guideline

Weeds and rainforests

significant weeds and types

rainforest weeds

Rainforest weed management in Australia

This guideline highlights the significant weeds and weed types found in the subtropical and tropical rainforests in eastern Australia. It is the first in a series of three rainforest weed guidelines that are based upon the Weeds CRC's publication, *Habitat management guide – Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats.* The second guideline in this rainforest series considers weed dispersal and the effect of disturbance on weed invasion. The third rainforest guideline highlights the principles of strategic weed management. The *Habitat management guide – Rainforests* focuses on the ecological principles that govern weed invasion in rainforest habitats (particularly the sub-tropical and tropical rainforests of eastern Australia). These principles have three primary weed management goals:

1. Reduce the threat of weeds to rainforest habitat.
2. Create resistant habitat.
3. Manage for resilient landscapes.

The drier, semi-deciduous vine thickets, like those in the Brigalow Belt, or monsoonal vine thickets scattered over northern Australia, are not targeted in the management guide, however similarities will exist with respect to management principles.

VET sector resource: RTD5401A *Define the pest problem in a regional or broader context;* RTD5402A *Develop a strategy for the management of target pests;* RTC5519A *Conduct biological surveys.*

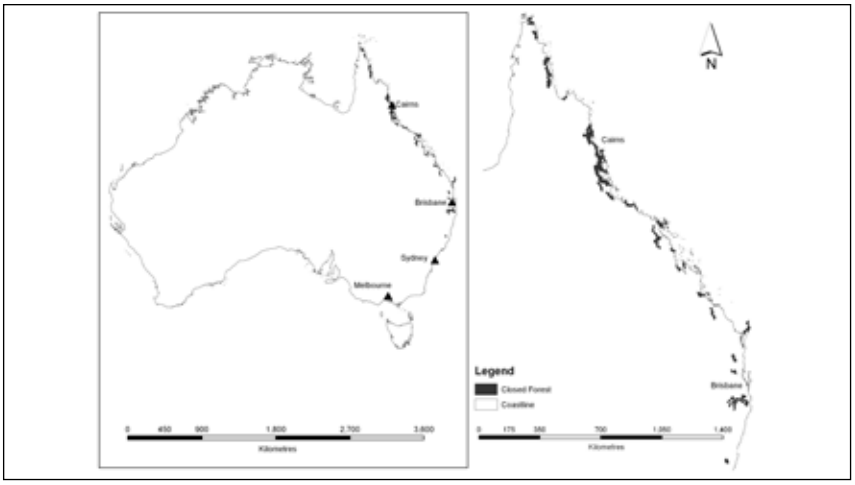
Rainforest characteristics

Rainforest types have several characteristics in common:

- *High species diversity and low species densities*. Tropical tree inventories typically show that the most abundant species are not very abundant in absolute terms, while rare species are extremely rare.
- *Relatively large proportion of shade tolerant species*. A small proportion of rainforest species may require a large gap to grow in (pioneer species). Many species require or prefer some level of open canopy for germination or growth (Denslow 1987).
- *Typically evergreen*. Tree ferns, cycads and epiphytes are abundant. Conifers also occur but not commonly. Herbs and grasses are sparse in the understorey except in gaps. Deciduous and semi-deciduous species do occur.

Rainforests in Australia

In Australia, rainforests are scattered across cool temperate, warm temperate, sub-tropical and tropical areas of Queensland, New South Wales, Victoria and Tasmania. Small patches are also found in north coastal Northern Territory and the Kimberley region of Western Australia (NLWRA 2001). Rainforests occur from sea level to high altitudes and normally within 100 km of the coast. They mostly occur in areas receiving more than 1200 mm of annual rainfall, or else within climatic and fire-proof refuges (NLWRA 2001).



The geographical distribution of eastern Australian rainforests 1980. Present vegetation at 1:5000000. The emphasis of this guideline is the sub-tropical and tropical rainforests of eastern Australia (eg Qld and NSW).
Figure: Geosciences Australia.

Weeds and rainforests

Tropical rainforests are becoming increasingly fragmented and impacted by human activities and weed invasion is now a major management issue.

Significant weeds of rainforests

There have been numerous attempts to list and classify the weeds that threaten rainforests (see Table page 3). Depending on their perspective and intent, these different lists describe weeds that:

- are in various stages of invasion
- have more or less serious potential impacts
- are suitable for eradication rather than containment or control
- are major problem weeds in other countries or
- are potential sleeper weeds.

Sleeper weeds

Plant species may be wrongly perceived to be not invasive (Grice and Ainsworth 2003). There are many examples of species that occurred in Australia for long periods before their populations spread to the point of being considered invasive (see Table page 3).

Five situations or characteristics that may restrict potential **sleeper weeds** include:

- current limited ability to adapt to the local environment
- spread limited by suitable habitat
- limited opportunities to colonise new habitat
- low population growth rates (eg long times to maturity)
- absence of mutualists (**mutualism** occurs when there is an association between organisms of two different species in which each member benefits eg plants and pollinators).

National eradication programs

Some of the exotic weeds occurring in Australia have the potential to seriously impact at the national level on the country's primary industries, trade, the economy and the environment. If the total elimination of a weed from Australia is justified and feasible, a national eradication program is implemented (see Table page 3).

Categorising plants

The high diversity of plant species in rainforests means that for convenience, species are placed into categories. These categories provide an imperfect but useful summary of plant ecological and invasive attributes. The categories assist with determining likely weed distributions and appropriate management responses.

The categories chosen will vary. For example, invasive and non-invasive rainforest plants can be categorised into a variety of **lifeforms** based primarily on their above-ground structure eg herbs, shrubs, vines and trees (see Table below).

Weed categorisation based on lifeform structure	
Lifeform structure	Information and example rainforest weeds
Grasses	Invasive grasses do not generally dominate intact rainforest habitat. They persist readily along the rainforest edges.
Herbs	Invasive herbs do not generally dominate intact rainforest. Common invaders of rainforest edges or in heavily disturbed areas: • thickhead (*Crassocephalum crepidioides*) • bluetop (*Ageratum conyzoides* ssp. *conyzoides*) • Singapore daisy (*Sphagneticola trilobata*).
Vines	Important part of sub-tropical and tropical rainforests (NLWRA 2001). In south-eastern and northern New South Wales sub-tropical rainforests, 70% of the exotic species are vines (ANPWS 1991). Most exotic vines were introduced for ornamental purposes and the majority of these originate from South America. Vines have the capacity to smother all layers of a rainforest from the canopy to the forest floor. Occurring in high or low light conditions, vines can smother disturbed and undisturbed forest, reduce light levels and alter microclimate conditions of the understorey (ANPWS 1991). Examples of problem vines in the sub-tropics include: • thunbergia (*Thunbergia grandiflora*) - fast growing and can reduce healthy rainforests to a stand of vine-draped poles within one to two decades (ANPWS 1991, Setter and Vitelli 2003). • cat's claw creeper (*Macfadyena unguis-cati*) • Madeira vine (*Anredera cordifolia*) • balloon vine (*Cardiospermum grandiflorum*) • *Asparagus* spp. • white moth vine (*Araujia sericifera*) • *Passiflora* spp.
Trees and shrubs (woody plants)	The most successful invasive trees are often ornamental or forestry escapees (Fine 2002). Problem weeds in tropical rainforest include: • pond apple (*Annona glabra*) • harungana (*Harungana madagascariensis*) • miconia (*Miconia calvescens*). Tree weeds In the sub-tropics include: • camphor laurel (*Cinnamomum camphora*) • large-leaved privet (*Ligustrum lucidum*) • small-leaved privet (*L. sinensis*). (ANPWS 1991)

Lists and classifications of weeds in rainforests		
Weed list, Act or Program	**Intention of weed list or list criteria**	**Number of weeds listed and example weeds found in rainforests**
Wet Tropics Weed List	Included in the publication, *Environmental weeds of the Wet Tropics bioregion: risk assessment and priority ranking.* This publication contains information gathered by Rainforest CRC scientists on invasive plants. The report was prepared as part of a consultancy for the Wet Tropics Management Authority.	504 species
Ranked Wet Tropics Weeds		Preliminary ranking of 57 species
Weeds of National Significance (WoNS)	Weed species that have management and funding priority. Species assessed against several criteria including: • invasiveness • impacts • potential for spread and • socio-economic and environmental values. • require long-term, strategically coordinated action at the national level in order to minimise their economic, social and environmental costs.	20 species Several of these WoNS species occur in and around rainforest landscapes: • lantana (*Lantana camara*) • pond apple (*Annona glabra*) • hymenachne (*Hymenachne amplexicaulis*) • cabomba (*Cabomba* spp).
National Environmental Alert List	Weed species that have management and funding priority. Complements the WoNS list.	28 species Includes the tropical weeds: • Siam weed (*Chromolaena odorata*) • laurel clock vine (*Thunbergia laurifolia)* • praxelis (*Praxelis clematidea*)
Sleeper weed list	Complements the WoNS list. Currently weeds that occur in low numbers but have the potential to increase their population size dramatically given the right conditions. Sleeper weeds are identified by the Bureau of Rural Sciences, in consultation with the Australian Weeds Committee.	Brillantaisia (*Brillantaisia lamium*) is currently listed as a Class 4 sleeper weed (species for which eradication is desirable but probably not feasible). It occurs in areas adjacent to rainforest in north Queensland and is somewhat shade-tolerant allowing it to potentially colonise gaps in intact rainforest and form dense mats, competing with native vegetation.
Land Protection (Pest and Stock Route Management) Act 2002	'Declared' plants listed in Act. Declared plants assigned to Class 1, 2 or 3. A range of statutory restrictions are activated depending upon the Class. This may include restrictions on the species: • sale • introduction • possession or • transport. There is a legal requirement on all landowners to take reasonable steps to keep their land free of Class 1 and 2 pests.	The full list of declared Class 1, 2 and 3 weeds can be seen on the Queensland Government web page associated with the Act (currently www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/4790_7005_ENA_HTML.htm). Declared Class 1 weeds occurring in and around rainforest landscapes include: • *Clidemia hirta* (Koster's curse) • *Miconia calvescens*, *M. racemosa* and *M. nervosa* • *Mikania* species • *Chromolaena odorata* (Siam weed) • *Cecropia* species • *Thunbergia annua*, *T. fragrans* and *T. laurifolia* • *Limnocharis flava* (Limnocharis).
Four tropical weeds eradication program	In 2001 a national, cost-sharing, weed eradication program commenced focusing on four Class 1 genera.	Six species: • *Clidemia hirta* (L.) D.Don • *Limnocharis flava* (L.) Buchenau • *Miconia calvescens* DC. • *Miconia nervosa* Triana • *Miconia racemosa* (Aubl.) DC. • *Mikania micrantha* (Kunth).
National Siam weed eradication program	This program commenced in 1995 to eradicate Siam weed (*Chromolaena odorata*) from Queensland where it is currently infesting areas in the Far North. It is recognised as one of the world's worst tropical weeds.	1 weed targeted Siam weed (*Chromolaena odorata*)

Functional traits of plants

Some plant characteristics or **functional traits** can increase the chance of a plant becoming weedy.

Functional groups

Functional groups represent sets of species that share similar traits such as:

- lifeform
- seed type
- dispersal mode
- shade tolerance.

The species in these functional groups exhibit similar responses to environmental conditions or have similar effects on the dominant ecosystem processes.

Traits of native rainforest species

It is common for native rainforest species to:

- tolerate shade well
- have fleshy fruits
- be trees.

Herbs and grasses are uncommon.

Traits of rainforest weeds

Most weeds that impact rainforest habitat are:

- intolerant of shade (an uncommon trait in the native flora)
- herbs or shrubs (trees are usually the most common lifeform among native species).

An invasions theory suggests that exotic species with traits that are absent or uncommon in the native rainforest flora may become invasive because they fill a vacant niche (*see next section*).

Niche space

A **niche** is the set of characteristics that define the environmental conditions under which a particular species is found and its role in an ecological community.

A species' niche represents the full range of physical and biological conditions under which it exists and can include parameters relating to:

- physical structure
- space requirements
- habitat
- response to environmental change.

Species diversity and invasion resistance

Rainforests are generally species diverse and are thought to resist weed invasion more readily because they utilise the available resources (eg space, light, soil nutrients etc) more fully.

Homogenisation occurs within a region when the species in the plant communities become similar to each other over time.

Homogenisation is driven by the:

- extinction of resident native species (losers)
- invasion of exotic species (winners).

Anzac flower (*Montanoa hibiscifolia*) (Asteraceae) is one weed that is able to retard the succession of native species in rainforest gaps eg at Crater Lakes National Park, Qld Photo: D. Metcalfe (CSIRO)..

Homogenisation might play a significant role in increasing the rate of spread of invasive species and decreasing community resistance to invasion.

The loss of ecological specialists from communities creates opportunities for other species to capture resources and

Invasive vines are able to smother native rainforest vegetation, (top L-R): water yam (*Dioscorea alata*), Photo: A. Ford (CSIRO); balloon vine, Photo: G. Vivian-Smith (QDPI&F); (bottom L-R): cats claw vine, Photo: Mariano Trevino (QDPI&F) and Matchbox bean vine, Photo: A. Ford (CSIRO).

may benefit further invasion. The result is a type of **invasional meltdown**, where invasive species in the system directly or indirectly facilitate the invasion of other species.

Disturbance and niche space

Disturbance plays a critical role in weed invasions in rainforests. It creates opportunities for weeds to claim previously utilised space and resources.

The impact of disturbance on rainforests and subsequent weed invasion is further discussed in the Weeds CRC's guideline, *Weeds and rainforests: impact of disturbance and dispersal on weed invasion*.

Example of weed invasion into vacant niches: Mabi Forest, Qld.	
Location	The Mabi Forest is found on the Atherton Tableland in north Queensland and is listed as a critically endangered ecological community. It is currently spread over remnant patches containing a total area of only 3.2% of its past extent (Goosem 2003).
Forest type	The Mabi Forest is listed as a complex notophyll vine forest - type 5b. The notophyll vine forest categories include a diverse group of communities. These communities occur on small areas of basic volcanic soils on cool wet uplands and highlands and on a range of drier sites at various elevations, on sandy beach ridges in drier coastal zones and exposed sites backed by foothills. These notophyll vine forest communities, are variable but can be characterised by: • a canopy range of 12 to 45 metres in height • rattans or palm lianes • strangler figs • frequently conspicuous epiphytes • variable amounts of ferns, walking stick palms and fleshy herbs.
Disturbance	Clearing of Mabi Forest has left a severely fragmented and modified landscape, comprising remnant patches of various sizes, shapes, connectivity and condition. Grazing and other incompatible land management practices in the landscape, contribute to ongoing degradation of Mabi Forest remnants. Highly fragmented ecosystems like Mabi Forest, with their abrupt boundaries and high edge-to-area ratios, are vulnerable to the destructive forces of a severe cyclone.
Weed invasion	Fragmentation has allowed weeds to displace native species. The dispersal of native seeds within the remaining forest has been threatened, as the forest fragments no longer support populations of the southern cassowary and musky rat-kangaroo, both of which are key seed dispersers in this rainforest.
Functional characteristics of native and invasive species	Murphy *et al*. (2006) undertook research to identify differences in functional characteristics between native and invasive species. The research showed that if an invading species is of a particular functional group not well represented within the native community, there is an increased likelihood of successful invasion. For example: • **rare native functional groups** include shade-intolerant and partly-tolerant species, particularly those with dry or large fleshy fruits. • **most common weeds** all have small, fleshy fruit which is a common trait in the native flora. This allows them to exploit the full range of bird dispersers; but they do not tolerate full shade (*Solanum seaforthianum*, *S. mauritianum*, *Lantana camara* and *Rivina humilis*). They therefore are able to disperse easily to disturbed areas but still fill a niche which is rare or vacant in the native flora, ie shade intolerant, and so have the capacity to out-compete native species during regeneration after disturbance.
National recovery plan for Mabi Forest	**Objective:** to protect and rehabilitate Mabi Forest and, where possible, expand Mabi Forest into adjacent areas through an integrated program of habitat protection, on-ground management, rehabilitation, research and public involvement. **Actions:** • mapping the extent of remnant and rehabilitating forest • undertaking biodiversity surveys of fragments to assess condition for priority protection and management • reviewing and evaluating the regional planning framework to ensure that conservation is promoted and incorporated appropriately in planning, management and development assessment • developing strategies to enhance protection and management of forest on private lands • rehabilitating disturbed areas and corridors based on established priorities • developing and implementing a weed management strategy • implementing a feral and domestic dog control program • minimising the impacts of roads and vehicles on wildlife • encouraging landholders to develop and implement land management practices that are compatible with recovery and agricultural sustainability • identifying information needs and design and conduct research • promoting and facilitating community and landholder involvement in recovery actions by raising community awareness • facilitating Aboriginal participation in implementation of actions and the use of traditional knowledge in Mabi Forest recovery.

Further information	
People to contact	**Publications**
Weeds Officers - at your local council, rural lands board, or state department of agriculture, primary industries, environment or natural resources. They have excellent local knowledge, a wide network of contacts and access to appropriate literature.	Bush invaders of south-east Australia - a guide to the identification and control of environmental weeds in south-east Australia. A.Muyt (2001). **www.weedinfo.com.au**
	Environmental Weeds: a field guide to SE Australia. Kate Blood (2001). **www.weedinfo.com.au**
Landcare, Bushcare or Catchment Management staff will have information on using herbicides in natural environments.	Bushland weeds. A practical guide to their management. Kate Brown and Kris Brooks, (2003). **www.weedinfo.com.au**
Helen Murphy CSIRO Sustainable Ecosystems Tropical Forest Research Centre PO Box 780, Atherton QLD 4883 **Helen.Murphy@csiro.au**	Introduced flora and its weed status **http://weedscrc.org.au/weed_management/intro_flora.html**
Websites	National recovery plan for Mabi Forest, **www.environment.gov.au/biodiversity/threatened/publications/mabi-forest-factsheet.html**
www.weedscrc.org.au CRC for Australian Weed Management	A global compendium of weeds **http://www.hear.org/gcw/**
www.weedinfo.com.au Weed information website providing information on weed identification, weed management and control of environmental and agricultural weeds.	Habitat management guide – Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats. **www.weedscrc.org.au/publications**
www.landcareaustralia.com.au Landcare Australia for general information on weed management.	Weeds CRC Guidelines (**www.weedscrc.org.au/publications**): Weeds and rainforests: impact of dispersal and disturbance on weed invasion. Weeds and rainforests: strategic weed management principles.

Weed management in rainforests

The principles of weed management in rainforests are the focus of the Weeds CRC's guideline, *Weeds and rainforests: strategic weed management principles*.

References

A complete reference list of the research referred to in this guideline can be found in the Weeds CRC's publication, *Habitat management guide - Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats* (www.weedscrc.org.au/publications).

For further information visit the website: www.dpi.nsw.gov.au/weeds

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Further reading: This guideline was adapted from the Weeds CRC's publication, *Habitat management guide – Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats*.

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guideline

Weeds and rainforests

impact of disturbance and dispersal on weed invasion

Rainforest weed management in Australia

This guideline highlights the effects of disturbance with respect to weed invasion on rainforests in the subtropical and tropical regions of eastern Australia. The methods of weed dispersal within these rainforests are also considered. This resource is the second in a series of three rainforest weed guidelines that are based upon the Weeds CRC's publication, *Habitat management guide – Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats.* The first guideline in this rainforest series considers the significant weeds and weed types in rainforests. The third rainforest guideline highlights the principles of strategic weed management. The *Habitat management guide – Rainforests* focuses on the ecological principles that govern weed invasion in rainforest habitats (particularly the sub-tropical and tropical rainforests of eastern Australia). These principles have three primary weed management goals:

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VET sector resource: RTD5401A *Define the pest problem in a regional or broader context;* RTD5402A *Develop a strategy for the management of target pests;* RTC5519A *Conduct biological surveys.*

Weed entry into rainforests

Large intact stands of rainforest usually have introduced plants only at their perimeter (Goosem 2003). These weeds are either:

- **shade-intolerant** and enter rainforests from the edges; or
- **shade-tolerant** and enter via dispersal agents (*see page 5*) and disturbance events (*see page 4*) and invade from within.

Undisturbed rainforest is generally resistant to invasion by weeds.
Photo: A. Ford (CSIRO).

Creation of forest fragments

Land clearing and human disturbance causes fragmented rainforest patches within a landscape (*see pages 3 and 4*).

Edge-influenced habitat

The creation of smaller, discrete rainforest fragments increases the amount of edge-influenced habitat.

These edges make the rainforest patches more exposed to wind, sunlight and drying and susceptible to weed invasion. Edge-affected zones as wide as 1 km have been reported for tropical forests, though most edge effects occur within 150 m in forest fragments (Laurance 2000).

Connectivity between fragments

In many tropical regions rainforest is cleared for agriculture or pasture. Strips of riparian vegetation are left along watercourses to protect against erosion, and isolated trees are left standing to provide shade for stock or for aesthetic reasons. Free-standing trees in the landscape surrounding rainforest patches may be important perch sites for fruit and seed eating birds (*see page 5*). Isolated patches of vegetation become frugivore magnets and foci for the recruitment of both native and introduced plant species.

Corridors, small fragments and even lone trees may serve as important stepping stones for pollinators and dispersers. These areas of vegetation increase the connectivity between larger patches of tropical forest and facilitate weed movement within the landscape (Buckley *et al.* 2006).

Social aspects of weed invasion

There are many ongoing social pressures on rainforest habitats which may be:

- obvious and complete (eg clearing for urban areas) or
- subtle (eg the proliferation of lifestyle parcels adjacent to rainforest).

The increase in the number of urban gardens and the proximity of new developments to rainforest mean that there must be a focus on weed management in these areas.

Impact of lifestyle blocks

Many lifestyle or hobby farmers live on small parcels of land around and beyond the urban fringe and may:

- plant tropical fruits, exotic flowers and ornamentals
- invest in plantation timber
- have farm animals including horses and cattle.

It is thought that:

- from anecdotal evidence, these people have limited knowledge about natural resource management but have strong environmental values.
- the impacts on existing rainforest fragments and remnant vegetation through increased disturbance and a mixture of management styles and goals can reduce the ecosystem properties that were the initial drawcard.
- the sheer number of these lifestyle properties means that they have the potential to significantly influence the dynamics of invasive species in a rainforest region. There are more than 2500 individual blocks of land of mixed tenure and management along the 3000 km boundary of the Wet Tropics World Heritage Area (Setter and Vitelli 2003).
- the dramatic growth in urbanisation in rainforest regions will provide sources of weed infestation.

Miconia - an example of an escaped garden plant	
Miconia in Australia	
Threat	Invasion of the Australian Wet Tropics rainforests poses a major threat to the World Heritage values of the area.
First introduction	Townsville Botanic Gardens in 1963 as seed from the Peradeniya Botanic Gardens in Sri Lanka (Csurhes 1998). Popularity of tropical foliage plants grew and by the 1970s plant nurseries in north Queensland were sourcing miconia plants mainly from Sydney, NSW and Tully, Qld.
Naturalised infestations	Two naturalised miconia infestations were discovered in north Queensland around 1996 (Csurhes 1998). 15 naturalised populations have been recorded.
Management	All naturalised populations are in various phases of an eradication program.
Miconia overseas	
Threat	Sometimes called 'the green cancer' in French Polynesia or 'the purple plague' in the Hawaiian Islands. Considered by scientists and land managers to be the worst pest plant in these two Polynesian archipelagos and potentially the most damaging weed of Pacific island rainforests.
Problem	Serious invader in the tropical Pacific, including the Hawaiian and Tahitian Islands. Forms extensive monocultures and dense thickets that have essentially taken over large tracts of rainforest habitat.
Introduction and spread	Thrived and spread to all the wetter habitats on Tahiti. Covers approximately 65% of the island after a single specimen was introduced to the Papeari Botanical Garden in 1937.
Cost	It is estimated that the planting of a handful of miconia trees in Hawaii for ornamental purposes in the 1960s has the potential to cost several billion US dollars of loss in revenue, stemming from a loss in biodiversity, increase in runoff and sedimentation, reduction in groundwater recharge and damage to infrastructure.

Impact of escaped garden plants on weed numbers

The majority of weeds in Australia have come from plants deliberately introduced for gardening, landscaping and agricultural production.

Miconia calvescens is one garden escape that threatens the World Heritage value of north Queensland rainforests. Here it has been found growing in a hanging basket in a garden in Cairns.
Photo: M. Blackwell (Biosecurity Qld).

Many of Australia's future rainforest weeds are yet to make the move from garden plant to weed and many exotic garden plants may also never become invasive. One of the most useful ways to determine if a species is likely to become invasive is its reputation elsewhere.

The Weeds CRC's, *The introduced flora of Australia and its weed status,* lists every introduced plant species in Australia, past and present and if, and where, it is 'weedy' elsewhere in the world. The publication aims to inform gardeners about potentially weedy plants that should be avoided.

Disturbance and weeds

There a number of different causes of disturbance in rainforests (*see Table page 4*).

Disturbance can be:

- a natural phenomenon in rainforests
- considered a key process in the maintenance of species diversity as it creates opportunities for species to claim previously utilised space and resources.
- the cause of modified conditions required for weed invasion (eg changes in temperature, humidity and / or light levels) depending on the type, extent and frequency.

Changes in tropical systems

Rainforest weeds rarely tolerate shade so some kind of minor disturbance resulting in an opening of the canopy is usually necessary for weed establishment.

Change in tropical plant communities is most likely due to a combination of:

- the **driver model** where an invasive species is directly responsible for its own dominance because it is a superior competitor and
- the **passenger model** where invasives are passengers to other types of disturbance.

For example, the weed, *Lantana camara*, requires light to colonise, therefore initially it may be considered a 'passenger' to some other kind of disturbance, but it may then competitively dominate native species, 'driving' subsequent community change.

Dispersal and weeds

Dispersal is one of the most important processes determining **invasion success**. There are a number of dispersal mechanisms (see Table page 5).

Seed shadows and dispersal curves

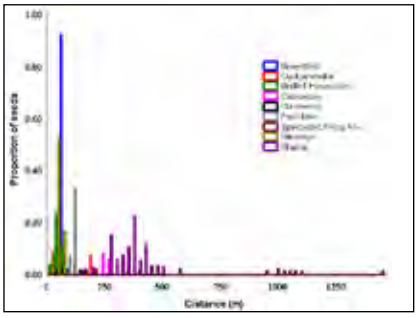
The pattern (shape and scale) in which dispersal occurs is called a **seed shadow**.

Seed shadows vary depending on:

- fruit characteristics (fleshy, dry, protected, size, shape)
- seed characteristics (shape, size, obtrusions)
- the dispersal vector(s) (social behaviour, fruit-handling techniques, gut-passage rates, patterns and distances of movement through time, prevailing winds, direction of water flow)
- plant-disperser interactions
- habitat structure within the landscape including landscape patchiness (Buckley *et al*. 2006; Stansbury and Vivian-Smith 2003; Westcott and Dennis 2003; Westcott *et al*. 2005; White *et al*. 2004).

Seed shadows usually demonstrate that most seed dispersal occurs:

- at relatively short distances from the parent plant; and
- in smaller proportions over longer distances.



Dispersal curves can be generated to show the distance a disperser moves seed. Captive feeding trials determine how long the disperser retains the seed. Continuous radio-telemetry of animals in the field shows how far it travels from the seed source.
Figure: H. Murphy (CSIRO).

Dispersal distance

Dispersal distances for a given species depend on the type, number and frequency of the dispersal mechanisms

Short-distance dispersal and weed invasion

The early stages of weed invasion are often characterised by one or a few patches that are much larger than all the others. These large weed patches are most easily detected.

Short distance seed dispersal:

- maintains and replenishes the weed patches; and
- contributes to the increase in local weed density and spread.

Long-distance dispersal and weed invasion

Long-distance dispersal is:

- rarer and harder to measure than short-distance dispersal.
- most influential in determining the rate and pattern of spread across the landscape even if the dispersal event is rare.
- commonly found to involve unique mechanisms over very long-distances.
- primarily responsible for the establishment of new **satellite populations** in tropical forest.

A single seed dispersed over a long distance may result in a new infestation far from the established infestation.

Management of weeds

The principles of managing the rainforest weed populations are discussed in the Weeds CRC's guideline, *Weeds and rainforests: strategic weed management principles*.

The significant weeds and weed types in rainforests are discussed in the Weeds CRC's guideline, *Weeds and rainforests: significant weeds and types*.

Types of disturbance		
Type	**Cause of disturbance and comments**	**Example**
Natural	**Cause:** seasonal rainfall and flooding or large-scale disturbance eg fire, cyclones and landslides. **Comments:** *Seasonal rainfall and associated flooding* can result in high velocity flows and erosion. *Large-scale disturbance* events such as cyclones, fire and landslides can cause large-scale defoliation, loss of major branches and multiple tree falls. These areas are more susceptible to invasion because weed seeds, by chance, are more likely to arrive in them than they are in small-scale disturbances. *Gaps:* Windthrown trees, treefalls and large broken branches create a mosaic of light gaps and opportunities for invaders in tropical forests (Sanford *et al.* 1986). Small gaps may only have a marginally improved light regime that is unsuitable for shade-intolerant species and so shade-tolerant species may be favoured (Hartshorn 1980). Clumped patterns of disturbance may be common in tropical forests with these gap clusters sometimes formed by multiple treefalls during disturbance events.	Areas affected by large-scale disturbances such as cyclones may have • a slower recovery rate (Boose *et al.* 2004). • a wider window of opportunity and range of opportunities, for colonisation by invasive plants. • increased opportunities for weed invasion as wind and flood waters may carry seeds over long distances. If the number or intensity of cyclones becomes greater due to changes in climate, opportunities for plant invasions over large scales will also increase.  Cyclone damage opens the canopy and permits high light levels to reach the forest floor. Photo: T.Sydes, (Biosecurity Qld).
Diseases and pest	**Cause:** invasive species themselves eg introduced animal activity or effects of disease. **Comment:** *Introduced animal pests* can disperse weed seed into new areas and over long distances.  Pig damage in the understorey of a rainforest. Photo: D. Metcalfe (CSIRO).	Root rot fungus, *Phytophthora cinnamomi* • First recorded in north Queensland rainforests in 1975 and associated with patches of defoliation, crown dieback and plant death (Gadek 1999). • In areas showing symptoms opportunities for invasion arise with an opening of the canopy, disruption to habitat structure or the death / reduced health of native plants. • Introduced species that are resistant to Phytophthora or require light are then given opportunity for entry, establishment and spread within a rainforest. *Feral pigs* (*Sus scrofus*) help pond apple (*Annona glabra)* to proliferate (Setter *et al*. 2002) in areas where it currently occurs by: • dispersing seed up to 10 km (only about 2% of seed survives passage through the gut). • destroying existing vegetation • creating ideal conditions for germination with soil disturbance. Germination of defecated seed is assisted by warm, moist conditions and ready fertiliser.
Human	**Cause:** 200 years of European settlement (construction of roads, clearcuts, logged areas and development of agricultural crops as well as from urban development and industry). **Comments:** *Eastern Australian rainforests:* large areas have been cleared and landscapes fragmented. Approximately a quarter of the pre-European settlement rainforest still exists. *Wet Tropics*: contain more than 75% of the original rainforest vegetation. *Wet tropics - lowlands and fertile uplands*: some communities at less than 10% of pre-European settlement levels.	*Planned disturbances* eg community service corridors (power easements, roads, walking tracks), logging, transport corridors, etc • Typically different from natural disturbances and often disrupt the soil profile over a large scale. • Areas left to 'revegetate' naturally usually contain the highest richness and abundance of invaders (Hobbs 2001; Hansen and Clevenger 2005). • Community service corridors and riparian zones act as weed reservoirs and are primary conduits for weed spread. • High concentrations of weeds are observed in transport corridors (Panetta and Hopkins 1991; Hansen and Clevenger 2005). Traffic aids in the dispersal of weeds into surrounding habitat by causing air turbulence and by acting as vectors for spread of seeds and vegetative plant parts (Hansen and Clevenger 2005). • Revegetation plans are often used to minimise disturbance to, and reconstruction of, the soil profile after disturbance. Sampling the pre-disturbance seedbank can assist in determining whether exotics might become abundant at a site. (van der Valk and Pederson 1989).

Methods of dispersal		
Method	**Cause of dispersal and comments**	**Examples**
Frugivore	**Cause** A large proportion of plant species in Australian tropical rainforest habitats have fleshy fruits that are eaten by birds and animals. Birds are particularly important dispersal agents of invasive species in tropical rainforests. **Comments** Opportunities for invasion by fleshy-fruited weed species is often enhanced by the distance involved in bird movement and greater time in the air (Werren 2003). *Seed spread* can be random, directed, scattered or clumped, with the latter resulting in the deposition of multiple species and a potential suite of introduced plants establishing together (Stansbury and Vivien-Smith 2003). *Probability and quality of seed dispersal* affected by: • fruit morphology eg seed size, colour, nutritional quality, fruit crop size, presentation and accessibility (Dennis and Westcott 2007). • fruit timing eg where fruit is present on the plant for long periods this increases opportunities for bird dispersal, and fruiting when native fruit production is limited allows fruit to be more readily consumed by frugivores (Gosper *et al.* 2005).	A survey conducted in south-east Queensland and northern New South Wales found that fruit from one weed species could be consumed by up to 20 different frugivorous bird species (Stansbury and Vivian-Smith 2003). The results also indicated that fruit size was the most important trait determining fruit choice by birds.  Birds such as metallic starlings consume a wide variety of rainforest fruits and therefore aid in dispersal. Photo: A. McKeown (CSIRO).
Wind and water	**Cause** Environmental factors such as wind, water and soil. **Comments** *Wind* can remove seeds or fruit from the parent plant under intact rainforest canopies to allow short-distance dispersal. However cleared patches of land create significant air movement, and transport corridors can act as funnels for seeds such that wind-dispersed seeds like those in the Asteraceae family can travel long distances (Goosem 2003, Metcalfe *et al.* 2008). *Water* can disperse seeds in a number of ways: • Seeds can fall into water and be moved with the current • Raindrops impact onto the fruiting body causing expulsion of seed (Westcott and Dennis 2003). • Rapid and wide-spread dispersal can take place where seasonal flooding occurs.	Some invasive species in tropical regions show capacity to spread over long distances via water movement. • Cat's claw creeper (*Macfadyena unguis-cat*), balloon vine (*Cardiospermum grandifolium*) and moth vine (*Araujia sericifera*) have lengthy buoyancy periods indicating a strong capacity for fruits to be spread downstream (Vivian-Smith and Panetta 2005). • Pond apple (*Annona glabra*) seed viability in marine environments is currently being investigated and research suggests that fruit and seeds are buoyant and can survive very long periods in both salt and fresh water (S. Setter, pers. comm. 2008). Floating plant parts facilitate efficient dispersal in flowing water and can significantly increase weed distribution during seasonal flooding. Plants generally establish in areas of slow river current, and in particular pond apple poses a significant threat to disturbed (flood prone) ecosystems including high water marks in coastal riparian and rainforest communities (Holloway 2004).
Human-mediated	**Cause** *Dispersal vectors*: • Contaminated grain, soil and gravel, stock movement, and machinery and vehicle movement. • Sale and exchange of garden products and landscaping materials. • Roads provide a pathway for weed seeds to be moved over very long distances. • Roadsides often provide very good conditions for weed establishment. **Comment** An analysis of potential dispersal vectors of all noxious weeds in Australia in 1995 revealed that humans contributed to the dispersal of nearly 90% of these species with 21% dispersed by humans alone (Panetta and Scanlon 1995).	

Further information	
People to contact	**Publications**
Weeds Officers - at your local council, rural lands board, or state department of agriculture, primary industries, environment or natural resources. They have excellent local knowledge, a wide network of contacts and access to appropriate literature.	Bush invaders of south-east Australia - a guide to the identification and control of environmental weeds in south-east Australia. A.Muyt (2001). **www.weedinfo.com.au**
	Environmental Weeds: a field guide to SE Australia. Kate Blood (2001). **www.weedinfo.com.au**
Landcare, Bushcare or Catchment Management staff will have information on using herbicides in natural environments.	Bushland weeds. A practical guide to their management. Kate Brown and Kris Brooks, (2003). **www.weedinfo.com.au**
Helen Murphy CSIRO Sustainable Ecosystems Tropical Forest Research Centre PO Box 780, Atherton QLD 4883 **Helen.Murphy@csiro.au**	Introduced flora and its weed status **http://weedscrc.org.au/weed_management/intro_flora.html**
Websites	National recovery plan for Mabi Forest, **www.environment.gov.au/biodiversity/threatened/publications/mabi-forest-factsheet.html**
www.weeds.crc.org.au CRC for Australian Weed Management	A global compendium of weeds **http://www.hear.org/gcw/**
www.weedinfo.com.au Weed information website providing information on weed identification, weed management and control of environmental and agricultural weeds.	Habitat management guide – Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats. **www.weedscrc.org.au/publications**
www.landcareaustralia.com.au Landcare Australia for general information on weed management.	Weeds CRC Guidelines (**www.weedscrc.org.au/publications**): Weeds and rainforests: significant weeds and weed types. Weeds and rainforests: strategic weed management principles.

References

A complete reference list of the research referred to in this guideline can be found in the Weeds CRC's publication, *Habitat management guide - Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats* (www.weedscrc.org.au/publications).

For further information visit the website: www.dpi.nsw.gov.au/weeds

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Further reading: This guideline was adapted from the Weeds CRC's publication, *Habitat management guide – Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats*.

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guideline

Weeds and rainforests

strategic weed management principles

rainforest weed management

Rainforest weed management in Australia

This guideline highlights the principles of weed management for the subtropical and tropical rainforests in eastern Australia. It is the third in a series of three rainforest weed guidelines that are based upon the Weeds CRC's publication, *Habitat management guide – Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats.* The first guideline highlights significant rainforest weeds and weed types The second guideline in this rainforest series considers weed dispersal and the effect of disturbance on weed invasion. The *Habitat management guide – Rainforests* focuses on the ecological principles that govern weed invasion in rainforest habitats (particularly the sub-tropical and tropical rainforests of eastern Australia). These principles have three primary weed management goals:

1. Reduce the threat of weeds to rainforest habitat.
2. Create resistant habitat.
3. Manage for resilient landscapes.

The drier, semi-deciduous vine thickets, like those in the Brigalow Belt, or monsoonal vine thickets scattered over northern Australia, are not targeted in the management guide, however similarities will exist with respect to management principles.

VET sector resource: RTD5401A *Define the pest problem in a regional or broader context;* RTD5402A *Develop a strategy for the management of target pests;* RTC5519A *Conduct biological surveys.*

Weed detection

Weed management guides often assume that weeds are readily detectable and that available resources are the major limitation to weed control The reality of detecting and managing weeds in tropical forests is very different.

Detection of rainforest weed infestations

The search and eradication of weeds in rainforests is severely hampered by dense vegetation, high species diversity, difficult terrain, trying climatic conditions and remoteness of much of the area from vehicle access.

Even a high density weed infestation in its early stages may be difficult to detect and the discovery of a satellite infestation can present a major challenge. Therefore neither reducing seed dispersal from larger source populations, the power behind the establishment of new satellite infestations, nor the establishment or rate of spread of satellite populations can be ignored since both can continue to contribute to 'invisible' weed spread.

Identifying weeds

The significant weeds and weed types in rainforests are discussed in the Weeds CRC's guideline, *Weeds and rainforests: significant weeds and types*.

The high native species diversity and vegetation density means that ground crews are often best suited to the difficult search task of finding new weeds. On many occasions these crews will be only a couple of metres away from a plant when it is detected. When plants are young, it can also be difficult for the search crews to identify new problem weeds from native species.

Controlling weeds

Once rainforest weeds are identified, control operations are often undertaken on foot and commonly manual control methods are required. Broad-scale herbicide use is rarely an option in or close to rainforest and biocontrol has not been particularly successful with rainforest weeds.

Detection and management of rainforest weeds can often by difficult due to factors such as dense vegetation and difficult terrain. Photo: Carl Gosper.

Resilience and resistance in rainforests

Resilience and resistance are useful concepts for considering ecological objectives for weed management in rainforests.

Resilience

Resilience is often described as the capacity of a system to undergo disturbance, and still maintain its functions. A patch would be considered resilient if, despite becoming invaded, there is no significant change in its native species diversity, ecological function or some other ecological value.

Resistance

Resistance is the ability of a system to be proofed against disturbance. For example, a patch of habitat might be considered resistant to invasion if it remains relatively uninvaded over long-periods of time despite high external pressure from surrounding land-uses.

Principles of strategic weed management

The strategic weed management principles proposed here have three over arching goals:

1. Reduce the threat of weeds to rainforest habitat
2. Create resistant habitat
3. Manage for resilient landscapes.

These key principles form the basis of a robust weed management strategy.

A weed management strategy needs to be:

- based on a sound knowledge and understanding of a given landscape
- adaptable and not a rigid set of instructions
- a long-term plan of actions
- able to take account of potential time-lags
- able to anticipate future scenarios and circumstances.

Building knowledge will take time, and needs to be compiled to inform the principles and translate them into strategic management guidelines.

Management approaches

Introduction of invasive species in tropical systems has far out paced the ability of researchers and managers to:

- study the consequences of,
- develop a management strategy for, or
- implement control for,

every established species (Radosevich *et al.* 2003; Marvier *et al*. 2004).

Furthermore, ecological information on invasive species is often incomplete, not quantitative, nor relevant to its invaded range (Mack 1996). A range of strategies are necessary for rainforest weed management. Strategies may target (see Table page 3):

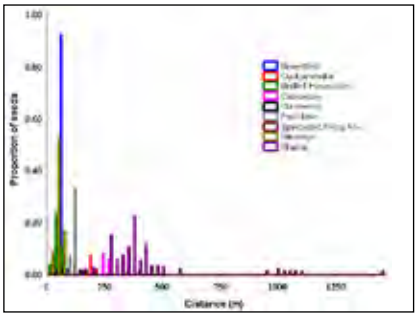
- high-risk single species
- suites of species
- entire landscapes.

It is necessary to prioritise the control of source populations on dispersal highways eg weed population A located in a riparian area and wind dispersed weed population B are a high control priority.
Figure: Qld DNRMW

Reducing the threat of weeds to rainforest habitats

The first step in reducing seed sources and dispersal potential is to identify and control priority populations ie:

- populations that may contribute disproportionately to the tail of the long-distance dispersal curve (see figure below), and
- major source populations or populations at risk of becoming sources.



Populations that contribute disproportionately to the tail of the long-distance dispersal curve should become a priority for control.
Figure: H. Murphy (CSIRO).

Managing long-distance dispersal

Populations are considered important sources if they are located on the equivalent of a **dispersal highway**. Examples of species located on a dispersal highway may include:

- a fleshy-fruited woody weed located in a riparian area a short distance away from another riparian network which has connectivity to large patches of uninfested habitat (*see population A in figure left*).
- a wind-dispersed species located on a major transportation corridor close to a divergence leading to currently uninfested patches of habitat (*see population B in figure left*).

For wind- and water-dispersed species, 'upstream' populations may be more important for control regardless of their size since they may contribute more to long-distance dispersal.

Managing sources and satellites

Resources for prevention and control of invasive species are finite, making decisions about where to direct resources an important consideration.

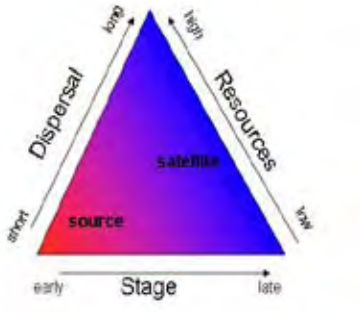
Most control and eradication programs include a mix of source and satellite control.

Prioritising investment to control weeds

The figure below illustrates where the higher proportional investment should be directed.

When developing strategies for control of sources and satellites each weed species or group of weed species will need to be assessed in terms of the:

- particular functional type of weed and predominant dispersal distance, particularly the capacity for long-distance dispersal
- stage of invasion (early or late)
- resources available for management (high or low)



Prioritisation of the control of weed sources (red) and satellites (blue) in rainforests requires the consideration of the i) stage of weed invasion, ii) weed dispersal and iii) available resources.
Figure: H.Murphy, (CSIRO).

Approaches to weed management	
Approach type	**Comments**
Single species	Often necessary for high-risk or high-impact species eg those targeted under national eradication programs or for WoNS species. Tactics should still be considered in terms of the three strategic level principles (see page 2). Similar to the 'umbrella species' approach in conservation management strategies. Land management decisions, (eg habitat size, distance from other communities and risk from threatening processes), are based primarily on one species and the needs of other species present are then automatically met. Other benefits include: • identification of important processes of invasion which can then be applied to other species (Lindenmeyer *et al.* 2008), and • opportunistic targeting of other invasive species.
Multiple species and landscape-level	Landscape-level management of invasive species necessarily involves consideration of multiple species. invasive species in tropical regions are highly diverse and are characterised by a variety of life-history traits, growth forms and seed dispersal vectors. **Functional classification** Classifying species into functional groups allows consideration of the effects of management on groups of species that can be expected to respond in a similar way (Gosper *et al.* 2005) (see Guideline 1). Species are classed as either pioneers or non pioneers based on some combination of morphological or ecological traits (Köhler and Huth 1998; Slik 2005). Native rainforest species are usually classified on the basis of: • shade tolerance; and • regeneration strategy. Dispersal plays a key role in landscape-level population dynamics and the attributes influencing the primary dispersal agent or mode (eg adaptations for particular modes of dispersal or to attract particular dispersers) is an important consideration in any functional classification (Westcott and Dennis 2003; Westcott *et al.* 2008). Many management strategies will be similar for woody, fleshy-fruited species, for wind-dispersed herbaceous species, or for tropical vines, although the method for on-ground tactical control might be quite different. **Habitat patches** Rainforest habitats of eastern Australia: • are embedded in multi-use landscapes • have a variety of ecological, social and economic values. • can be very large swathes of habitat • can be patches of all shapes and sizes • can be surrounded by highly modified land-uses • can be connected by corridors of habitat. The area of a particular habitat type rarely reflects the amount of suitable habitat for a given species. Habitat for some species is strongly associated with extensively modified landscapes characterised by long-standing human use (Lindenmeyer *et al.* 2008). Patch-based habitat management is the norm in multi-use landscapes. However: • if a single patch is subjected to intense invasives management it may still degrade if the surrounding landscape continues to contribute to the problem. • patches need to be assessed and managed within the context of the landscape mosaic and the interactions among patches and the surrounding matrix (Lindenmeyer *et al.* 2008, Murphy and Lovett-Doust 2004).

Reducing the threat of weed invasion: identifying populations and prioritising their management	
Long-distance dispersal	**Comments**
Water-dispersed species	**Upstream populations** may be more important for control regardless of their size since they may contribute more to long-distance dispersal eg targeting upstream populations in a catchment before spending time and resources on downstream areas will greatly reduce the probability of reinfestation of downstream areas following control. Reducing connectivity between different drainage networks where possible (eg by use of fencing when networks are separated by grazing landuse and when cattle are dispersal vectors) together with targeting potential source populations for control, may be effective in some circumstances, particularly when drainage networks are located relatively close together. Backflow of floating seeds up drains and creeks during flooding may also increase dispersal of some species (Swarbrick 1993). Anticipatory management of these potential avenues of dispersal such as through restoration of natural levee banks to reduce overspill, may reduce the probability of immigration upstream. However, it should be remembered that secondary dispersal modes, such as dispersal by animals, may move propagules across these barriers producing patterns of spread that are unexpected (Westcott *et al.* 2008).
Wind-dispersed species	A large population of a wind-dispersed invasive species located on the side of a hill or on a major transportation easement might contribute disproportionately to seed dispersal.
Animal-dispersed species	Control practices could be prioritised for populations located in areas more heavily utilised by potential long-distance dispersers. **Example: Cassowary dispersal of pond apple** The situation where an endangered native species, such as the cassowary in North Queensland, acts as the primary biotic dispersers of the invasive pond apple (*Annona glabra*), requires some balanced management. Cassowary dispersal can be long distance and differs from the dominant water dispersal mode in that cassowary-dispersed infestations can be established up-stream from the source infestation, or even across drainage boundaries and into previously uninfested drainages (Westcott *et al.* 2008). Control of pond apple populations in areas heavily utilised by cassowaries, including in corridors of native vegetation within the matrix, would serve to reduce propagule pressure at the long-distance tail of the dispersal curve. Management of pond apple must also consider the needs of cassowaries. Due to the restricted and fragmented nature of cassowary habitat in coastal areas of the Wet Tropics, complete pond apple removal may (at least temporarily) be detrimental to some cassowary populations. Control programs should include revegetation with appropriate cassowary food plants, and perhaps staggering control efforts over time.
Human mediated dispersed species	The prevention of the spread of weed seeds via movement of people and vehicles is a crucial element in containing long-distance dispersal. This will primarily be managed through education and awareness of these pathways of weed spread and the availability of suitably placed wash down facilities. The Queensland Weed Spread Prevention Strategy 2002–2006 and the Far North Queensland Regional Organisation of Councils Regional Weed Spread Prevention Strategy (2007–2009) outline actions for minimising the spread of weed seeds.
Scale of invasion	**Comments**
Source populations (high density)	Ecological theory suggests prioritising control of large populations, because these supply the majority of seeds at a regional scale. Furthermore, in tropical rainforests where logistics make searching for isolated populations or individuals resource intensive, these are the easiest populations to locate and delimit. Researchers agree that early in the invasion 'offensive' tactics (that is preventing spread from invaded areas) reduces overall spread rates. As a general rule, current research indicates that if an invasion is in the early stages and resources are limited, and when short-distance dispersal predominates, management should target high-density, or source populations.
Satellite populations (outlying, low density)	The results of some models highlight eradication of small outlying populations, or satellites, since these contribute the most to range expansion (Moody and Mack 1988; Higgins *et al.* 2000) and eventually become sources themselves. At later stages of the invasion, and particularly when long-distance dispersal is common, more resources should be invested in satellite populations regardless of the amount of resources available.
Uninvaded locations	Research has also shown that later in the invasions process after many areas are already invaded, 'defensive' tactics, that is preventing spread to uninvaded locations, reduces overall spread rates (Drury and Rothlisberger 2008).

Creating resistant habitat

Managing edges

The spread of weeds into a rainforest can be reduced by managing the vegetation structure at rainforest edges. Rainforest edge management includes:

- minimising the impact of changes to the edges' physical condition and
- removal of weeds from the edges.

Creation of hard edges

Habitat fragmentation and the associated impacts of edge effects cause hard edges between natural and human environments. In rainforest ecosystems this leads to a break down in the natural buffering ability of dense rainforest canopies and provides suitable habitat for light-loving weeds.

Soft edges and buffer strips

Buffer-strip planting is a restoration technique that can reduce weed incursions in fragmented rainforests. It aims to soften the transition zone edges and restore the rainforest's natural buffering ability (see Table below).

Managing the matrix

When creating a rainforest that is resistant to weed invasion it is important to identify the key landscape elements in the matrix that contribute disproportionately to weed dispersal (see Table page 6).

Weed spread into rainforests can be reduced by managing the hard edges (eg those bordering a cleared area of land) and soft edges (eg those bordering a buffer strip of native vegetation) surrounding the rainforest fragments.
Figure: H.Murphy, (CSIRO).

Managing succession

Extinction rate of weeds

After a disturbance occurs, suitable patches for most tropical forest weeds will only exist early in the successional process. The older a patch is the higher the extinction rate of the weed population (see Table page 6). Accelerating the successional process will shorten the time to extinction of a weedy population (Johnson 2000; Boughton and Malvadkar 2002).

Managing landscapes for resilience

Managing weed response to disturbance

The impact of disturbance on rainforests and subsequent weed invasion is further discussed in the Weeds CRC's guideline, *Weeds and rainforests: impact of disturbance and dispersal on weed invasion*.

Predicting species' responses to disturbance has been a major focus of ecological research (see Table page 7). In many cases weeds are opportunists that take advantage of environmental mismanagement and degradation (ie they are passengers to disturbance). Consequently efforts to manage weeds may be repeatedly frustrated while the underlying environmental problems remain unresolved (Hulme 2006).

If weed establishment is enhanced by disturbance, then weed management may cause a 'weed-shaded hole' providing ideal conditions for re-invasion by the same or another invasive species (Buckley *et al.* 2007).

Pro-active planning for weed management following cyclones

Extreme natural disturbances can have profound effects on rainforests, and are difficult to predict and manage. Rather than allowing extreme events to drive management responses, these events can be anticipated and appropriately planned responses implemented.

Weed invasion following a disturbance such as a cyclone occurs for a number of reasons, including:

- the creation of ideal conditions for weed regeneration due to higher light levels in the understorey and
- the increased likelihood of weed seed spread due to the urgency of clearing debris from roads and easements and the restoring of services. There is also an influx of external operators, resources, heavy machinery and equipment from across and outside the region and a lower priority is given to hygiene measures.

Casestudy: Creation of soft edges, Mabi Forest	
Background	In 1993, a 30 m to 40 m buffer strip of native rainforest species was planted along the perimeter of the Malanda Scrub (Mabi Forest) and the Malanda Falls Scenic Reserve.
Effectiveness of buffer strip	An evaluation of the buffer strip (Laura Sonter, University of Queensland Honours Project 2008) fournd: • a reduction in the overall weed abundance on restored edges. • subsequent protection of the interior from further weed invasions. • successful softening of edge transition zones between the interior and the surrounding human-created environment. In this instance, the buffer strip planting was shown to be a suitable tool for reducing weed abundance in tropical rainforest fragments.

Creating resistant habitat	
Management	**Comments**
Edges	Edges are the point of entry for exotic species invasion (Cadenasso and Pickett 2001). **Patch edge:interior area ratios** can be minimised by reducing the exposure of native habitat patches to these external influences. Realistically, once a landscape is fragmented it is difficult to influence patch edge:area ratios other than by: • maintaining large, continuous patches of habitat, and minimising fragmentation of existing large patches. The effect of edges is reduced as larger patches have a lower edge:area ratio. • strategic revegetation eg infilling of gaps (particularly linear disturbances in forest fragments) or the creation of buffer zones. Circular or square patch shapes have the lowest edge:area ratios. The more irregular the patch shape, the greater the edge:area ratio and the more interior habitat is influenced by edge effects. **Edge sealing** will decrease the **permeability of edges** to key weed dispersers (Cadenasso and Pickett 2001) and to the physical influences that modify edge habitat (Harper *et al.* 2005). Forest edges are: • a favoured feeding site for many frugivorous birds. Plants there may have more rapid removal of their fruits (Galetti *et al.* 2003). • a favoured route for movement of some disperser species (Levey *et al.* 2005) and consequently might be expected to be subject to increased seed deposition. • found to have less pronounced edge-related gradients in biophysical variables (such as light, heat and wind) when the adjoining habitat is more similar in structure to that of the rainforest fragment. **Hard edges** are impenetrable boundaries that some dispersing individuals never cross and in which native species never recruit, eg the boundary between a cane field and a rainforest patch. **Soft edges** are very permeable to dispersers where recruitment of natives is possible, eg edge between a mature forest patch and regrowth forest (Stamps *et al.* 1987). Maintaining soft edges as a buffer around rainforest patches wherever possible will minimise the likelihood of weeds permeating into rainforest patches. **Buffer zones** can be used to minimise the influence of edges on natural forest habitats. The sustainability of a rainforest is at risk when it is unable to regenerate at its edge or to buffer its interior. For example they are a useful management strategy where tropical forest remnants are embedded in agricultural land on which burning or herbicide application is routinely carried out. Buffer zones can be created between forest and farming land and managed to resemble a natural ecotone. This allows a transition from forest to matrix habitat, rather than an abrupt edge (Gascon *et al.* 2000). In areas where matrix habitat is more similar to the native habitat, most edge effects will either remain stable over time or decrease as vegetation regenerates along a fragment's edge (Gascon *et al.* 2000). In such cases, normal forest succession occurring at the edge may at least achieve a balance between exposure and regeneration, where the interior of the fragment is buffered and retains most of its primary forest character (Gascon and Lovejoy 1998).
Matrix	**Considerations:** *Isolated, standing invasive trees planted or established in human-managed landscapes.* Removal needs to be thoughtfully considered. Research suggests they may contribute disproportionately as sources of seed within the landscape and importantly may play a landscape connectivity role for dispersal of native species. If they serve as perching sites for birds or are utilised by other vertebrates for foraging or as stepping stones, they should be replaced with appropriate native species and in the short term with structures, which could be the tree itself killed off but left standing, to encourage continued use by dispersers of native species. *Isolated standing native trees in highly modified habitats.* Research suggests that they may contribute significantly to successional patterns in nearby rainforest patches. Planting early successional native trees in cleared land, or preferably leaving mature trees when clearing occurs, close to forest fragments, may help accelerate successional processes in forest fragments, since these trees have been shown to contribute disproportionately to recruitment (Aldrich and Hamrick 1998; Carrière *et al.* 2002). *Windbreaks.* May significantly increase the deposition of native tree and shrub seedlings in tropical agricultural regions (Harvey 2000) and become foci for seed deposition and targets for weedy plant search and eradication efforts.
Succession	**Controlled succession** involves manipulating: • disturbances, to create or eliminate site availability for particular plant species • colonisation, to decrease or enhance availability and establishment of specific species • species performance, to decrease or enhance the growth and reproduction of particular species (Sheley and Kreuger-Mangold 2003). Some researchers have recently shown how augmentative restoration techniques using **framework species** can accelerate the successional process in natural systems (Bard *et al.* 2004). The framework species: • are fast-growing and provide a leafy, closed canopy within 12 to 18 months to quickly shade out weeds • provide a framework under which shade-tolerant native species can establish and perching sites and a bait crop to entice seed-dispersing animals from adjacent areas to accelerate species establishment. In tropical systems, sites rehabilitated using suites of fleshy-fruited native species from different stages of the successional process have been shown to significantly accelerate colonisation by a range of other species of a variety of lifeforms (Tucker and Murphy 1997). However, deposition of invasive plant seeds can also be high beneath these replantings (Buckley *et al.* 2006) and these may become foci of invasive spread (With 2002).

Managing landscapes for resilience		
Management	Comments	Example
Weed response to disturbance	**Short-lived weeds** that appear following a disturbance may be successional to native species and require little management effort to remove them in the post-disturbance environment. **Long-lived** plants or persistent annuals that have the capacity to alter the long-term successional trajectory of a site should be a top management priority. Research should also be conducted to understand the system attributes that promote their invasion or are altered by them as they establish. **Weed management plans and revegetation plans** Weed management itself creates disturbance through mechanical removal, herbicide use, soil disturbance, track creation etc. Management plans that include weed removal are often not linked to a post-removal revegetation plan. The regeneration consequences of control actions should be examined and incorporated in management strategies in order to prevent the creation of a 'weed-shaped hole', ie post-control reinvasion by the same invader or another disturbance adapted invader (Buckley *et al*. 2007). On the other hand, revegetation in tropical landscapes is often managed with the goal of minimising impacts from weeds as the vegetation grows. This knowledge and experience can also be used to manage natural habitat following weed control. Impacts to rainforest habitat from activities associated with weed control should be carefully considered and planned for.	**Persistent invaders—'strangled gaps'** Strangled gaps occur when there is rapid growth of scrambling species and vines after eg a post-cyclone disturbance. This inhibits recruitment of native species in tropical forests (Horvitz and Koop 2001). The species may: • persist for tens to hundreds of years • retard the succession response of natives • dramatically alter the structure and composition of the forest in the longer-term.  Giant bramble (*Rubus alceifolius*) is a fleshy-fruited, shade-intolerant, non-native scrambling shrub capable of smothering other plants and forming dense thickets. It often covers large expanses of rainforest in the Wet Tropics. Photo: T. Sydes (Biosecurity Qld).
Whole-of-system and scale appropriate	Applying a systems perspective to a strategic weed management response. **1. Whole-of-system response**. Response needs to incorporate as many of the relevant ecological aspects of the weeds and native ecosystem as possible and of the human dimension of the problem. Human dimensions have a huge impact on whether management is begun or is successful. They are no less varied than the ecological dimensions and include social, economic and institutional considerations. **2. Appropriate scaling**. Management should incorporate the entire area of the known infestation, and the likely range of dispersal around this. Management and its follow up need to be viewed and funded for in timeframes that incorporate time lags for the location of missed populations and for known seedbank longevity. **3. Spread**. Biological invasions are essentially a process of spread through a landscape. Management resources and effort must be aimed at containing this spread and then at reducing abundance within the infested area. **Tactical responses** are only part of the weed response. They are • the focus of most current management efforts and look at the eradication of a species from a particular location and how best to achieve this and • fundamentally important to the management of weeds as they determine how individual plants are destroyed **Scaling management to the range of the weed problem** Successful weed management is dependent on recognising that individual infestations are just a fragment of the problem. Success in removing a species from one site will be for nought if nothing is done about the infestation on the property next door. It is important that, wherever possible, management efforts are scaled to the range of the problem. For example, if a weed is restricted to a catchment, then resources and effort need to be coordinated across that catchment so that it maximises the probability of its eradication or results in the greatest reduction in spread by targeting the locations that are most likely to contribute to this.	**Far North Queensland Regional Organisation of Councils—Strategic management of weeds** Pond apple (*Annona glabra*) is: • a Weed of National Significance (WONS) • a major environmental weed of the Wet Tropics bioregion, • covers around 2000 hectares of land in far north Qld. Six local councils across the infestation area have been controlling pond apple with various levels of intensity since 2004. The Far North Queensland Regional Organisation of Councils (FNQROC) in partnership with Terrain NRM recently facilitated a coordinated approach to pond apple control across the local shires through a strategic management project. Strategic control of pond apple infestations: • activities initially target upstream areas (or source populations), since pond apple seeds are dispersed primarily by water, so that when control is initiated in heavily infested downstream areas there is less opportunity for replenishment. • revegetation of heavily infested areas that have been treated, reducing the 'weed-shaped hole' effect and the likelihood of reinfestation. The project has forged new partnerships between traditional owners, private land holders and state and local government officers, which has greatly enhanced control outcomes through cooperative arrangements.

Further information	
People to contact	**Publications**
Weeds Officers - at your local council, rural lands board, or state department of agriculture, primary industries, environment or natural resources. They have excellent local knowledge, a wide network of contacts and access to appropriate literature.	Bush invaders of south-east Australia - a guide to the identification and control of environmental weeds in south-east Australia. A.Muyt (2001). **www.weedinfo.com.au** Environmental Weeds: a field guide to SE Australia. Kate Blood (2001). **www.weedinfo.com.au**
Landcare, Bushcare or Catchment Management staff will have information on using herbicides in natural environments.	Bushland weeds. A practical guide to their management. Kate Brown and Kris Brooks, (2003). **www.weedinfo.com.au**
Helen Murphy CSIRO Sustainable Ecosystems Tropical Forest Research Centre PO Box 780, Atherton QLD 4883 **Helen.Murphy@csiro.au**	Introduced flora and its weed status **http://weedscrc.org.au/weed_management/intro_flora.html**
Websites	National recovery plan for Mabi Forest, **www.environment.gov.au/biodiversity/threatened/publications/mabi-forest-factsheet.html**
www.weedscrc.org.au CRC for Australian Weed Management	A global compendium of weeds **http://www.hear.org/gcw/**
www.weedinfo.com.au Weed information website providing information on weed identification, weed management and control of environmental and agricultural weeds.	Habitat management guide – Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats. **www.weedscrc.org.au/publications**
www.landcareaustralia.com.au Landcare Australia for general information on weed management.	Weeds CRC Guidelines **www.weedscrc.org.au/publications** Weeds and rainforests: significant weeds and weed types. Weeds and rainforests: impact of dispersal and disturbance on weed invasion.

A **local government disaster management code of practice** has been prepared by the Far North Queensland Regional Organisation of Councils to help prevent the spread of weeds during natural disasters such as cyclones and flooding.

Whole-of-system and scale-appropriate management

A single strategic framework for managing an entire weed invasion is likely to be extremely complex and unwieldy.

Components of the management plan will need to be adopted at different scales (see Table page 7). For example, many of the institutional and economic decisions will need to be considered at the scale of the range of the species. Decisions about which infestations to be managed, and which resources to deploy and when, will be made at the landscape or local scale.

References

A complete reference list of the research referred to in this guideline can be found in the Weeds CRC's publication, *Habitat management guide - Rainforests: Ecological principles for the strategic management of weeds in rainforest habitats* (www.weedscrc.org.au/publications).

For further information visit the website: www.dpi.nsw.gov.au/weeds

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