purpose, in the sense that in the absence of quantitative data they allow policy makers to derive estimates of a key component of weed risk analysis, i.e., management feasibility. However, on-ground practitioners have lacked assistance—a scoring exercise is unlikely to have much appeal to them and would be tedious to conduct for the number of sites that might need to be managed in order to protect biodiversity values.

For any given site, most practitioners will know the transformer species with which they are confronted, and also have a good sense of transformer life history traits, such as time to reproduction and the nature of soil seed banks. The difficulty in weed management lies in the identification of differences between native species and transformers relative to 1) patterns of seedling emergence; and 2) detectability in relation to growth stage. These two factors will determine the timing of control actions that attempt to address the trade-off between weed control and off-target damage during the period when both categories of plant are recovering from a major disturbance event.

The model that I am proposing should be robust, and also will encourage the practitioner to focus on factors that capture the fundamental problem of controlling transformers within a native species matrix—how to maximize control of the weed while minimising damage to the indigenes.

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