Identifying and managing key weed threats, their sources and vectors, in relation to priority remnant ecosystems in the Condamine catchment

A report for Condamine Alliance

K. Reardon-Smith
Australian Centre for Sustainable Catchments
USQ, Toowoomba

February 2009

Report Summary

This report is a part of the Condamine Alliance's Biodiversity Program Project 200808: "*Improve condition of remnant endangered ecosystems within priority corridors by addressing weed vectors*".

The report provides reviews of:

(i) the roles of species traits, infestation levels and ecosystem condition in dispersal and establishment of invasive weeds,

(ii) current and potential weed threats in the Condamine region,

(iii) key weed threats, sources and vectors impacting on the conservation values of priority ecosystems in the region, and

(iv) actions to limit impacts from high risk weed vectors on priority remnants.

Priority ecosystems addressed in this project include three nationally-listed ecosystems (bluegrass grasslands, brigalow woodlands and semi-evergreen vine thickets), as well as regionally-important floodplain wetlands.

The risk of spread of established weeds, as well as the establishment and spread of additional invasive species, in the region is high and the strategic management of weed risk is a necessary priority. A total of 553 non-native (or invasive native) species has been recorded in the catchment, including 48 species currently listed as weeds of national and/or state-significance, as well as another 20 species of regional or local concern. In addition, the number of non-native species newly-recorded in the region continues to climb, currently at a rate of 9.5 species per year.

A key finding in this report is that there are currently significant deficiencies in the recording and reporting of weed species presence and infestation levels throughout the region. This relates in particular to the quality of data collected. In most cases, presence only data is collected, leaving uncertainty as to whether a lack of data indicates a true absence of the species in question. There is also no indication of the amount of effort expended in data collection, making cross-jurisdiction comparisons difficult. In terms of identifying key weed treats to priority ecosystems, many of the species recognised in the scientific literature as key threats to these ecosystems are not currently included in weed mapping or management programs.

Identification of weed dispersal traits and key weed vector categories provides a basis for investigating risks associated with priority ecosystem types, as well as prioritisation of management strategies. The relative importance of different vectors for the spread of significant weeds in ecosystems of conservation concern in the Condamine region was found to vary between ecosystem types:

(i) bluegrass grassland remnants were at most threat from weed species likely to be spread by vehicles (including road maintenance equipment), followed by water, then livestock;

(ii) no clear pattern was evident for brigalow remnants, although dispersal by fruit-eating birds/other animals, water and vehicle movement may be more important than other vectors;

(iii) SEVT remnants were most at risk from weeds transported by fruit-eating birds and other animals, with vehicle movements, water and wind also important vector pathways and translocation of ornamental or agricultural species by people also potentially-important;

(iv) wetlands within the region were most threatened by water-dispersed species and, to lesser extents, by transport of weed propagules by people and vehicles.

Key recommendations in the report include:

(i) the establishment of best practice management guidelines to ensure that priority remnants (and designated buffer areas) are maintained in good condition to limit opportunities for establishment and spread of invasive weed species,

(ii) appropriate signage of infested areas on public lands, including stock routes and roadside reserves,

(iii) the establishment of protocols and facilities for the decontamination of livestock and vehicles moving from infested to non-invaded areas,

(iv) source property weed status certification procedures for fodder movements,

(v) targeted control of fruit-eating pest animal species, including common mynas, starlings, foxes and feral pigs,

(vi) promotion of local native fruit-producing species by targeted planting of these species in revegetation projects, including following weed control,

(vii) the identification of high risk weed species currently on the market in local nurseries and landscape businesses, and

(viii) working with local nurseries and gardeners (including local government) to reduce weed risk in the Condamine region by encouraging the sale and use of non-invasive and native species alternatives to identified high-risk garden plants.

CONTENTS

TABLES

FIGURES

APPENDICES

ACRONYMS

BoM	Bureau of Meteorology
CA	Condamine Alliance (NRM regional body)
DPI&F	Department of Primary Industries and Forestry (Queensland Government)
EPA	Environmental Protection Agency (Queensland Government)
NRM	Natural Resource Management
NRW	Natural Resources and Water (Queensland Government)
RE	Regional Ecosystem
SRN	Stock Route Network

ACKNOWLEDGEMENTS

Access to weed species and vegetation survey records was kindly granted, under data-sharing agreements[1], by Condamine Alliance, the Queensland Herbarium, the Department of Primary Industries and the Environmental Protection Agency. Sincere thanks also to Dr Harry Butler from the Australian Centre for Sustainable Catchments & Faculty of Sciences, University of Southern Queensland, for valuable discussion on interpreting wind speed records and for access to data for the catchment.

[1] **Copyright:** Condamine Alliance, 2009; Department of Primary Industries & Fisheries, 2009; Environmental Protection Agency, 2009. **Disclaimer:** In consideration of Condamine Alliance and the State permitting use of this data, no warranty is given in relation to the data (including accuracy, reliability, completeness, currency or suitability) and no liability (including without limitation, liability in negligence) is accepted for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for direct marketing or be used in breach of the privacy laws.

A. Weed invasion and management

Invasive weeds

Invasive plant species represent a significant risk to the conservation values of native ecosystems. This is especially so where invasive plants act to modify existing disturbance regimes or introduce new disturbances (e.g. fire, erosion), which alter community structure and ecosystem function (Mack and D'Antonio 1998). Species which are capable of transforming ecosystems, generally in ways that favour their own persistence and often to the detriment of native species, have been termed 'ecosystem engineers' (Hastings *et al.* 2007). These are the species most likely to be listed as significant environmental weeds, and which pose the most significant challenges in terms of weed management and ecosystem protection and restoration.

Disturbance

Disturbance is a key factor in the initial establishment of weed species, both in native and modified ecosystems. Opportunities for establishment occur with soil movement, reduction in existing vegetative cover, and where the levels of resources (e.g. nutrients, light, space) change. Weed species are generally capable of rapid germination and establishment under these conditions, enabling them to pre-empt available resources and exclude many native and/or more desirable species. Subsequent management of weed-infested areas within native remnants (e.g. chemical or mechanical control) can be problematic, again providing conditions which favour either re-invasion by the target species or invasion by newly-arrived species which can take advantage of management-induced disturbance (the 'weed-shaped hole' *sensu* Buckley *et al.* 2007).

Propagule pressure

Propagule pressure (i.e. the quantity of seed and vegetative material capable of establishment as an independent plant) is also a critical factor in weed invasion success. The abundance of seed in soil seedbanks and of newly-arrived seed and vegetative material increase the probability of establishment of new individuals of a species when suitable conditions arise. Site-based weed management (the standard response to weed presence) can have significant impacts on the quantity of seed produced locally. However, while this is an important component of weed management, its impact can be limited if the influx of weed seed or vegetative propagules from surrounding areas is not also addressed.

Weed dispersal

Many plant species (both weeds and native species) exhibit adaptations which, usually via secondary agents (vectors), can enhance their ability to spread often over significant distances. This capacity has significant positive outcomes for otherwise-sedentary plant species. It allows new individuals of the species to exploit suitable conditions at sites where there is limited competition from conspecifics, thus enhancing individual fitness. From a species persistence viewpoint, it expands the species' distribution, limiting the risk of local population failure, and enhances the genetic diversity of the species (through genetic mixing), increasing the species' resilience to changing environmental conditions.

Adaptive traits

Key dispersal adaptations evident in plants include seed coats or appendages specialized for attachment (e.g. awned, hooked, sticky, barbed), attraction (e.g. fleshy fruit, fatty arils) and wind dispersal (e.g. plumes, wings). Other seed traits such as small size and buoyancy enhance transport by wind and water, as do plant traits such as the ability to disarticulate either seed-bearing sections (e.g. panicles) or the entire above-ground plant (e.g. tumbleweeds).

Vector pathways

Types of dispersal adaptations evident in plant species also indicate the types of vectors or vector pathways most likely to be involved in the dispersal of certain species. Key vector pathways to which plants show apparent adaptations include external and internal (i.e. within the gut of herbivores and frugivores) transport by passing animals, seed collection by seed-hoarding animals including ants, and transport by wind and water movement. Many of these traits also increase the probability that seed will be transported by anthropogenic agents, either on clothing or vehicles) or in association with domestic stock movements or fodder transport.

Seed fates

Not all seeds disperse successfully (i.e. reach suitable habitat then establish and mature to a reproductive state), nor do all successful seeds follow the same dispersal pathway (despite adaptations). Davies and Sheley (2007) present a conceptual diagram outlining possible alternate fates of invasive plant seeds (Figure 1). These include:

- seeds may be shed close to the parent plant or population (P1 – see Figure 1), or immediately dispersed (P2);
- seeds shed next to their source may remain at that location (P3) or later be dispersed (P4);
- seed may be redispersed (P11 and P16), often by different vectors to those involved in the original dispersal event; and
- seed may be destroyed in the dispersal process (P7 and P12).

Figure 1 indicates aspects of seed dispersal which can be effectively targeted in management to limit invasive weed dispersal. A strategic integrated management approach would be three-pronged, and include:

(i) management to increase seed mortality (P5) and retention of weed seed at invaded source locations (P1 and P3);

(ii) management to disrupt dispersal pathways (P2 and P4, and P11 and P16) or increase mortality of dispersing seed (P7 and P12) to reduce the probability of seed arrival at previously uninfested locations; and

(iii) management to prevent successful establishment of new infestations at previously-uninvaded locations (P10 and P15).

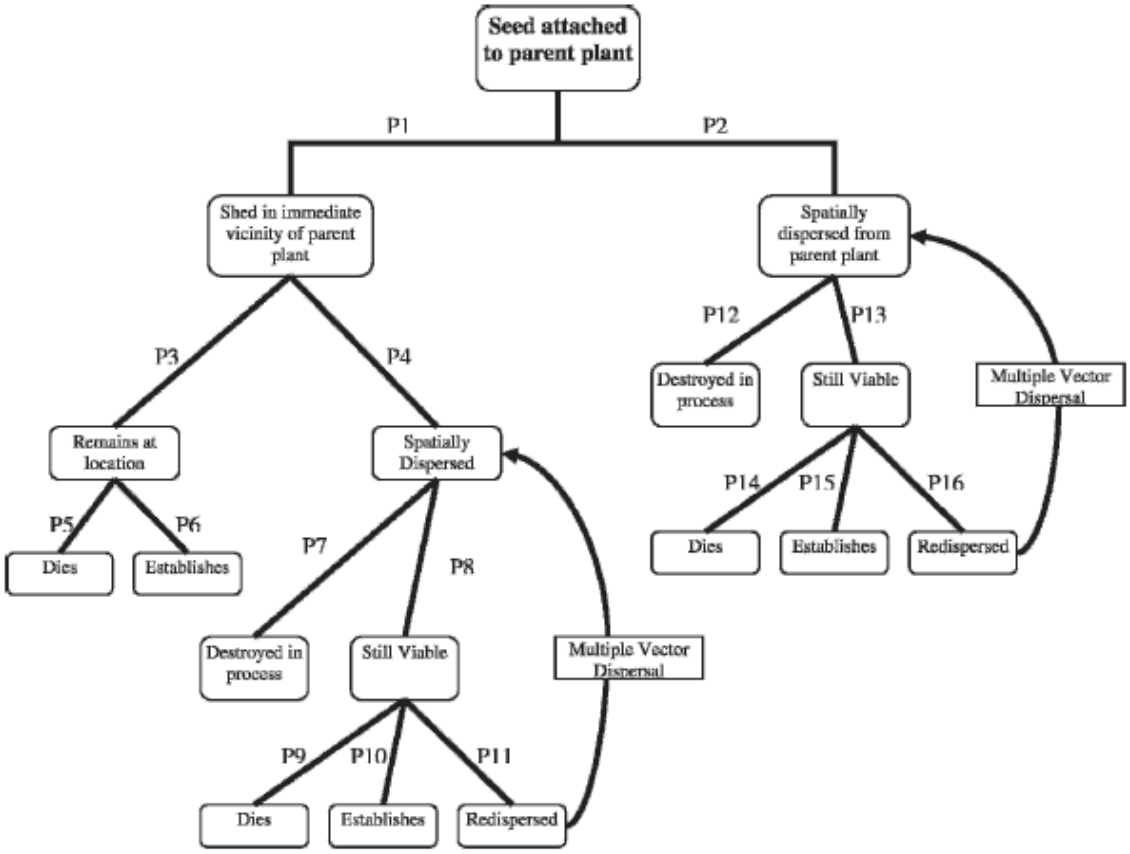


Figure 1. Potential seed dispersal outcomes (P1: pathway 1; P2: pathway 2; …; P16: pathway 16). (Reproduced from Davies & Sheley 2007)

Vector management

Weed management strategies frequently advise greater awareness and management of vectors, but this advice is rarely developed to account for differences in the specific dispersal behaviors of invasive plant species (Davies & Sheley 2007). Davies and Sheley (2007) propose a general strategic framework of weed dispersal vectors and mechanisms (Figure 2) based on (i) the morphology (specific seed and/or propagule traits) of invasive plant species, and (ii) the location of infestations relative to vector pathways. Such a framework provides a basis for designing and prioritising management actions to address specific vectors (depending on the weed species present) at particular locations.

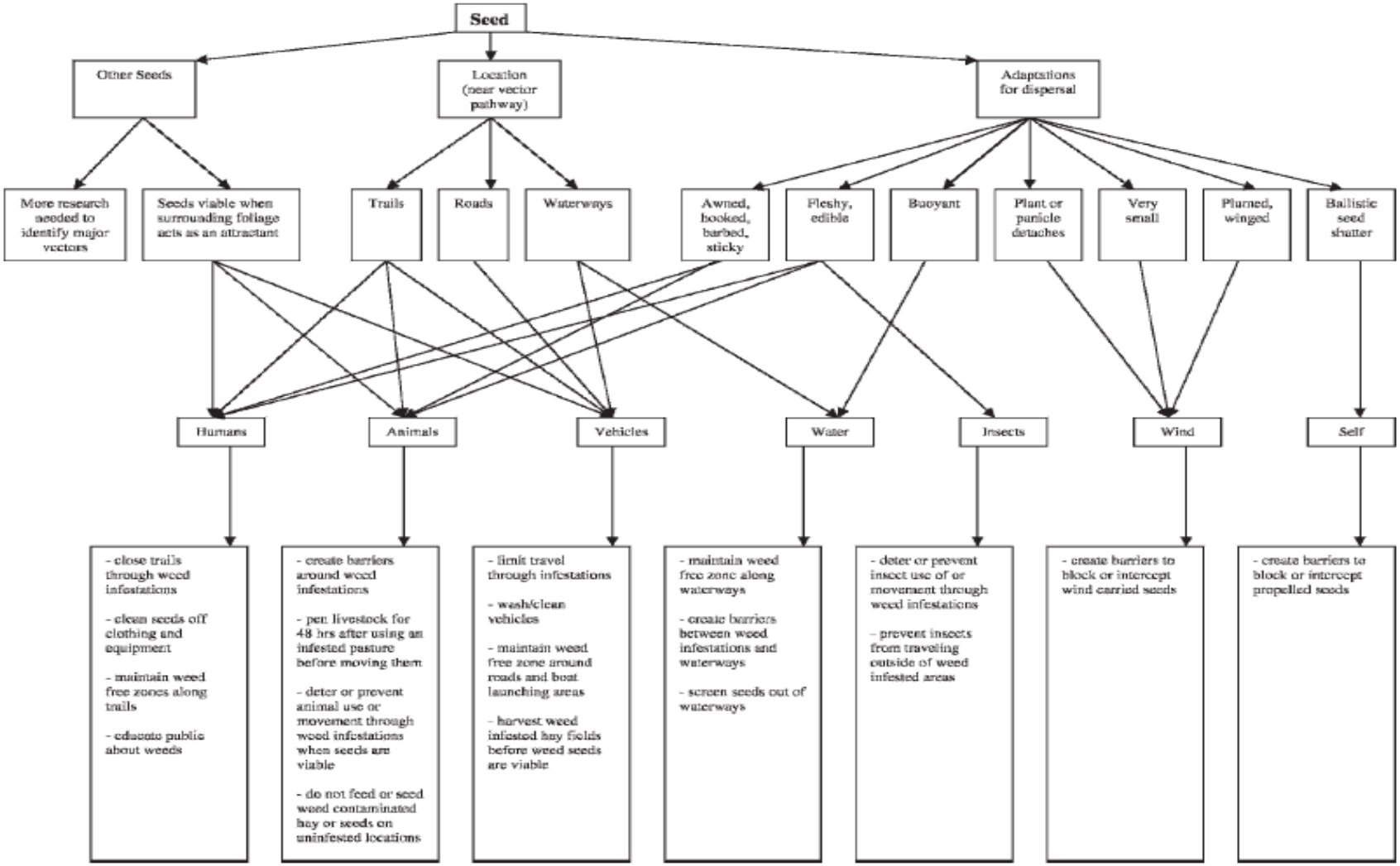


Figure 2. Conceptual framework of weed dispersal vectors and mechanisms (Reproduced from Davies & Sheley 2007)

B. Weed management in the Condamine Catchment

Weed mapping in Queensland

Weed management (from local to regional to national) relies on knowledge of current levels of infestation and changes in distribution and abundance over time. Hence, weed mapping is a fundamental component of weed management programs (Virtue *et al.* 2001).

Weed distribution data is generally collated from a variety of sources from opportunistic sightings and records of specimens lodged with herbaria, to more systematic field surveys and scientific studies. In Queensland, a number of databases have been developed to store and analyse species distribution information and to act as a reference point for ongoing data collection (Queensland Government, n.d):

- the Pestinfo (DPI&F) database is specifically designed to hold pest species distribution and abundance records, contributed by dedicated staff within local government, NRM management and state government agencies. Data collection is largely targeted towards specified listed (State and National) species (see below) and species recognised as invasive at the local or regional level.

- the Queensland Herbarium's Herbrecs database records details of lodged plant specimens (including non-native species) held in the Queensland Herbarium. The Herbarium also holds CORVEG records (including non-native species) from validated systematic field surveys.

- the Wildnet (EPA) database holds vascular plant and animal species (including non-native species) presence records derived from a variety of field surveys, studies, and sightings.

While a significant amount of weed species data is available, it is worth noting that there are a number of acknowledged limitations in much of the data used to map and manage weeds (Queensland Government, n.d). Much of the data available is of low quality (presence-only data, with different levels of spatial precision). A key issue with this is that lack of data does not necessarily represent true absence values, and there is no way of knowing whether all areas have been comprehensively sampled (Arriaga *et al.* 2004, Martin *et al.* 2006).

Data reliability may also be an issue. Potential bias exists when records are collected by people with different levels of training, experience and skill (e.g. PestInfo data), and differing levels of effort is expended in collecting and recording weed species data across regions. In addition, a focus on species of known invasive status may mean that emerging weeds, or weed species not generally recognized as problematic but of significance to certain ecosystem type, are not recorded until infestations have reached significant levels. Management programs need to be aware that data limitation issues such as these can contribute to incomplete understanding of the scope of the weed problem (Arriaga *et al.* 2004, Martin *et al.* 2006).

Identification of priority weeds

Weeds pose significant economic and environmental risks to land management in Australia at an estimated annual cost to the agricultural industry of $4billion and significant impacts on biodiversity and conservation values in natural habitats (Groves *et al.* 2005).

The 20 worst weeds nationally have been identified and prioritized as Weeds of National Significance or WoNS (Thorp and Lynch 2000), and are the target of significant research and management effort. Strategic management plans have been designed and are implemented to control current infestations and prevent further spread, and best practice management guides have been developed for each species (CRC for Australian Weed Management 2003).

A further list of 28 weeds, currently in the early stages of establishment and considered to pose significant risk in Australian environments, have been placed on a National Environmental Alert List (DAFF and DEW 2007a), and management guidelines have been established for each of these (CRC for Australian Weed Management 2003).

At the State level, the Queensland Government has lists of Declared Plants (3 levels) under the *Land Protection (Pest and Stock Route Management) Act 2002* (DPI&F 2009):

(i) Class 1 Plants are species not commonly present in Queensland but expected to pose significant economic, environmental or social risk if they become established; these are subject to eradication, and serious penalties apply if appropriate action is not taken against these weeds.

(ii) Class 2 Plants are pest species established in Queensland and having adverse economic, environmental or social impact; these are subject to management aimed at control and penalties apply if appropriate action is not taken against these weeds.

(iii) Class 3 Plants are pest species established in Queensland with potential to cause adverse economic, environmental or social impact; listing is focused on preventing their spread by imposing a ban on the sale of these species (with penalties for unauthorised supply), and management of infestations is not enforced unless adjacent to environmentally significant areas.

Full lists of WoNS, Alert-listed and State (Queensland) Declared species are given in Appendix 1A-C.

Invasive weeds in the Condamine catchment

The number of records of non-native plant species held (January 2009) in state government department (EPA, DPI&F) databases for the Condamine region, and accessed for this report, was 17,753 individual records (482 in WildNet, 2,536 in HERBRECS and 14,735 point locations[2] in PestInfo) from 553 alien plant species.

All non-native species recorded (WildNet, HERBRECS and PestInfo databases) within the CA region are listed in Appendix 2[3]. These are grouped according to their reported status as significant and invasive environmental and/or economic (some State-listed species) weeds, and the number of records for each species is listed by database. Details of reported

[2] PestInfo also collects polygon location data (not included in this report)
[3] An additional dataset collected by Clifton Shire Council (2403 records) is presented separately in Appendix 3.

invasiveness, based on published reports, are also provided for each species: 201 of the recorded taxa within the catchment are reported as being invasive (or potentially so) within Queensland, and another 69 have been reported as invasive in other states

Of the species recorded, 36 species groups (48 species; 14,419 records) are considered priority environmental and/or economic weeds at the National and State (Queensland) level; these include 7 of 20 WoNS taxa, 3 of 28 Alert-list taxa, 5 of 44 Class 1, 16 of 29 Class 2 and 11 of 20 Class 3 State-Declared Plants (Table 1).

An additional 20 species (702 records) are included as species of current regional or local concern (Table 2); these are either species which have been recorded regionally in the PestInfo database (DPI&F Annual Pest Distribution Survey; Appendix 4) or species which have been the focus of on-ground weed management projects within the region (Jayne Thorpe, pers.com.). Coolatai grass (*Hyparrhenia hirta*) is also included due to its recent rapid expansion along roadsides throughout the eastern Downs (pers. obs.); this species is of serious concern in similar landscapes in northern NSW (DECC 2008).

Table 3 lists the 20 most frequently recorded non-native plant species in the catchment (WildNet, HERBRECS and PestInfo databases). These species account for almost 84% of non-native plant species records, with over 98% of these held in the PestInfo database[4]. Of these, all species are recognized National, State or regional priority weeds (as above) except for clockweed (*Gaura parviflora*) and Mayne's pest (*Verbena aristigera*).

A further 126 non-native plant species, absent from the catchment records, are recorded (HERBRECS database) from within 25km of the catchment boundary (Appendix 5). These include 44 species recognized as invasive within Queensland (as above), of which 6 are National and/or State listed. These are climbing asparagus fern (*Asparagus plumosus*), giant Parramatta grass (*Sporobolus fertilis*), harrisia cactus (*Harrisia martini*), tipuana or rosewood (*Tipuana tipu*), water hyacinth (*Eichhornia crassipes*) and yellow raspberry (*Rubus ellipticus*). A further 13 species are known to be invasive in other states.

There is no evidence to suggest that the number of non-native species occurring in the catchment has stabilized. In fact, Figures 3 and 4 indicate that the number of new weed species recorded over time within the catchment has continued to increase at an average rate of 3.8 species (0 to 25 species) per year over the 134 years of Herbarium records for the catchment. Given that this rate is increasing (over the past 10 years, it has averaged 9.5 new species per year), it should be expected that new non-native plant species will continue to be recorded in the catchment, and that a percentage of these will be invasive within catchment ecosystems.

[4] 9777 of these records are from the former Warwick Shire Councils (now part of the Southern Downs Regional Council).

Table 1: National and state-listed weed species recorded (WildNet, HERBRECS and PestInfo databases) within the Condamine catchment (Weed categories are as per text)

Species	Scientific name(s)	WoNS	Alert	C 1	C 2	C 3	Recorded in the catchment
African boxthorn	*Lycium ferocissimum*				✓		Yes
Annual ragweed	*Ambrosia artemisiifolia*				✓		Yes
Asparagus fern	*Asparagus aethiopicus*, *A. africanusA. plumosus*					✓	Yes (*A. africanus*)
Balloon vine	*Cardiospermum grandiflorum*					✓	Yes
Blackberry	*Rubus fruticosus* agg.	✓				✓	Yes
Bridal creeper	*Asparagus asparagoides*	✓		✓			Yes
Broadleaved pepper tree	*Schinus terebinthifolius*					✓	Yes
Camphor laurel	*Cinnamomum camphora*					✓	Yes
Cat's claw creeper	*Macfadyena unguis-cati*					✓	Yes
Chilean needle grass	*Nassella neesiana*	✓		✓			Yes
Chinese celtis	*Celtis sinensis*					✓	Yes
Chinese rain tree	*Koelreuteria elegans* ssp. *formosana*		✓				Yes
Cholla cactus	*Cylindropuntia fulgida* (Coral cactus), *C. imbricata* (devil's rope pear) and *C. spinosior* (snake cactus)				✓		Yes (*C. imbricata*)
Fireweed	*Senecio madagascariensis*				✓		Yes
Groundsel bush	*Baccharis halmifolia*				✓		Yes
Harrisia cactus	*Harrisia martini* syn. *Eriocereus martini, H. tortuosa* and *H. pomanensis* syn. *Cereus pomanensis*				✓		Yes (*H. pomanensis* & *H. tortuosa*)
Honey locust	*Gleditsia* spp. including cultivars and varieties.			✓			Yes
Karroo thorn	*Acacia karroo*		✓				Yes
Kudzu	*Pueraria montana* var. *lobata*				✓		Yes (*P. lobata*)
Lantana	*Lantana camara*	✓					Yes

Species	Scientific name(s)	WoNS	Alert	C 1	C 2	C 3	Recorded in the catchment
Lantanas	*Lantana camara, L. montevidensis*					✓	Yes
Madeira vine	*Anredera cordifolia*					✓	Yes
Mesquites	*Prosopis* species – *P.pallida, P velutina, P glandulosa* and hybrids	✓			✓		Yes (*P. glandulosa, P. pallida, P. velutina*)
Mother of millions	*Bryophyllum delagoense* syn. *B. tubiflorum, Kalanchoe delagoensis*				✓		Yes
Mother of millions hybrid	*Bryophillum x houghtonii* syn. *B. daigremontianum x B. delagoense, Kalanchoe x houghtonii*				✓		Yes
Parthenium weed	*Parthenium hysterophorus*	✓			✓		Yes
Prickly pear	*Opuntia* spp. not yet found in Qld (*O. ficus-indica* (not declared) and *O. stricta, O. aurantiaca, O. monocantha, O. tomentosa* and *O.streptocantha* are Class 2)			✓			Yes (*O. elatior*)
Prickly pear	*Opuntia stricta* syn.*O. inermis* (Common pest pear, spiny pest pear), *O. aurantiaca* (tiger pear), *O. streptacantha* (westwood pear), *O. monocantha* syn. *O. vulgaris, O. tomentose* (tree pears)				✓		Yes (*O. aurantiaca, O. stricta, O. tomentosa*)
Privets	*Ligustrum lucidum, L. sinense*					✓	Yes
Rat's tail grass	*Sporobolus jacquemontii, S. fertilis, S. pyramidalis, S. natalensis* and *S. africanus*				✓		Yes (*S. pyramidalis, S. natalensis, S. africanus*)
Rosewood or tipuana tree	*Tipuana tipu*		✓				Yes
Rubber vine	*Cryptostegia grandiflora*	✓			✓		Yes
Thunbergia	*Thunbergia grandiflora*				✓		Yes
Water lettuce	*Pistia stratiotes*				✓		Yes
Witch weeds	*Striga* spp. other than native species			✓			Yes
Yellow bells	*Tecoma stans*					✓	Yes
TOTALS		**7**	**3**	**5**	**16**	**11**	**36**

Table 2: Weed species of current regional concern* not listed in National or State (Queensland) lists of priority weed species

Weed	Scientific name
African lovegrass	*Eragrostis curvula*
Bathurst burr	*Xanthium spinosum*
common thornapple	*Datura stramonium*
Coolatai grass	*Hyparrhenia hirta*
crofton weed	*Ageratina adenophora*
firethorn	*Pyracantha angustifolia*
guava	*Psidium guajava*
hemlock	*Conium maculatum*
knobweed	*Hyptis capitata*
kudzu	*Pueraria lobata*
leucaena, coffee bush	*Leucaena leucocephala*
lippia	*Phyla canescens*
moth vine	*Araujia sericifera*
olive	*Olea europaea*
Paterson's curse	*Echium plantagineum*
saffron thistle	*Carthamus lanatus*
sisal hemp	*Agave sisalana*
St. John's wort	*Hypericum perforatum*
swamp foxtail	*Pennisetum alopecuroides*
sweet briar	*Rosa bracteata*

* species recorded in the DPI&F Annual Pest Distribution Survey and/or the focus of on-ground weed management projects within the region, with the exception of Coolatai grass (*Hyparrhenia hirta*).

Table 3: The 20 most frequently recorded taxa (HERBRECS, WildNet and PestInfo databases) for the Condamine catchment.

Common name	Taxon	HerbRecs	WildNet	PestInfo	Total
African boxthorn	*Lycium ferocissimum*	15	0	5576	5591
honey locust tree	*Gleditsia triacanthos*	5	0	2568	2573
Chilean needle grass	*Nassella neesiana*	3	0	1746	1749
prickly pears	*Opuntia* spp.	0	0	1433	1433
blackberry	*Rubus fruticosus*	0	0	893	893
groundsel bush	*Baccharis halimifolia*	8	3	481	492
lantana	*Lantana camara*	11	15	412	438
broad-leaved privet	*Ligustrum lucidum*	9	1	371	381
fireweed	*Senecio madagascariensis*	7	0	331	338
crofton weed	*Ageratina adenophora*	1	3	236	240
mother of millions	*Bryophyllum* spp.	0	0	156	156
small-leaved privet	*Ligustrum sinense*	4	3	140	147
orange firethorn	*Pyracantha angustifolia*	6	0	103	109
Paterson's curse	*Echium plantagineum*	16	0	102	118
annual ragweed	*Ambrosia artemisiifolia*	4	0	45	49
St. John's wort	*Hypericum perforatum*	0	1	27	28
hemlock	*Conium maculatum*	6	0	24	30
clockweed	*Gaura parviflora*	29	4	0	33
Mayne's pest	*Verbena aristigera*	22	10	0	32
moth plant/moth vine	*Araujia sericifera*	18	11	0	29

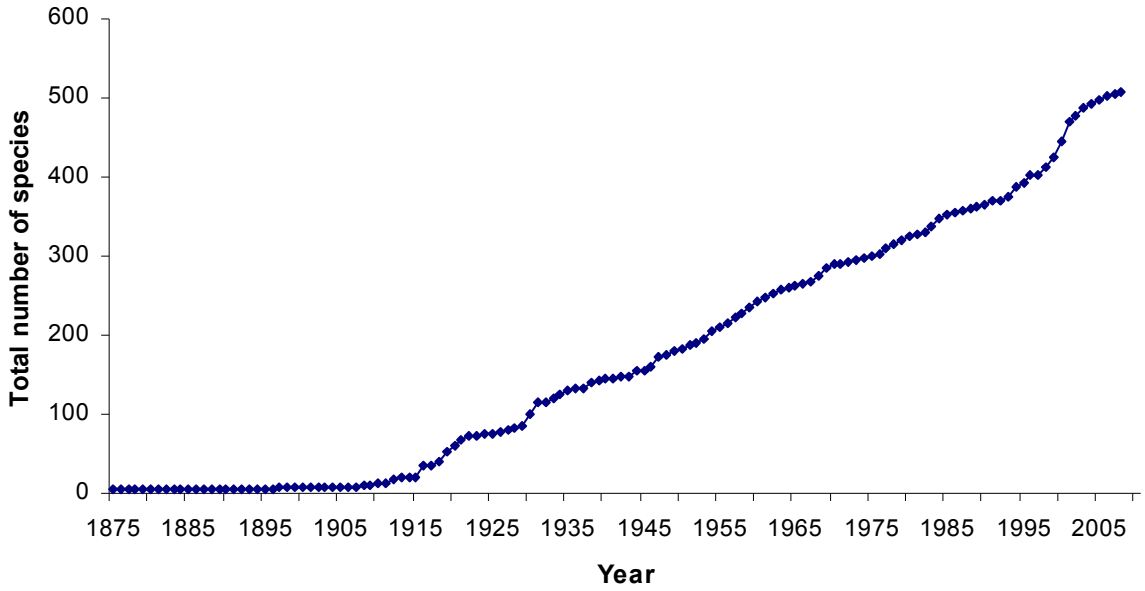


Figure 3: **Species accumulation curve of non-native plant species, HERBRECS data (1875 – 2008), Condamine catchment.**

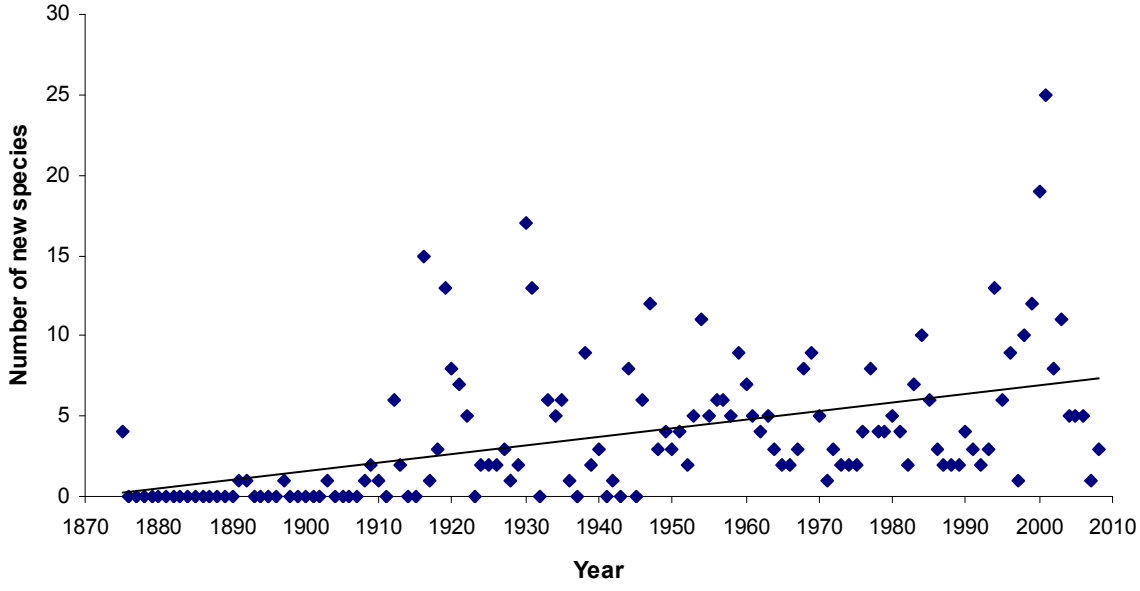


Figure 4: **Number of new non-native species recorded in the HERBRECS database, 1875 – 2008, in the Condamine catchment.**

C. Invasive weeds and priority remnants within the Condamine Catchment

Priority remnants within the Condamine catchment

A number of ecosystem-types occurring in the Condamine Catchment are of significant conservation concern, and are listed nationally under the Australian Government *Environment Protection and Biodiversity Conservation Act* 1999 (DEWHA n.d.):

(i) Bluegrass (*Dichanthium sericeum*) grassland (Regional Ecosystem 11.3.21, Sattler and Williams 1999), along with *Themeda avenaceae* grassland (RE 11.3.24), has recently been listed (gazetted 7 January 2009) as the critically-endangered ecological community **Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland**;

(ii) a number of Brigalow (*Acacia harpophylla*) dominated ecosystem types (REs 11.3.1, 11.4.10, 11.4.3a and b, 11.9.5, 11.9.6 and 12.8.23) occurring in the catchment are included in the listed endangered **Brigalow (*Acacia harpophylla* dominant and co-dominant)** ecological community; and

(iii) semi-evergreen vine thicket communities (REs 11.8.3 and 11.9.4a and c) are included in the listing for endangered **Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions.**

The majority of these RE-types (with the exception of RE 11.8.3 which is listed as 'not of concern'; EPA 2009) are also classified as 'endangered' under the Queensland Government *Vegetation Management Act 2005* (EPA 2009). Details of these communities are provided in Appendix 6.

Within the Condamine Catchment, priority remnants of these listed ecosystems have been identified (Condamine Alliance; Figure 5), based on location within defined "corridors of action" and remnant extent (greater than 50ha). In all, 37 sites with a total area of 4400ha have been selected, including 500ha of Brigalow woodland, 2000ha of Semi-evergreen vine thickets (SEVT), and 1900ha of Bluegrass grassland.

Wetland ecosystems are also a regional conservation priority. On this basis, two priority floodplain wetland areas have also been included on advice from Steve Cupitt of Greening Australia. These are Longswamp and Tralee wetlands (Figure 6); both of these wetlands were included in an earlier study of wetland condition and key threatening processes (Cupitt 2007).

Functional weeds in priority remnant types in the Condamine region

While landclearing and subsequent fragmentation have been primary threatening processes influencing the conservation status of these ecosystem types, subsequent factors such as altered fire regimes, grazing by domestic stock and invasion by weeds and pest animals are significant drivers of on-going decline. Invasive weed species contribute to this by competing with native plant species for key resources (moisture, light, space and nutrients) and, in some instances, altering the structure and ecology of remnant communities (as discussed in Part A above).

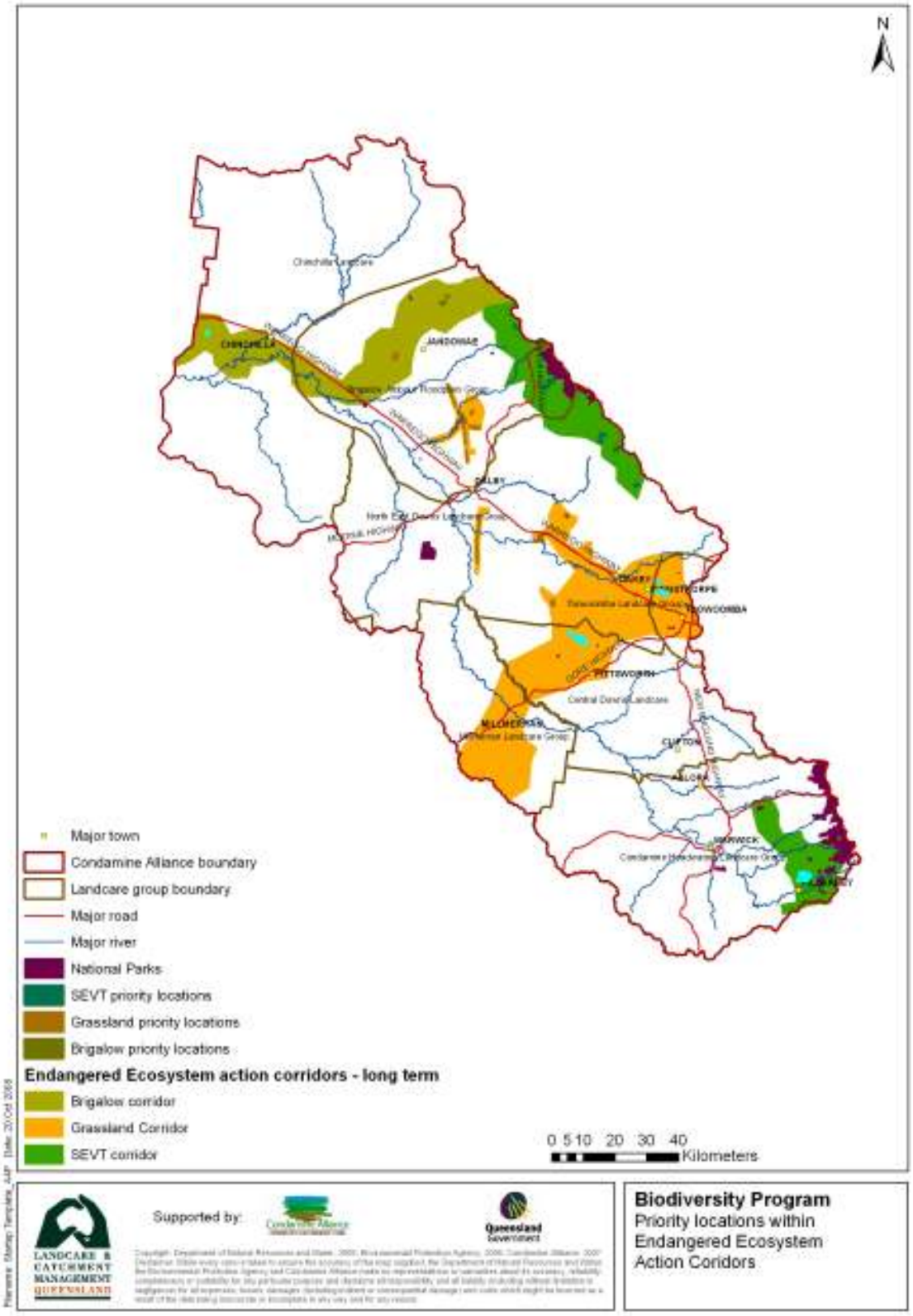


Figure 5: Action corridors and priority remnants of endangered ecosystem types within the Condamine catchment.

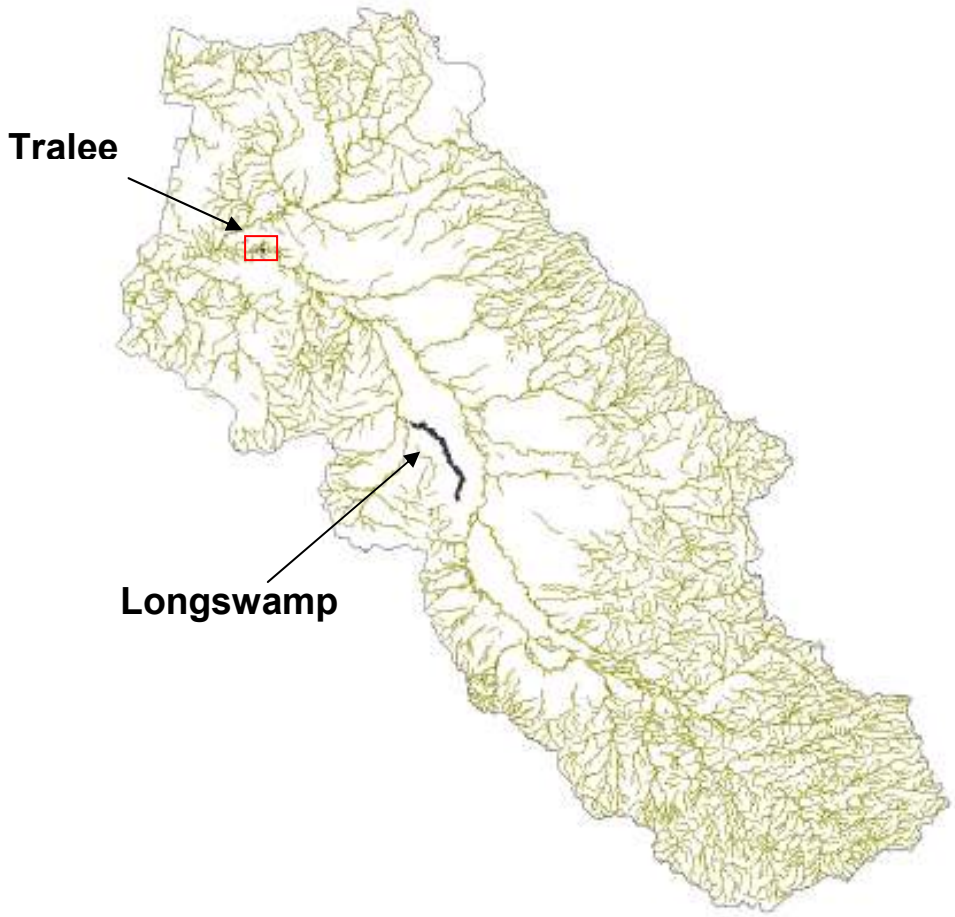


Figure 6: Priority wetlands in the Condamine catchment.

Key weed species associated with priority ecosystem types in the region and reported in the published literature are briefly listed below. Information accessed is drawn from studies of these ecosystems across their ranges, and in some cases weed species which do not currently threaten remnants within the catchment (but may potentially do so) are included.

Details of these key species recorded in or near (within 1 km of) remnants of each ecosystem type in the catchment are given in Appendix 7, as are details of other national, state and regional priority species recorded.

Bluegrass grasslands

Six weed species are considered to pose a significant risk to the integrity and condition of Bluegrass grassland remnants in southern Queensland and northern NSW (Table 4). These are African love grass (*Eragrostis curvula*), buffel grass (*Pennisetum ciliare*), Coolatai grass (*Hyparrhenia hirta*), lippia (*Phyla canescens*), parthenium weed (*Parthenium hysterophorus*) and nut grass (*Cyperus rotundus*). A further 7 species are common in this ecosystem type, but their ecological impact is unreported and presumably of less concern.

Table 4: Key weed species reported to be associated with degradation of Bluegrass grasslands

Weed	Scientific name	Impact	References
African love grass	*Eragrostis curvula*	Competition threatens listed species such as *Bothriochloa biloba* (listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*).	Beeton, n.d.
		Noted as common along roadsides in grassland remnants within the Condamine catchment.	Goodland 2000
buffel grass	*Pennisetum ciliare*	Invasion threatens remnants, particularly following periods of heavy grazing and/or drought.	Beeton, n.d.; Fensham 1999
Coolatai grass	*Hyparrhenia hirta*	Competition with native grass species reduces species richness and community integrity, and threatens listed species such as *Bothriochloa biloba* (listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*).	Beeton, n.d.; CRC Weed Management 2007
		Noted as common along roadsides in grassland remnants within the Condamine catchment.	Goodland 2000
lippia	*Phyla canescens*	Competition with native grass species reduces species richness and community integrity, and threatens listed species such as *Bothriochloa biloba* (listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*).	Beeton, n.d.
		Reported to be one of the most common weeds in riverine and flood-prone communities on the Darling Downs.	Fensham 1997
		Noted as common along roadsides in grassland remnants within the Condamine catchment.	Goodland 2000
parthenium weed	*Parthenium hysterophorus*	Invasion threatens remnants, particularly following periods of heavy grazing and/or drought.	Fensham 1999
nut grass	*Cyperus rotundus*	Competition threatens listed species such as *Bothriochloa biloba* (listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*)	Beeton, n.d.
Also reported			
Green panic	*Megathyrsus maximus*	Noted as common along roadsides in grassland remnants within the Condamine catchment.	Goodland 2000
Johnson's grass	*Sorghum halapense*	Noted as common along roadsides in grassland remnants within the Condamine catchment.	Goodland 2000

Weed	Scientific name	Impact	References
Mayne's pest	*Verbena aristegera*	Noted as common along roadsides in grassland remnants within the Condamine catchment.	Goodland 2000
Mimosa	*Acacia farnesiana*	Shrub cover alters ecosystem structure; may have limited impact on grass species richness (other impacts not reported).	NPWS 2003
Mintweed	*Salvia reflexa*	Reported to be one of the most common weeds in riverine and flood-prone grasslands on the Darling Downs.	Fensham 1997
Paspalum	*Paspalum dilatatum*	Noted as common along roadsides in grassland remnants within the Condamine catchment.	Goodland 2000
Rhodes grass	*Chloris gayana*	Noted as common along roadsides in grassland remnants within the Condamine catchment.	Goodland 2000

Seven of these species have been recorded (WildNet, HERBRECS and PestInfo databases)[5] in or adjacent to Bluegrass grassland remnants in the Condamine catchment. These are Coolatai grass (*Hyparrhenia hirta*), lippia (*Phyla canescens*), nut grass (*Cyperus rotundus*), parthenium weed (*Parthenium hysterophorus*), green panic (*Megathyrsus maximus*), Johnson's grass (*Sorghum halepense*) and Mayne's pest (*Verbena aristigera*) (Appendix 7a).

Brigalow woodlands

Two weed species are considered to pose a significant risk to the integrity and condition of Brigalow woodlands in Queensland and northern NSW (Table 5). These are buffel grass (*Pennisetum ciliare*) and parthenium weed (*Parthenium hysterophorus*). Another 3 species are common in this ecosystem type, but their ecological impact is unreported and may be of less concern.

Table 5: Key weed species reported to be associated with degradation of Brigalow woodlands.

Weed	Scientific name	Impact	References
buffel grass	*Pennisetum ciliare*	Invasion alters fuel characteristics and fire risk in Brigalow remnants; interactions between Buffel grass and fire may contribute to accelerated degradation of remnant vegetation (e.g. in central Queensland, promoted invasion by Parthenium weed)	Butler & Fairfax, 2003

[5] Records over 25 years old or with accuracy of > 5000m are excluded.

Weed	Scientific name	Impact	References
parthenium weed	*Parthenium hysterophorus*	Invasion following fire contributes to degradation of remnant vegetation in central Queensland	Butler & Fairfax, 2003
Also reported:			
prickly pear	*Opuntia stricta*	Present in the understorey of brigalow communities	Johnson 2004; Seabrook *et al.* 2007
spiked malvastrum	*Malvastrum americanum*	Naturalised in RE11.4.3	EPA 2009
velvet tree pear	*Opuntia tomentosa*	Common in the understorey of brigalow communities	Johnson 2004; Seabrook *et al.* 2007

Three of these species have been recorded (WildNet, HERBRECS and PestInfo databases)[6] in or adjacent to Brigalow woodland remnants in the Condamine catchment. These are parthenium weed (*Parthenium hysterophorus*), prickly pear (*Opuntia stricta*) and spiked malvastrum *Malvastrum americanum* (Appendix 7b).

Semi-evergreen vine thickets

Twelve weed taxa are considered to pose a significant risk to the integrity and condition of SEVT remnants in southern Queensland (Table 6). These are the weedy asparagus species (*Asparagus* spp.), billygoat-weed (*Ageratum conyzoides*), buffel grass (*Pennisetum ciliare*), cat's claw creeper (*Macfadyena unguis-cati*), coral berry (*Rivina humilis*), green panic (*Megathyrsus maximus*), lantana (*Lantana camara*), Madeira vine (*Anredera cordifolia*), moth vine (*Araujia sericifera*), parthenium weed (*Parthenium hysterophorus*), rubber vine (*Cryptostegia grandiflora*) and velvet tree pear (*Opuntia tomentosa*). Another 5 species are common or noted as recorded in this ecosystem type, but their ecological impact is unreported and presumably of less concern.

Table 6: Key weed species reported to be associated with degradation of semi-evergreen vine thickets.

Weed	Scientific name	Impact	References
asparagus group	*Asparagus* spp.	Invasive in SEVT remnants in eastern parts of the Condamine catchment, often occurring in association with Madeira vine	Mark Schuster, pers.com.
billygoat-weed	*Ageratum conyzoides*	Adapted to for growth in shady conditions and capable of invading apparently	McDonald 2007

[6] Records over 25 years old or with accuracy of > 5000m are excluded.

Weed	Scientific name	Impact	References
		undisturbed SEVT vegetation	
buffel grass	*Pennisetum ciliare*	Invasion alters fuel characteristics and fire risk in areas adjacent to SEVT remnants	Fensham 1996; McDonald 1996
		Invasive in SEVT remnants throughout the Condamine catchment, especially where canopy gaps occur due to dieback and treefall.	Mark Schuster, pers.com.
cat's claw creeper	*Macfadyena unguis-cati*	Invasive in SEVT remnants in eastern parts of the Condamine catchment; covers the canopy in wetter areas.	Mark Schuster, pers.com.
coral berry	*Rivina humilis*	Adapted for growth in shady conditions and capable of invading apparently undisturbed SEVT vegetation.	Fensham 1996; McDonald 1996, 2007
green panic	*Megathyrsus maximus*	Adapted for growth in shady conditions and capable of invading apparently undisturbed SEVT vegetation.	Fensham 1996; McDonald 1996, 2007
		Invasion alters fuel characteristics and fire risk in areas both adjacent to, and within, SEVT remnants.	
		Invasive in SEVT remnants throughout the Condamine catchment	Mark Schuster, pers.com.
lantana	*Lantana camara*	Poses a serious threat to this community in areas with > 600 mm mean annual rainfall.	Fensham et al. 1994; Fensham 1996; McDonald 1996
		Invasion alters fuel characteristics and fire risk, promoting the spread of fire into vine thickets.	
		Reduces the species richness of mature plants in semi-evergreen vine thickets, and can cause broad-scale displacement of native plants.	
		Invasive in SEVT remnants across the eastern Downs; high infestation levels in some remnants in the Condamine catchment.	Mark Schuster, pers.com.
Madeira vine	*Anredera cordifolia*	Invasive in SEVT remnants in eastern parts of the Condamine catchment, covering the canopy in some areas (a major problem, comparable to rubber vine in this area)	Mark Schuster, pers.com.
moth vine	*Araujia sericifera*	Invasive in SEVT remnants in eastern parts of the Condamine catchment, covering the canopy in some areas (a major problem)	Mark Schuster, pers.com.
parthenium weed	*Parthenium hysterophorus*	As a pasture weed, facilitates incursion of fire into SEVT remnants.	Fensham 1996; McDonald 1996
rubber vine	*Cryptostegia grandiflora*	Poses a serious threat to this community (dry rainforest is considered one of the	Fensham 1996; Fensham et al. 1994 ;

Weed	Scientific name	Impact	References
		prime habitats for *C. grandiflora*).	Humphries et al. 1991 ; McDonald 1996
		Competition and altered light regimes may limit regeneration of native plant species, and cause broad-scale displacement of native plants.	
		Not currently an issue in SEVT remnants in the Condamine catchment (but see Madeira vine)	Mark Schuster, pers.com.
velvet tree pear	*Opuntia tomentosa*	The most widespread introduced species in the listed SEVT ecological community in Queensland.	Fensham 1996; McDonald 1996
		Large infestations present in SEVT remnants in northern parts of the Condamine catchment	Mark Schuster, pers.com.
Also reported:			
African boxthorn	*Lycium ferocissimum*	Locally common in SEVT remnants in the Pittsworth area of the Condamine catchment.	Mark Schuster, pers.com.
Brazilian nightshade	*Solanum seaforthianum*	Recorded in vine thickets in Queensland.	Fensham 1996; McDonald 1996
coolatai grass	*Hyparrhenia hirta*	Locally common in some NSW remnants.	DEWHA 2009b
prickly pear	*Opuntia stricta*	The most common introduced plant recorded in listed vine thickets in NSW.	Benson et al. 1996
rope pear	*Cylindropuntia imbricata*	Currently a large infestation in a single SEVT remnant in the eastern part of the Condamine catchment.	Mark Schuster, pers.com.

Seven of these species have been recorded (WildNet, HERBRECS and PestInfo databases)[7] in or adjacent to SEVT remnants in the Condamine catchment. These are lantana (*Lantana camara*), moth vine (*Araujia sericifera*), parthenium weed (*Parthenium hysterophorus*), velvet tree pear (*Opuntia tomentosa*), African boxthorn (*Lycium ferocissimum*), rope pear (*Cylindropuntia imbricata*) and unspecified pest pears (*Opuntia* sp.) (Appendix 7c).

Asparagus fern (*Asparagus* spp.), buffel grass (*Pennisetum ciliare*), cat's claw creeper (*Macfadyena unguis-catii*), green panic (*Megathyrsus maximus*), and Madeira vine (*Anredera cordifolia*), while not listed in databases, are reported to be present in significant numbers within SEVT remnants in the catchment (Mark Schuster, pers. com.). Madeira vine (*Anredera cordifolia*), moth vine (*Araujia sericifera*) and lantana (*Lantana camara*) are reportedly the most abundant and problematic weeds in these remnants and a significant challenge to land managers, while the infestation of rope pear (*Cylindropuntia imbricata*)

[7] Records over 25 years old or with accuracy of > 5000m are excluded.

could readily be controlled if action were taken in the near future (Mark Schuster, pers. com.).

Floodplain wetlands

There are almost 2000 non-riverine wetlands recorded in the Condamine catchment (Condamine ACA), with a combined area of approximately 120km^2 (Table 7). The extent and conservation values of many of these are under severe threat due to major changes in landuse and hydrology within the catchment.

Table 7: Mapped wetlands included in the Aquatic Conservation Assessment (EPA 2008) for the Condamine catchment

System	# Wetlands	Area (km²)	% Wetlands Area	% Total Area
Lacustrine	1419	92.83	49.3%	0.4%
Combined Lacustrine/Palustrine	4	3.13	1.7%	0.0%
Palustrine	554	23.30	12.4%	0.1%
Riverine	1400	68.91	36.6%	0.3%
Total	**3377**	**188.17**	**100.0%**	**0.8%**

Four species are reported to be of concern in priority wetlands in the Condamine region, with lippia (*Phyla canescens*) posing the most significant threat (Cupitt 2007). Another 17 weed species are listed as associated with wetlands, either in the catchment or in association with the Freshwater Wetland Regional Ecosystem type, RE11.3.27 (Table 8).

Table 8: Key weed species reported to be associated with wetlands in the Condamine catchment.

Weed	Scientific name	Impact	Reference
lippia	*Phyla canescens*	major weed of concern[8] in priority wetlands in the Condamine region	Cupitt 2007
mimosa	*Acacia farnesiana*	of concern in some priority wetlands in the Condamine region	Cupitt 2007
smartweed	*Persecaria* sp.	of concern in some priority wetlands in the Condamine region	Cupitt 2007
tiger pear	*Opuntia aurantiaca*	of concern in some priority	Cupitt 2007

[8] "Lippia (is) a major problem along the entire length of Longswamp and is suffocating native vegetation and starving seedlings of available moisture" (Cupitt 2007, p33).

Weed	Scientific name	Impact	Reference
		wetlands in the Condamine region	
Also reported:			
annual beardgrass	*Polypogon monspeliensis*	wetland indicator species	EPA 2007
awnless barnyard grass	*Echinochloa colona*	wetland indicator species	EPA 2007
barnyard grass	*Echinochloa crus-galli*	wetland indicator species	EPA 2007
couch	*Cynodon dactylon* var. *dactylon*	naturalised in RE11.3.27	EPA 2009
dense waterweed	*Egeria densa*	wetland indicator species; naturalised in RE11.3.27	EPA 2007; EPA 2009
-	*Egeria dulca*	naturalised in RE11.3.27	EPA 2009
jointed rush	*Juncus articulatus*	wetland indicator species	EPA 2007
kikuyu grass	*Pennisetum clandestinum*	wetland indicator species	EPA 2007
noogoora burr	*Xanthium pungens*	present in priority wetlands in the Condamine region	Cupitt 2007
prickly pear	*Opuntia* spp.	present in priority wetlands in the Condamine region	Cupitt 2007
salvinia	*Salvinia molesta*	wetland indicator species	EPA 2007
swamp foxtail	*Pennisetum alopecuroides*	wetland indicator species	EPA 2007
umbrella sedge	*Cyperus eragrostis*	wetland indicator species	EPA 2007
water lettuce	*Pistia stratiotes*	wetland indicator species	EPA 2007
water parsnip	*Berula erecta*	wetland indicator species	EPA 2007
weeping willow	*Salix babylonica*	wetland indicator species	EPA 2007
Yorkshire fog	*Holcus lanatus*	wetland indicator species	EPA 2007

Eleven of these taxa have been recorded (WildNet, HERBRECS and PestInfo databases)[9] in or adjacent to wetland remnants in the Condamine catchment. These are lippia (*Phyla canescens*), mimosa (*Acacia farnesiana*), barnyard grasses (*Echinochloa colona* and *E. crus-galli*), couch (*Cynodon dactylon* var. *dactylon*) kikuyu grass (*Pennisetum clandestinum*), prickly pears (*Opuntia* spp.), swamp foxtail (*Pennisetum alopecuroides*), umbrella sedge (*Cyperus eragrostis*), weeping willow (*Salix babylonica*) and Yorkshire fog (*Holcus lanatus*) (Appendix 7d).

Conservation advice for nationally-listed ecosystems occurring in the Condamine region

Conservation advice for the nationally-listed ecosystems which occur in the Condamine region (i.e. Bluegrass grasslands, Brigalow woodlands and semi-evergreen vine thickets) include a number of priority actions regarding invasive weeds. These include the following:

[9] Records over 25 years old or with accuracy of > 5000m are excluded.

(i) Bluegrass grasslands (DEWHA 2008)

- to identify and remove weeds which could threaten the ecological community,
- to develop and implement a regional management plan for the control of weeds such as lippia (*Phyla canescens*), Coolatai grass (*Hyparrhenia hirta*), African love grass (*Eragrostis curvula*) and buffel grass (*Pennisetum ciliare*),
- to manage sites to prevent the introduction of invasive weeds which could threaten the ecological community, and
- to implement good hygiene measures for mowing and grading equipment and observe appropriate state protocols for moving stock.

(ii) Brigalow woodlands (DEWHA 2009a)

- no specific conservation advice is provided for weed management in these communities.

(iii) Semi-evergreen vine thickets (DEWHA 2009b):

- to manage SEVT remnants on a whole-of-landscape basis, due to their relatively small extent, location within agricultural landscapes and associated high risk of weed invasion, fire incursion or clearing for fences,
- to develop integrated management programs for feral animals, exotic plant species and fire in SEVT remnants and the matrix of surrounding vegetation and land cover types,
- to determine the extent and condition of SEVT remnants affected by invasive plant species, particularly weeds of national significance,
- to undertake studies of the impact on SEVT remnants of invasive shade-tolerant grasses and other ground stratum species (e.g. *Rivina humilis*, *Ageratum* spp.),
- to develop appropriate fire management practices, in liaison with landholders and other natural resource managers, to minimize fire damage to SEVT remnants on private and public lands
- to determine the impact of grazing animals, both domestic and native, on SEVT remnant areas, and develop guidelines and recommendations for fencing,
- to provide appropriate incentives to encourage landholders to protect and foster regrowth and associated vegetation in buffer areas around SEVT remnants and in corridors linking SEVT remnants,
- to research and develop the use of semi-evergreen vine thicket species for landscape rehabilitation in areas where SEVT would naturally have occurred prior to clearing, and encourage mines, main roads and others to use native SEVT species in plantings.

Management advice for wetlands areas is generally that wetland management issues (e.g. water flows, weeds and feral animals) require an integrated management approach across multiple scales from property to catchment levels (EPA 2006).

D: Priority weeds and weed vector pathways in the Condamine catchment

Priority weeds and dispersal adaptation

Ninety-seven (99) taxa of the 679 non-native taxa recorded either in the catchment or within 25km of the catchment boundary were identified as priority weeds for remnant types of concern in the Condamine catchment (Section B). Of these, 68 are either listed on national or state priority weed lists, or acknowledged as species of concern in the catchment (Section B). A further 31 taxa are weeds which have been recorded in priority ecosystem types in the catchment and are either known or suspected of having an ecological impact in these (Section C).

Information on the dispersal characteristics of these 99 taxa was sourced from published literature and World Wide Web-based species profiles (details presented in Appendix 8). Known vectors were also identified where possible from these sources; where this information was not available, probable vectors were inferred from information on seed characteristics and/or habitat details. For example, plants whose seeds/fruiting bodies have awns or hooked spines were assumed to be adapted for dispersal by attachment to animals; plants found in wetland/water-prone habitats were listed as water-dispersed; plants found in disturbed sites such as roadsides or cultivation areas were listed as readily transported by vehicles.

Information on probable dispersion pathways for each weed is summarised in Table 9. Dispersal of fruit (large seed pods, fleshy fruits, berries, large seed pods) by seed- or fruit-eating birds and animals appears to be the most common form of dispersal (up to 42 species), followed by water (40 species), vehicles (36 species) and deliberate translocation of ornamental and pasture plants (34 species). Fewer of these species are spread by wind (18 species), attachment to animals including humans (14 species) or ingestion along with foliage and transport in the gut of grazing animals (6 species).

Dispersal vectors and priority ecosystem types

The relative importance of different vectors for the spread of significant weeds in ecosystems of conservation concern in the Condamine catchment varies considerably between ecosystem types (Figures 7a and 7b):

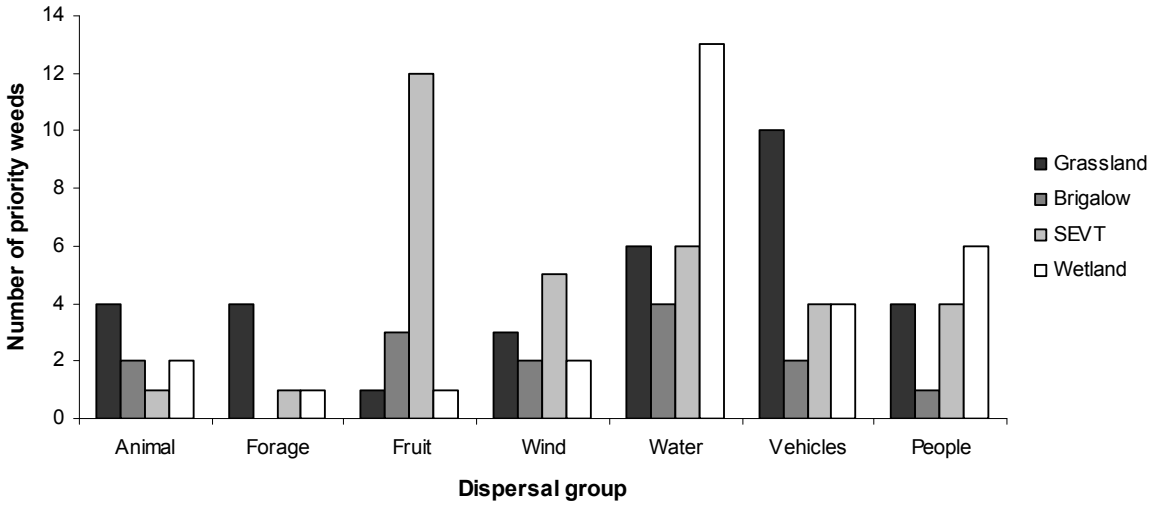
(i) the majority of significant weed species occurring in Bluegrass grassland remnants in the Condamine catchment are most likely to be spread by vehicles, followed by water, then movement either by exterior attachment to animals or clothing, or through ingestion and transport in the gut of grazing animals;

(ii) too few significant weed species were identified in association with Brigalow remnants to show any clear pattern in terms of dispersal pathways, although dispersal by fruit-eating birds/other animals, water and vehicle movement may be more important than other vectors;

(iii) SEVT remnants are most at risk from weeds transported by fruit-eating birds and other animals, however vehicle movements, water and wind are all important vector pathways while translocation of ornamental or agricultural species by people may also play an important role;

(iv) dispersal by water is the most significant pathway for significant weed species in wetlands within the catchment, although people may play an important role as may transport of weed propagules by vehicles.

a.



b.

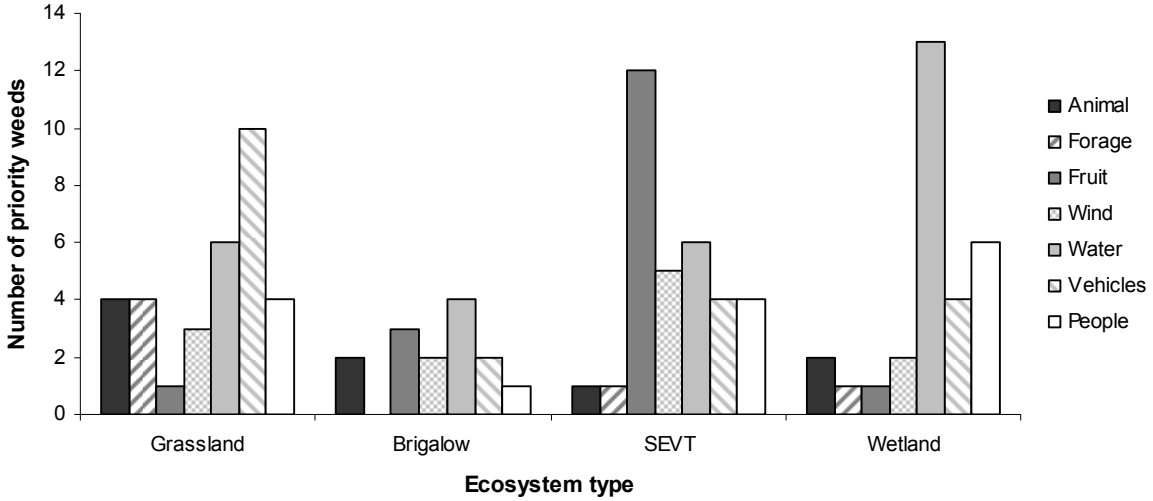


Figure 7: Priority ecosystems and significant weeds in the Condamine catchment

a. Number of significant weeds by ecosystem type within dispersal groups (based on species characteristics and/or preferred habitat).

b. Number of significant weeds by dispersal group within ecosystem types (weeds may occur in more than on dispersal group).

Table 9: **Primary adaptations for dispersal evident in weed species of National, State and regional importance and of reported significance to priority remnants recorded (WildNet, HERBRECS and PestInfo databases) in or adjacent to (within 25km of) the Condamine catchment.** Species numbers (Species #) relate to the species list provided in Appendix 2. Ecosystem types in which weed species are reported to have a significant impact are indicated (G: grassland; B: brigalow; S: semi-evergreen vine thicket; W: wetland).

Species #	Weed	Scientific Name	animals	forage	fruit	wind	water	vehicles	people
24	African boxthorn	*Lycium ferocissimum*			✓ S				
56	African lovegrass	*Eragrostis curvula*					? G	? G	
35	algaroba	*Prosopis pallida*			?		?		
463	annual beardgrass	*Polypogon monspeliensis*	✓ W	✓ W		✓ W	✓ W		✓ W
2	annual ragweed	*Ambrosia artemisiifolia*						✓	
4	asparagus fern	*Asparagus africanus*			✓ S				✓
114	awnless barnyard grass	*Echinochloa colona*					? W	✓ W	
11	balloon vine	*Cardiospermum grandiflorum*				✓	✓		
116	barnyard grass	*Echinochloa crus-galli*					? W	✓ W	
68	Bathurst burr	*Xanthium spinosum*	✓						
613	billygoat-weed	*Ageratum conyzoides*				✓			
38	blackberry	*Rubus anglocandicans*			✓				
39	blackberry	*Rubus fruticosus* spp. agg.			✓				
48	blue thunbergia	*Thunbergia grandiflora*					✓	✓	
184	Brazilian nightshade	*Solanum seaforthianum*			✓ S				✓ S
5	bridal creeper	*Asparagus asparagoides*			✓ S				✓
41	broad-leaf pepper tree	*Schinus terebinthifolius*			✓				✓
22	broad-leaved privet	*Ligustrum lucidum*			✓				
157	buffel grass	*Pennisetum ciliare*	✓ G, B, S			✓ G, B, S	✓ G, B, S	✓ G, B, S	✓ G, B, S

Species #	Weed	Scientific Name	animals	forage	fruit	wind	water	vehicles	people
28	cactus	*Opuntia elatior*			✓		?		
13	camphor laurel	*Cinnamomum camphora*			✓				✓
25	cat's claw creeper	*Macfadyena unguis-cati*			? S	✓ S			
26	Chilean needle grass	*Nassella neesiana*	✓	✓				✓	
12	Chinese elm	*Celtis sinensis*			✓				✓
561	climbing asparagus fern	*Asparagus plumosus*			✓ S				✓
30	common prickly pear	*Opuntia stricta*			✓ B, S		? B, S		
54	common thornapple	*Datura stramonium*	?					?	
57	Coolatai grass	*Hyparrhenia hirta*				? G, S		✓ G, S	
168	coral berry	*Rivina humilis*			✓ S				
110	couch	*Cynodon dactylon*					✓ W		✓ W
21	creeping lantana	*Lantana montevidensis*			✓				
50	crofton weed	*Ageratina adenophora*				✓	?	?	
117	dense waterweed	*Egeria densa*					✓ W		
66	firethorn	*Pyracantha angustifolia*			✓				✓
42	fireweed	*Senecio madagascariensis*				✓		?	
593	giant Parramatta grass	*Sporobolus fertilis*		✓				✓	
44	giant rat's tail grass	*Sporobolus natalensis*	✓	✓				?	
45	giant rat's tail grass	*Sporobolus pyramidalis*		✓				?	
19	golden rain tree	*Koelreuteria elegans*			?	✓	✓		
140	green panic	*Megathyrsus maximus*		✓ G, S		✓ G, S	✓ G, S	✓ G, S	✓ G, S
6	groundsel bush	*Baccharis halimifolia*	✓	✓		✓		✓	
64	guava, yellow guava	*Psidium guajava*			✓				✓

Species #	Weed	Scientific Name	animals	forage	fruit	wind	water	vehicles	people
575	Harrisia cactus	*Harrisia martini*			✓				
17	Harrisia cactus	*Harrisia pomanensis*			✓		?		
18	Harrisia cactus	*Harrisia tortuosa*			✓		?		
53	hemlock	*Conium maculatum*					?	?	
16	honey locust tree	*Gleditsia triacanthos*			?				✓
34	honey mesquite	*Prosopis glandulosa*			?				✓
512	Johnson's grass	*Sorghum halapense*					? G	✓ G	
129	jointed rush	*Juncus articulatus*					✓ W		
1	karroo thorn	*Acacia karroo*			?	✓	✓		✓
158	kikuyu grass	*Pennisetum clandestinum*					?		✓
59	knobweed	*Hyptis capitata*	✓				✓	✓	
65	kudzu	*Pueraria lobata*			?				
20	lantana	*Lantana camara*			✓ S				
60	Leucaena	*Leucaena leucocephala*			?			?	✓
63	lippia	*Phyla canescens*	? G				✓ G	✓ G	
3	Madeira vine	*Anredera cordifolia*					? S		✓ S
269	Mayne's pest	*Verbena aristegera*		? G			? G	? G	
36	mesquite	*Prosopis* spp.							
71	mimosa	*Acacia farnesiana*			? G				✓ G
173	mintweed	*Salvia reflexa*	✓ G	? G					
51	moth vine	*Araujia sericifera*				✓ S			
7	mother-of-millions	*Bryophyllum daigremontianum*							✓

Species #	Weed	Scientific Name	animals	forage	fruit	wind	water	vehicles	people
8	mother-of-millions	*Bryophyllum delagoense*					✓	✓	✓
9	mother-of-millions	*Bryophyllum* spp.					✓	✓	
10	mother-of-millions	*Bryophyllum* x *houghtonii*					✓	✓	
112	nutgrass	*Cyperus rotundus*						Soil G	
61	olive	*Olea europaea*			✓				✓
43	Parramatta grass	*Sporobolus africanus*		?			?	?	
32	Parthenium weed	*Parthenium hysterophorus*						✓ B, S	
152	Paspalum	*Paspalum dilatatum*	✓ G					✓ G	
55	Paterson's curse	*Echium plantagineum*						?	
29	prickly pears	*Opuntia* spp.			✓ B, S				
98	Rhodes grass	*Chloris gayana*		? G				? G	✓ G
15	rope pear	*Cylindropuntia imbricata*			✓ S				
40	rose-leaf bramble	*Rubus rosifolius*			✓				
14	rubber vine	*Cryptostegia grandiflora*					? S		
52	saffron thistle	*Carthamus lanatus*				✓		?	
-	salvinia	*Salvinia molesta*					✓ W		✓ W
49	sisal hemp	*Agave sisalana*							✓
23	small-leaved privet	*Ligustrum sinense*			✓				
417	spiked malvastrum	*Malvastrum americanum*	✓ B			✓ B	✓ B		
58	St. John's wort	*Hypericum perforatum*	?					✓	
62	swamp foxtail	*Pennisetum alopecuroides*	✓ W			✓ W	✓ W	✓ W	
67	sweet briar	*Rosa bracteata*			✓				✓
27	tiger pear	*Opuntia aurantiaca*	?		✓		✓		

Species #	Weed	Scientific Name	animals	forage	fruit	wind	water	vehicles	people
597	tipuana, rosewood	*Tipuana tipu*				✓	✓		✓
341	umbrella sedge	*Cyperus eragrostis*					✓ W		
37	velvet mesquite	*Prosopis velutina*			?				✓
31	velvety tree pear	*Opuntia tomentosa*			✓ B, S		? B, S		
574	water hyacinth	*Eichhornia crassipes*					✓		?
33	water lettuce	*Pistia stratiotes*			? W		✓ W		✓ W
290	water parsnip	*Berula erecta*					✓ W		
171	weeping willow	*Salix babylonica*					✓ W		✓ W
46	witchweeds	*Striga* spp.						?	
47	yellow bells	*Tecoma stans* var. *stans*				✓			✓
589	yellow raspberry	*Rubus ellipticus*			✓				
126	Yorkshire fog	*Holcus lanatus*					? W	✓ W	✓ W
			14	**6**	**42**	**18**	**40**	**36**	**34**

Vector management and the protection of priority remnants

Vector management to minimise weed spread is an important component of strategic weed risk management for the protection of priority ecosystems. Weed risk is the result of a combination of factors: the nature of the weed species (opportunist or environmental engineer), weed propagule source (both presence and abundance of individuals and/or propagules, including those present in the soil seedbank), dispersal vectors and pathways (presence and abundance/intensity of potential vectors, frequency of opportunities for movement) and the condition (e.g. levels of disturbance, availability of resources) of the receiving environment.

The protection of priority remnants requires good knowledge of weed species which are or could potentially be invasive and damaging in these environments, the location of source populations and levels of infestation, and the dispersal mechanisms likely to result in the transport of propagules from source populations to remnants (this applies for new invasions to currently uninvaded areas and re-invasion of areas in which weeds have been managed.)

The following discussion covers weed dispersal vectors identified as relevant to priority remnants within the Condamine catchment (above). However, these issues also apply generally to site protection across the catchment, and to the numerous weeds not on priority lists (including new potentially invasive species) which are also dispersed by these mechanisms.

Animal-mediated dispersal

(i) Dispersal by attachment

Many of the species identified as having a high probability of dispersal by this mechanism are species which occur as either introduced pasture species (e.g. buffel grass) or pasture weeds, and so are most likely to attach to and be carried by grazing stock and larger native grazers such as macropods (kangaroos and wallabies). While there are limited options to control the movements of macropods, stock movements within properties can be managed to limit the number of propagules translocated between infested and 'clean' paddocks. For example, strategies such as excluding grazing in infested paddocks at the time of weed seed-set and the establishment of decontamination areas (e.g. holding yards) to allow seeds to drop may be appropriate, depending on the reproductive characteristics of the species and nature of the weed seed.

Movement of stock between properties or from outside the catchment present a risk of more widespread dispersal of weeds; knowledge of weed issues in the area of origin is important, and it may be relevant to identify high risk areas and to either inspect and decontaminate stock travelling from these areas, or require that stock are only moved from properties certified to be free of specific priority weeds. Newly arrived stock should be held in decontamination areas for a specified period to reduce the probability that they retain weed seed in their coats.

While such restrictions may be viewed as an imposition on local livestock businesses, the livestock industry stands to benefit significantly from better management of weed spread, with current costs to the industry of weed control and lost productivity due to weeds estimated at $1.8 billion per year (MLA 2009).

Overland movement of stock along travelling stock routes presents a particular problem for Bluegrass grassland remnants in the catchment as many of the more significant remnants (including the priority remnants) of this ecosystem type occur within the stock route system (Goodland 2000). The administration of the stock route network (SRN) is shared between local governments and the Department of Natural Resources and Water (NRW). A review of protocols for managing the risk of weed spread by stock using stock routes within the catchment may be necessary to ensure that permits include restrictions on the use of sections of the stock route network identified as priority remnants (Figure 8), and also those areas in which significant weeds occur.

A key priority for better management of the Stock Route Network is improved mapping of significant weeds. Currently none of the species reported as important to the ecology of Bluegrass grasslands appears to be recorded systematically; there are just 35 records of the 10 taxa of Bluegrass grassland relevant weed species recorded in or adjacent to designated stock routes in the catchment (Table 10). Targeted mapping of these species would aid regional planning for weed risk management in this nationally-listed critically-endangered ecosystem type.

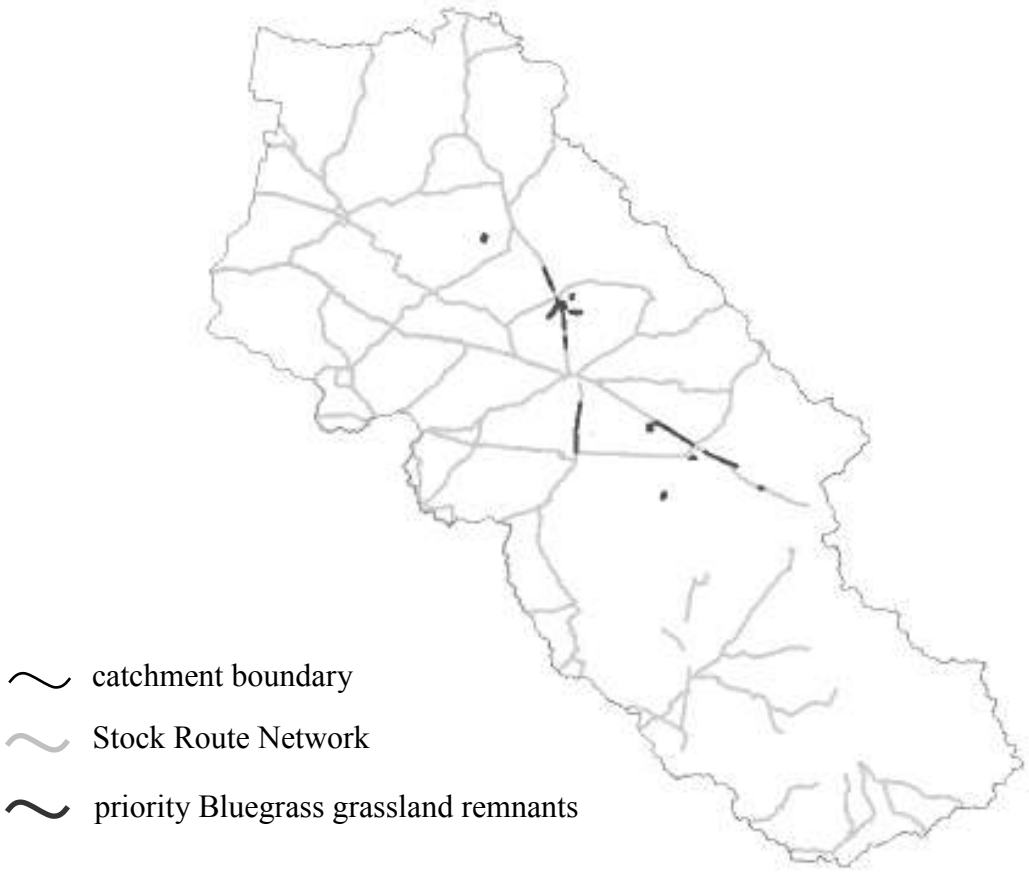


Figure 8: Location of priority Bluegrass grassland remnants in relation to the Stock Route Network within the Condamine catchment

Table 10: Priority weed species recorded within and adjacent to (within 100m of) the Stock Route Network within the Condamine catchment (WildNet, HERBRECS and PestInfo databases; 1984 – 2008). Records over 25 years old or with accuracy of > 5000m are not included. Species with a probability of dispersal by grazing stock (Table 11) are indicated (▪)

Weed	Scientific name	Records
Bluegrass grassland significant species		
African love grass	*Eragrostis curvula*	6
coolatai grass	*Hyparrhenia hirta*	5
lippia ▪	*Phyla canescens*	5
nutgrass	*Cyperus rotundus*	2
Bluegrass grassland important species		
green panic ▪	*Megathyrsus maximu*	1
Johnson grass	*Sorghum halepense*	1
Mayne's pest ▪	*Verbena aristigera*	8
mimosa	*Acacia farnesiana*	1
Paspalum ▪	*Paspalum dilatatum*	2
Rhodes grass ▪	*Chloris gayana*	4
Other priority (national, state, regional) species		
African boxthorn	*Lycium ferocissimum*	30
annual ragweed	*Ambrosia artemisiifolia*	6
balloon vine	*Cardiospermum grandiflorum*	1
blackberry	*Rubus anglocandicans*	6
blackberry	*Rubus fruticosus*	57
broad-leaved privet	*Ligustrum lucidum*	1
camphor laurel	*Cinnamomum camphora*	1
Chilean needle grass ▪	*Nasella neesiana*	46
common prickly pear	*Opuntia stricta*	1
firethorn	*Pyracantha angustifolia*	8
fireweed	*Senecio madagascariensis*	22
groundsel bush ▪	*Baccharis halimifolia*	2
honey locust tree	*Gleditsia triacanthos*	77
kudzu	*Pueraria lobata*	3
lantana	*Lantana camara*	7
Madeira vine	*Anredera cordifolia*	1
mexican poppy	*Argemone ochroleuca*	2
mother of millions	*Bryophyllum delagoense*	3
mother of millions	*Bryophyllum* sp.	32

Weed	Scientific name	Records
narrow-leaved privet	*Ligustrum sinense*	2
prickly pears	*Opuntia* sp.	93
tiger pear ■	*Opuntia aurantiaca*	8
velvety tree pear	*Opuntia tomentosa*	1

(ii) Dispersal by ingestion of seed associated with grazing

Weeds identified as having a high probability of dispersal by this mechanism are species whose seed is able to survive digestive processes within the gut of grazing animals. In many cases, there may also be an additional advantage in enhanced germination and establishment rates following passage through the gut.

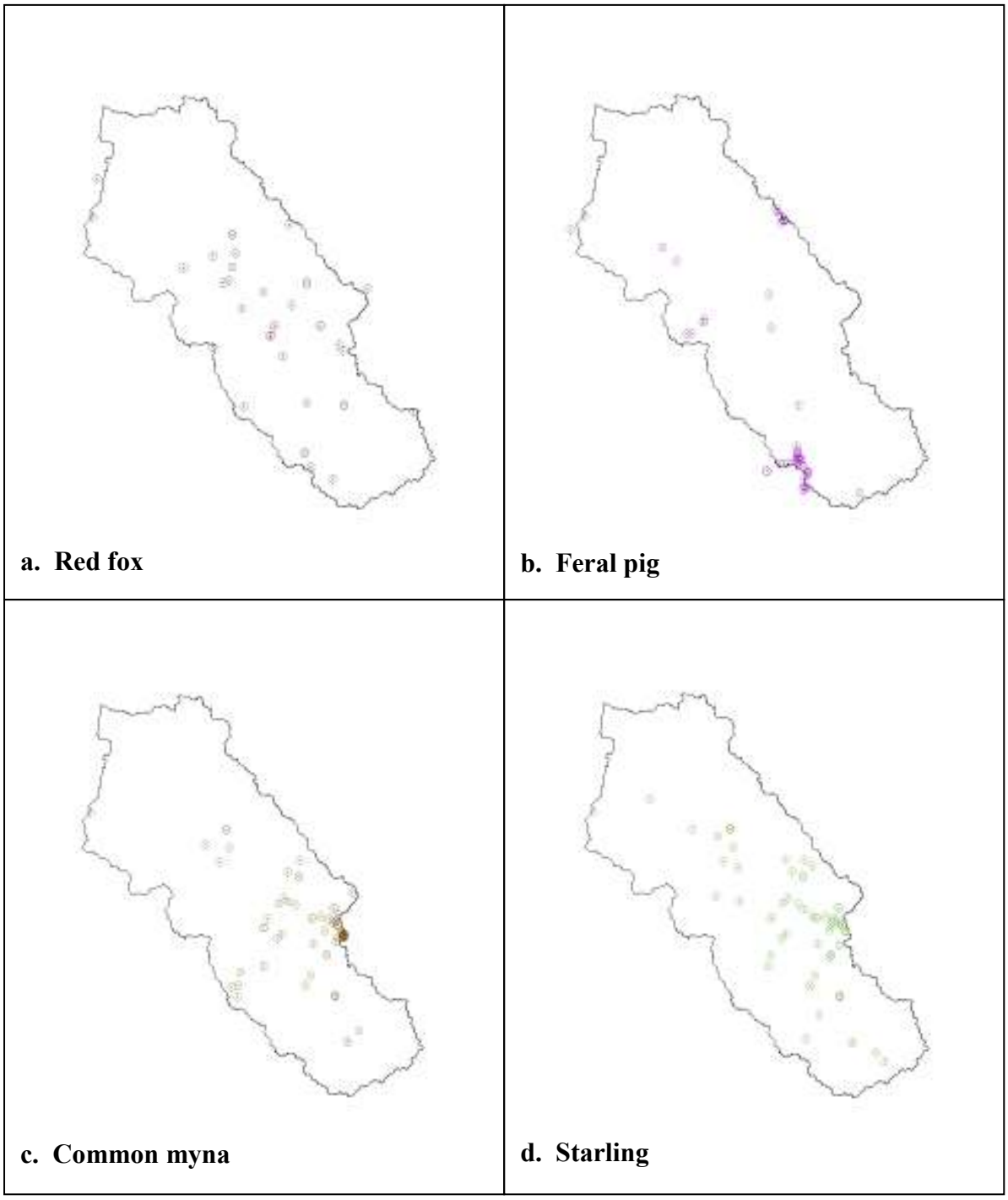
Similar management approaches to (i) above should be adopted to minimise weed spread by this means both within and between properties. Stock decontamination in holding yards between paddocks and properties is an effective means of controlling spread of seed dispersed by this means. This approach has been successfully adopted by pastoral properties in northern Australia to control the spread of prickly acacia (*Acacia nilotica*), with follow-up monitoring and control of emergent plants in the vicinity of the decontamination area an important component of the strategy (White 2004).

(iii) Dispersal associated with fruiting bodies attractive to birds and other animals

Fruits such as fleshy berries offer a rich food resource to many birds as well as a number of mammals (including fruit-eating bats). As in (ii) above, much of the seed of these species is adapted to survive ingestion and passage through the gut of animals, and exhibits enhanced germination and survival rates following deposition (e.g. Panetta and McKee 1997), particularly under perch trees (e.g. Stansbury 2001).

Weed species with fleshy fruits are a major component of the group of significant weeds in SEVT remnants in the catchment. These remnants also comprise a variety of native fruiting plant species (e.g. *Carissa ovata, Canthium* spp., *Jasminum* spp., *Alectryon* spp.) and support a range of fruit-eating birds, many of which may also feed on (and disperse) fruit from weed species. As dispersion of weed species in these environments may include many native fauna species (e.g. silvereyes, fruit pigeons, corvids), this dispersal pathway is extremely difficult to manage. This is especially the case for weeds such as lantana (*Lantana camara*), where infestations are frequently dense and widespread and probably contribute to population increases in a number of fruit-eating bird species, hence increased dispersion.

A number of introduced pest animals also act as dispersal agents for fruiting weed species. Within the Condamine catchment, these include common mynas, starlings, foxes and possibly feral pigs. These animals can be significant vectors, particularly as their habitat associations can be relatively broad, ranging from close links with human settlement (generally the source of original infestations of fruiting weed species), through open farmland to fragmented woodland remnants. They are also present throughout the catchment (Figures 9a-d), often in significant numbers (Figure 10), and strategic pest animal control programs need to be an ongoing part of weed risk minimisation projects.



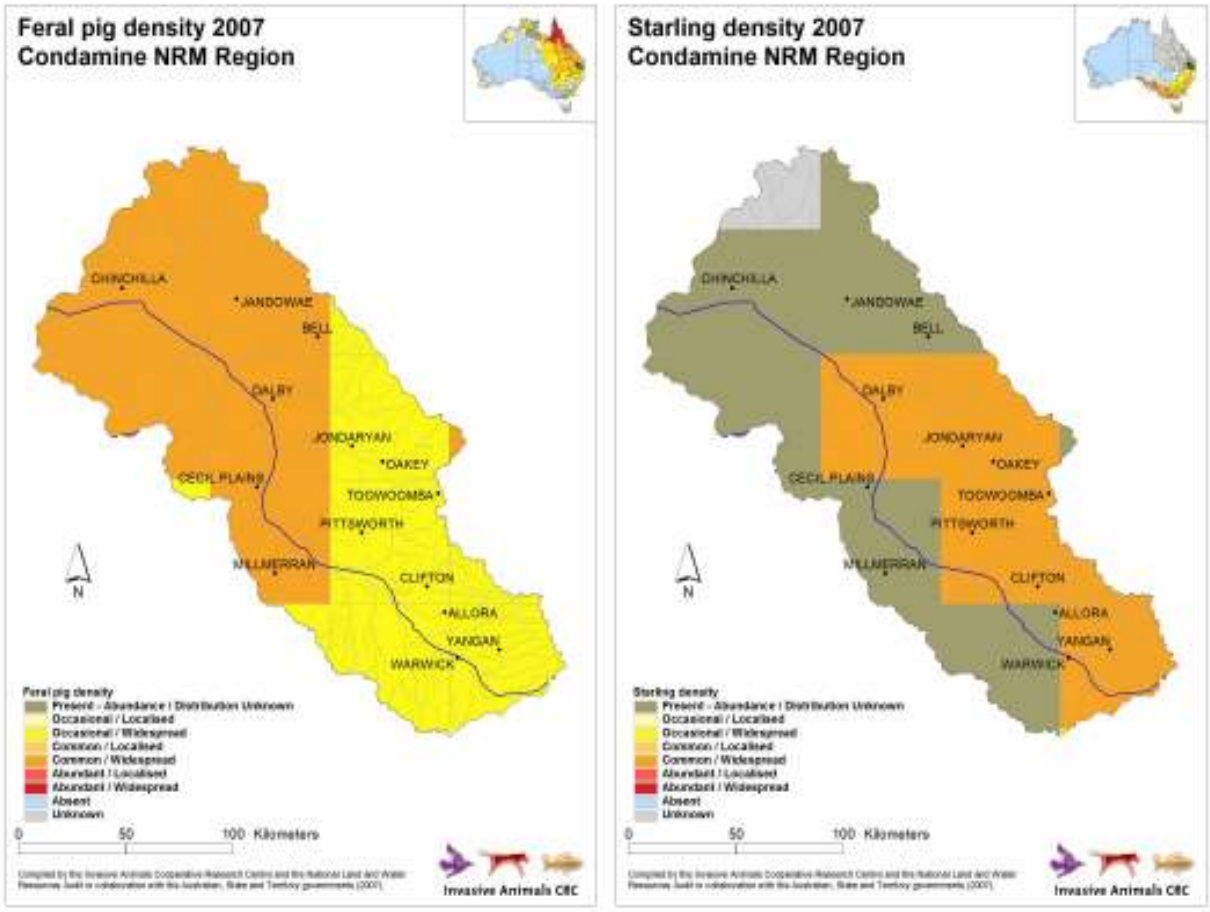
a. Red fox

b. Feral pig

c. Common myna

d. Starling

Figure 9: **Distribution of records (WildNet, HERBRECS and PestInfo databases; 1984 – 2008) of pest animals likely to act as vectors for the spread of fruiting weed species in the Condamine catchment.** Records over 25 years old or with accuracy of > 5000m are not included.



Source: Invasive Animals CRC (2007)

Figure 10: Density of feral pig and starling records in 2007 for the Condamine region (Annual Pest Distribution Survey results reported on a 0.5° or 50km x 50km grid)

Given the difficulties inherent in controlling vectors for weed species adapted to this type of dispersal, the main approach to limiting spread of recognised fruit-producing weed species needs to focus on control of infestations and minimising fruit production through integrated weed management practices including biocontrol agents where these are available. Where possible, the promotion of local native fruit-producing species by targeted planting of these species in revegetation projects in suitable locations within the catchment may be of benefit (Buckley *et al.* 2006, Gosper and Vivian-Smith 2009). Gosper and Vivian-Smith (2009) report on a process for scoring the fruiting traits of replacement native species for selection in local revegetation projects following control of invasive fruiting weed species.

There is an additional risk that a number of common fruit-producing garden plants, such as *Murraya* sp. and *Duranta* sp., will become invasive due to dispersal by fruit-eating birds[10]. Small naturalised infestations of these species should be controlled and monitored. Local nurseries and gardeners should also be encouraged to stock and plant native alternatives to these and other similar garden plants to reduce the weed risk posed by such species.

[10] Gosper *et al.* (2005) report a high probability of bird-dispersal of species with fruits less than 15mm in width.

Dispersal by abiotic vectors

(i) Wind

Several weed species of importance, largely to SEVT and Bluegrass grassland remnants, are either adapted for wind dispersal, or reported as wind-dispersed (Table 9), having light, fluffy or winged seeds. These include moth vine (*Araujia sericifera*), cat's claw creeper (*Macfadyena unguis-cati*), buffel grass (*Pennisetum ciliare*), green panic (*Megathyrsus maximus*) and Coolatai grass (*Hyparrhenia hirta*). A number of other priority weed species are also wind-dispersed, as are many of the opportunistic or ruderal non-native species which frequently establish on disturbed sites, such as fireweeds (*Senecio* spp.), fleabanes (*Conyza* spp.) and thistles (*Carthamus* spp., *Sonchus* spp., *Lactuca* spp., *Cirsium* spp.).

Only 4 Bureau of Meteorology (BoM) weather stations in the catchment record wind speed and direction. These are Toowoomba, Warwick, Oakey and Dalby. The period of recording varies between weather stations, with Toowoomba having the longest record dating back to1957 (a change in weather station location in 1997 means that this record is not continuous). An investigation of maximum daily wind speeds recorded (usually twice daily at 9am and 3pm) at the former Toowoomba location indicates that wind speeds in excess of 30km per hour (above which wind erosion[11] is generally considered to occur; Johnson 2003) are common, and have increased in speed and frequency over the recorded period (Figures 11 and 12). The predominant direction of the strongest winds recorded is from the east (49.90% of records), and the maximum speed of easterly winds is also increasing (Figure 13), although there is some variation between seasons. Records from Oakey Airport indicate a similar increase in maximum wind speeds over the period 1974 to 2005, while recent records (1992 on) from Warwick, Dalby and Toowoomba Airport show no major change (Appendix 9).

While the likelihood of wind dispersal of adapted species appears likely to increase, the options for controlling seed dispersal by wind are limited. Management options for these species should focus on the control of source populations of priority weed species, and maintaining priority remnants in good condition to limit opportunities for establishment of wind-dispersed weed species. The potential weed risk of garden plants adapted for wind dispersal should be assessed, and local nurseries and gardeners should also be encouraged to stock and plant native alternatives to these and other similar garden plants to reduce the weed risk posed by such species.

(ii) Water

A number of important weed species for each priority ecosystem type have potential to be dispersed by water. This is more likely to be an issue for ecosystem-types occurring in the lower parts of the landscape (e.g. wetlands, Bluegrass grasslands and brigalow woodlands) than for SEVT remnants which occur in more upland areas. Species identified as important to SEVT ecosystems and potentially-dispersed by water (Table 9, above) are also reported to be dispersed by other means, with the exception of Madeira vine (*Anredera cordifolia*) and rubber vine (*Cryptostegia grandiflora*). These species should be a priority for control in riparian areas associated with (including upstream of) SEVT remnants.

[11] Wind erosion risk is used as a proxy for seed dispersal risk. This is most probably a conservative threshold, as the probability of wind dispersal varies with seed type (some seeds being highly adapted to wind dispersal, and likely to be spread at lower windspeeds) and increases with plant height (Greene and Johnson, 1989).

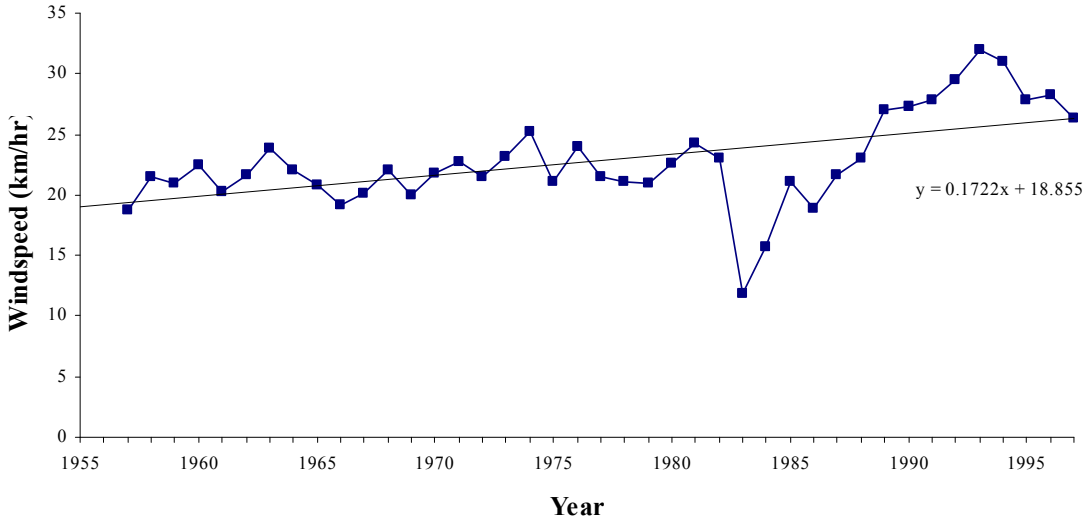


Figure 11: Annual average daily maximum windspeed, 1957-1997 (BoM station # 41103, Toowoomba)

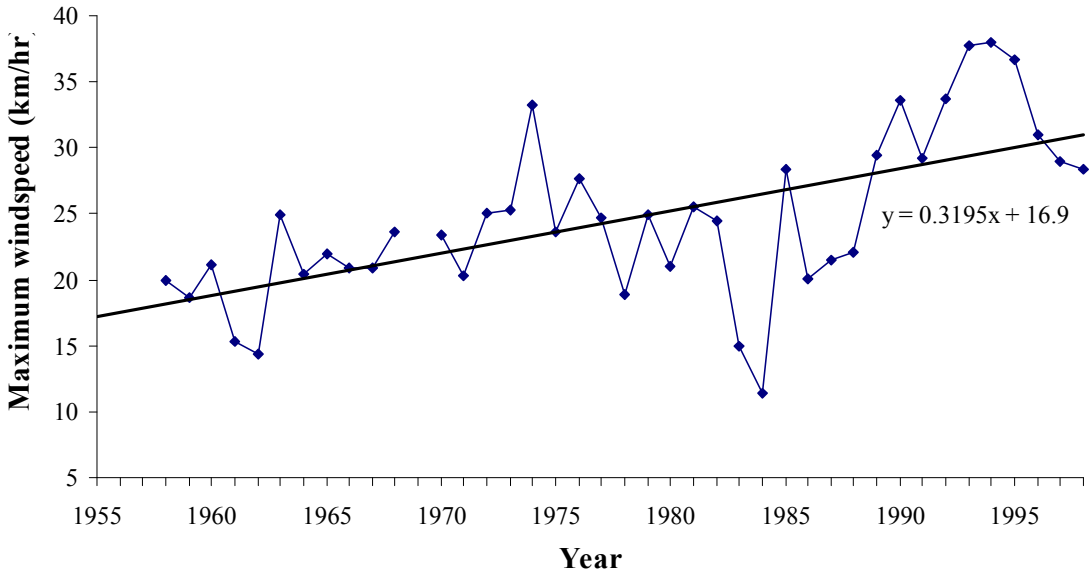


Figure 13: Average maximum windspeed of easterly winds during December, January and February, 1958-1998 (BoM station # 41103, Toowoomba)

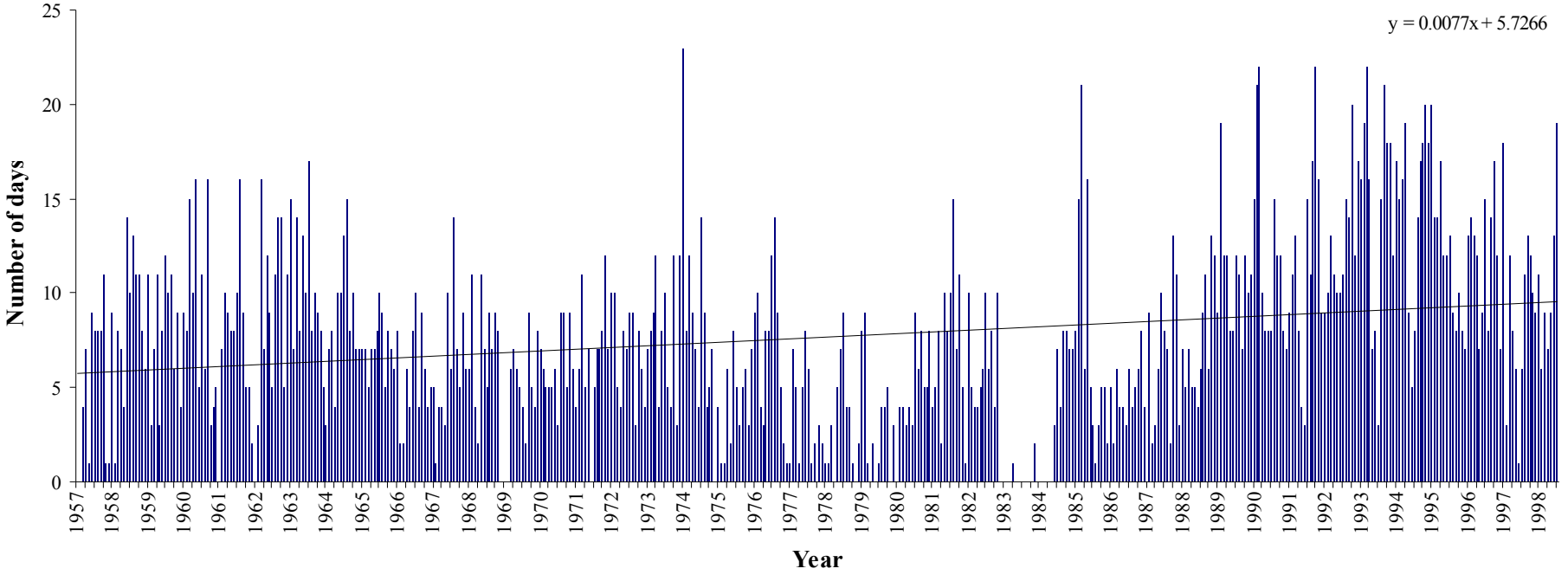


Figure 12: **Number of days per month with recorded wind speeds exceeding 30km per hour, 1957-1998 (BoM station # 41103, Toowoomba).** Trend line shows an average increase in the number of windy days per month of approximately 1 day per decade.

Weed species adapted for dispersal by water are of primary threat to wetland ecosystems within the catchment (Figure 7b, above). Water movement (particularly flooding) has the potential to spread water-borne plant propagules both downstream and across the floodplain to wetland areas normally disconnected from riverine flows, such as the two nominated priority wetland areas for this project, Longswamp and Tralee wetlands.

Flooding is a regular feature of the low-lying parts of the Condamine catchment, and vital to the replenishment of wetlands and the surrounding floodplain. Periodic reconnection of wetland areas enables the dispersion of native species and contributes to diverse and dynamic floodplain ecosystems which support a range of biodiversity. However, flooding also contributes to the spread of weeds, some of which are able to take advantage of the disturbance and additional resources (nutrients, soil moisture, space) associated with floods. For example, the spread of lippia (*Phyla canescens*) is significantly enhanced by flooding, with both seed and vegetative propagules transported in flood waters and increased germination and establishment rates post-flooding (Mcdonald *et al.* 2006, van Klinken 2006).

Rainfall in this region of southern Queensland is highly variable (for example, annual totals range from 268mm to 1,273mm (mean 673mm) over 133 years of BoM records at Dalby). Droughts and floods are a common feature of the climate, and extreme events such as these are expected to increase in frequency and intensity over time with anticipated climate change (Hennessy *et al.* 2007). The prevalence of both extremes is conducive to weed establishment in riparian and wetland environments across the catchment. While flooding promotes the spread of weed propagules, drought can contribute to reduced survival and abundance of native species, creating opportunities for establishment of opportunistic ruderals and invasives.

Recent modelling of rainfall, run-off and streamflow within the Condamine catchment (CSIRO 2008) predicts that both flood frequency and extent are most likely to decrease (60% of models tested) over the period to 2030 across the Condamine-Balonne catchment under current levels of water development. In some respects this indicates a potential reduction in the risk of water dispersal of weed species. However, increased moisture stress in native vegetation communities is likely to tip the balance in favour of invasive species where ecosystem condition is compromised (DAFF and DEW 2007b), pointing to an increased risk of successful weed establishment in lowland remnant ecosystems (including wetlands) with changing hydrological regimes.

A key priority for improved conservation value in wetlands in the catchment is retaining these, and associated riparian and floodplain ecosystems, in good condition, such that they are resistant and resilient to significant disturbance (including droughts) and subsequent invasion. Improved mapping of significant weeds in riparian areas is critical to this.

There is currently no systematic recording of species such as lippia (*Phyla canescens*), nor of other weed species potentially important to wetland ecology, in the catchment. Of the four species listed (Table 8) as priority weed species in these environments, only lippia and tiger pear (*Opuntia aurantiaca*) are recorded (12 records) in official databases; there are no records for either smartweed (*Persecaria* sp.) and mimosa (*Acacia farnesiana*) (Table 11). Other than these and *Opuntia* spp. (160 records), only 15 records of the remaining 18 taxa of wetland indicator weed species have been recorded in riparian and adjacent areas in the region. Targeted mapping of these species would aid regional planning for weed risk management in these important ecosystems.

Table 11: Priority weed species recorded within and adjacent to (within 100m of) mapped rivers and streams within the Condamine catchment (WildNet, HERBRECS and PestInfo databases; 1984 – 2008). Records over 25 years old or with accuracy of > 5000m are not included. Species with a reported probability of dispersal by water (Table 11) are indicated (▪).

Weed	Scientific name	Records
Wetland important species		
barnyard grass ▪	*Echinochloa crus-galli*	2
couch ▪	*Cynodon dactylon*	1
kikuyu grass ▪	*Pennisetum clandestinum*	1
lippia ▪	*Phyla canescens*	4
noogoora burr ▪	*Xanthium occidentale*	2
prickly pears ▪	*Opuntia* spp.	160
tiger pear ▪	*Opuntia aurantiaca*	8
umbrella sedge ▪	*Cyperus eragrostis*	4
weeping willow ▪	*Salix babylonica*	4
Yorkshire fog ▪	*Holcus lanatus*	1
Other priority (national, state, regional) species		
African boxthorn	*Lycium ferocissimum*	1133
African lovegrass ▪	*Eragrostis curvula*	5
annual ragweed	*Ambrosia artemisiifolia*	6
balloon vine ▪	*Cardiospermum grandiflorum*	4
blackberry	*Rubus anglocandicans*	4
blackberry	*Rubus fruticosus*	183
broad leaved privet	*Ligustrum lucidum*	81
camphor laurel	*Cinnamomum camphora*	1
Chilean needle grass	*Nasella neesiana*	516
Chinese elm	*Celtis sinensis*	3
common prickly pear ▪	*Opuntia stricta*	1
common thornapple	*Datura stramonium*	2
Coolatai grass	*Hyparrhenia hirta*	5
crofton weed ▪	*Ageratina adenophora*	58
firethorn	*Pyracantha angustifolia*	35
fireweed	*Senecio madagascariensis*	21
golden rain tree ▪	*Koelreuteria elegans* subsp. *formosana*	1
groundsel bush	*Baccharis halimifolia*	124
guava	*Psidium guajava*	1
hemlock ▪	*Conium maculatum*	20

Weed	Scientific name	Records
honey locust tree	*Gleditsia triacanthos*	1631
knobweed ▪	*Hyptis capitata*	1
kudzu	*Pueraria lobata*	4
lantana	*Lantana camara*	18
Madeira vine ▪	*Anredera cordifolia*	3
moth vine	*Araujia sericifera*	2
mother of millions ▪	*Bryophyllum* spp.	16
mother of millions ▪	*Bryophyllum delagoense*	1
narrow leaved privet	*Ligustrum sinense*	68
parthenium weed	*Parthenium hysterophorus*	1
Paterson's curse	*Echium plantagineum*	45
pest pear ▪	*Opuntia elatior*	1
saffron thistle	*Carthamus lanatus*	2
velvety tree pear ▪	*Opuntia tomentosa*	1

Dispersal by anthropogenic vectors

(i) Vehicles

A significant number of important weed species have potential to be dispersed by vehicle movements (including road maintenance machinery) along road and utility corridors, and between properties by farm vehicles and machinery such as harvesters. Specific protocols have been devised and management guidelines implemented for particular weed species at risk of spread through vehicle movement, such as Parthenium (*Parthenium hysterophorus*) (Austin, n.d.). However, in general, strategic weed risk management does not appear to be actively addressed either in local government pest management plans (as core road maintenance managers) or other corridor (road, rail, etc.) management utilities. Instead, project-based weed management plans appear to the standard approach by these organisations (e.g. Powerlink 2005).

Of the listed ecosystem types in the catchment, Bluegrass grasslands are at most risk from weed transported by vehicles (Figure 7b). As priority remnants of this ecosystem type also occur predominantly along roadsides (which in some cases also form the Stock Route network, above), there is a high level of risk to these remnants associated with this vector pathway.

The road network across the Condamine catchment is extensive, with over 13,000km of designated roads. Some 4,341 records (293 non-native taxa)[12] of non-native species, listed in databases accessed for this report, are located within 100m of mapped roads; these include 46 taxa listed on national, state and regional priority weed lists, and 10 taxa of importance to the integrity of Bluegrass grassland remnants in the catchment (Table 12).

[12] Records over 25 years old or with an accuracy of > 5000m are not included

Table 12: Priority weed species recorded within and adjacent to (within 100m of) mapped roads within the Condamine catchment (WildNet, HERBRECS and PestInfo databases; 1984 – 2008). Records over 25 years old or with accuracy of > 5000m are not included. Species with a reported probability of dispersal by vehicle movement (Table 11) are indicated (▪).

Weed	Scientific name	Records
Bluegrass grassland important species		
African lovegrass ▪	*Eragrostis curvula*	13
Coolatai grass ▪	*Hyparrhenia hirta*	9
green panic ▪	*Megathyrsus maximus*	3
Johnson's grass ▪	*Sorghum halepense*	4
Mayne's pest ▪	*Verbena aristigera*	13
mimosa	*Acacia farnesiana*	1
mintweed	*Salvia reflexa*	2
Nut grass ▪	*Cyperus rotundus*	3
paspalum ▪	*Paspalum dilatatum*	6
Rhodes grass ▪	*Chloris gayana*	9
Other priority (national, state, regional) species		
African boxthorn	*Lycium ferocissimum*	913
annual ragweed ▪	*Ambrosia artemisiifolia*	6
asparagus fern	*Asparagus africanus*	1
balloon Vine	*Cardiospermum grandiflorum*	4
blackberry	*Rubus anglocandicans*	8
blackberry	*Rubus fruticosus*	110
blackberry	*Rubus rosifolius* var. *rosifolius*	1
broad leaved privet	*Ligustrum lucidum*	51
cactus	*Opuntia elatior*	1
camphor laurel	*Cinnamomum camphora*	4
Chilean needle grass ▪	*Nassella neesiana*	859
Chinese elm	*Celtis sinensis*	5
common prickly pear	*Opuntia stricta*	4
common thornapple ▪	*Datura stramonium*	4
creeping lantana	*Lantana montevidensis*	1
crofton weed ▪	*Ageratina adenophora*	53
firethorn	*Pyracantha angustifolia*	25
firethorn	*Pyracantha crenulata*	1
fireweed ▪	*Senecio madagascariensis*	74
groundsel bush ▪	*Baccharis halimifolia*	76
hemlock ▪	*Conium maculatum*	2
honey locust tree	*Gleditsia triacanthos*	400

Weed	Scientific name	Records
knobweed ▪	*Hyptis capitata*	2
kudzu	*Pueraria lobata*	5
lantana	*Lantana camara*	210
Madeira vine	*Anredera cordifolia*	3
moth vine	*Araujia sericifera*	14
mother of millions ▪	*Bryophyllum delagoense*	10
mother of millions ▪	*Bryophyllum* spp.	68
mother of thousands ▪	*Bryophyllum* x *houghtonii*	1
narrow leaved privet	*Ligustrum sinense*	26
olive	*Olea europaea* subsp. *europaea*	2
Parramatta grass ▪	*Sporobolis indicus*	1
parthenium weed ▪	*Parthenium hysterophorus*	4
Paterson's curse ▪	*Echium plantagineum*	12
prickly pears	*Opuntia* spp.	593
saffron thistle ▪	*Carthamus lanatus*	2
sisal hemp	*Agave sisalana*	1
St Johns wort ▪	*Hypericum perforatum*	15
sweet briar	*Rosa* sp.	3
tiger pear	*Opuntia aurantiaca*	4
velvety tree pear	*Opuntia tomentosa*	5
yellow bells	*Tecoma stans* var. *stans*	1

A key priority for managing weed risk along roads and other transport and utility corridors is improved mapping of significant weeds. Currently none of the species reported as important to the ecology of Bluegrass grasslands appears to be recorded systematically; there are just 63 records of 10 taxa of Bluegrass grassland significant weed species recorded in or adjacent to roads in the catchment (Table 12). Interestingly, there are no records of lippia along roadsides in public databases, despite the fact that the Main Roads Department has expressed significant concern over the impact of lippia on its infrastructure and on Bluegrass grasslands in southern Queensland (QMDC 2005).

Targeted mapping of these species would aid regional planning for weed risk management along transport and utility corridors. A system such as Greening Australia's *EnviroMark* program might be implemented to alert linear corridor managers and motorists to weed infestations (Clark and Corbett 2004). Weed hygiene protocols might also be instigated to ensure that road maintenance works do not contribute further to weed spread (e.g. blowers and covers to avoid the accumulation of weed seed on slashers, washdown/decontamination procedures prior to entering uninfested areas). Some of these may already be in place in areas of the catchment, however it was not within the scope of this project to review these.

(ii) People

A key source of new weed infestations has historically been the introduction of novel non-native species into gardens and grazed pastures. The gardening industry in particular has been responsible for the introduction of some 25,360 new plant species (94% of all introductions) into Australia (Groves *et al.* 2005). Of the 2,779 species which are known to have naturalized and become established in the Australian environment, 1,831 (or 66%) are escaped garden plant species. Escaped garden species also comprise 69% of Australia's 954 listed agricultural weeds and 72% of the 1,765 listed environmental weeds (Groves *et al.* 2005).

Better screening of imported plant species is now in place, but the nursery trade in many known and potentially-weedy species continues; 54% of naturalised invasive garden plants (393 species, including 5 WoNS species) still available for sale in 2005 (Groves *et al*. 2005). In Queensland, the ten most serious invasive garden plants available for sale are Coreopsis (*Coreopsis lanceolata*), Glory lily (*Gloriosa superba*), Guava (*Psidium guajava* & *P. guineense*), Japanese honeysuckle (*Lonicera japonica*), Mickey Mouse plant (*Ochna serrulata*), Murraya (*Murraya paniculata* cv. *exotica*), Parrot's feather (*Myriophyllum aquaticum*), Pink periwinkle (*Catharanthus roseus*), Taro (*Colocasia esculenta*) and Yellow allamanda (*Allamanda cathartica*); other species may be more problematic regionally and it would be worth reviewing the range of plants sold in local nurseries on this basis.

Regional Councils and nursery and landscaping businesses in the Condamine region have an obligation to take greater responsibility for weed issues 'beyond the garden fence' by promoting the sale and planting of species which have a low probability of weediness, and developing voluntary guidelines to promote an environmentally-responsible future for gardening in the region. A 10-point plan proposed by Glanznig (2006) provides guidelines to reduce the threat of weeds introduced through the gardening industry, some of which could assist in the development of a local gardening industry strategy (Table 13).

Table 13: A 10 point plan for addressing weed risk from ornamental plants in Australia. Adapted from Glanznig (2006).

Point	Proposed action	Potential for local action
1	Close Australia's front door to new weeds	-
2	Give garden industry and communities certainty about the weed status of garden plants	yes
3	Better understand the extent and risk from continued trade in invasive garden plants	yes
4	Build knowledge about sterile garden plants and the dynamics of invasiveness	yes
5	Build garden industry understanding about the risks and costs associated with invasive garden plants, and capacity for positive action	yes
6	Mobilise garden industry to respond positively to the invasive species challenge	yes
7	Protect garden industry leaders and reduce transaction and compliance costs by establishing a streamlined national regulatory framework	-
8	Phase out supply and trade of high risk invasive plants nationally	-
9	Encourage gardeners to increase product demand for low risk garden plants	yes
10	Mobilise communities to locate and destroy new infestations of invasive garden plants	yes

E. Conclusions and general recommendations

Strategic management of native ecosystems should aim to prevent the spread and establishment of environmentally-significant weeds capable of altering the composition, structure and/or function of these systems. As such, control of weed seed dispersal (through the management of critical vectors and vector pathways) is an important priority for the protection and management of key conservation areas.

This report raises concerns that, while the main dispersal vectors for many weed species can be deduced, effective management of weed spread in the Condamine region is limited by a lack of information on the distribution and levels of infestation of key environmental weed species. Improved mapping, reporting (including signage) and management of functional weed species (and feral animal vectors) in the region is urgently needed.

Training and incentives to encourage the adoption of recommended best practices amongst on-ground managers of transport, utility and riparian corridors may also be required to ensure that weed spread is minimized and that vegetation cover in these areas is maintained in good condition to limit weed establishment. A review of current recommended best practices for these areas may be needed to ensure that these issues are adequately addressed.

Management guidelines and incentives should also be considered for managers of priority remnants, and for those in designated buffer areas surrounding these areas. Management of buffer areas will be of particular concern where pastures contain species such as buffel grass (*Pennisetum ciliare*) and green panic (*Megathyrsus maximus*), which are known to be invasive in priority remnants and to contribute to altered disturbance regimes.

In addition, there is an immediate need to address the contribution of gardeners and the local gardening industry to current and potential weed risk in the catchment. The risk associated with small-fruited plants has been discussed above. An increasing focus on water-wise gardening, with ongoing drought and water restrictions in place in many catchment communities (e.g. TRC 2008), may further contribute to significant weed risk in the region with the introduction of new drought-resistant plant types. For example, the drought-hardy ornamental Mexican feather grass (*Nasella tenuissima*), first introduced in 1996 and subsequently banned from sale in NSW and Victoria, may still be legally available for sale in Queensland, despite recognition that it is highly-invasive and poses significant risk and potential costs of $39million per year to the grazing industry (Skatssoon 2005, Glanznig 2006). Examples such as this indicate the need for an integrated assessment of risks associated with ornamental species.

Finally, altered climatic conditions associated with enhanced global warming may exacerbate existing threats to natural systems (e.g. loss of habitat, altered hydrological regimes, altered fire regimes and invasive species) within the Condamine region. An increased focus on climate adaptation is essential across the catchment. In particular, programs to protect the conservation values of priority ecosystem remnants must take an adaptive or experimental management approach (Bellamy *et al.*2001), with ongoing monitoring and evaluation of the effectiveness of management practices, to ensure that these are effective in maintaining remnants in good condition in the face of environmental change.

References

Arriaga, L., Castellanos, A.E., Moreno, V.E. and Alarcón, J. (2004) Potential ecological distribution of alien invasive species and risk assessment: a case study of buffel grass in arid regions of Mexico. *Conservation Biology* 18 (6): 1504-1514.

Austin, P. (n.d.) *Review of progress towards implementation of the Parthenium weed strategic plan (2006 – 2007)*. Available online at: http://www.weeds.org.au/WoNS/parthenium/docs/Parthenium_Strategic_Plan_Review_2006-07.pdf (accessed 19 February 2009).

Batianoff, G.N. and Butler, D.W. (2002) Assessment of invasive naturalised plants in south-east Queensland. *Plant Protection Quarterly* 17(1): 27-34. Available online at: http://www.epa.qld.gov.au/publications/p00727aa.pdf/Invasive_naturalised_plants_in_Southeast_Queensland_ranked_list.pdf (accessed 20 February 2009).

Beeton, R. (n.d.) *Advice to the Minister for the Environment, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on an Amendment to the list of Threatened Ecological Communities under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act): Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland.* Available online at: http://www.environment.gov.au/biodiversity/threatened/communities/pubs/88-listing-advice.pdf (accessed 20 February 2009)

Bellamy, J.A., Walker, H.D., Mcdonald, T.G., Syme, J.G., 2001. A systems approach to the evaluation of natural resource management initiatives. *Journal of Environmental Management* 63: 407–423.

Benson, JS, Dick, R and Zubovic, A (1996) Semi-evergreen vine thicket vegetation at Derra Derra Ridge, Bingara, New South Wales. *Cunninghamia* 4 (3): 497-510.

Buckley, Y. M., Anderson, S., Catterall, C. P., Corlett, R. T., Engel, T., Gosper, C. R., Nathan, R., Richardson, D. M., Setter, M., Spiegel, O., Vivian-Smith, G., Voigt, F. A., Weir, J. E. S. and Westcott, D. A. (2006) Management of plant invasions mediated by frugivore interactions. *Journal of Applied Ecology*, *43* 5: 848-857.

Buckley, Y.M., Bolker, B.M. and Rees, M. (2007) Disturbance, invasion and re-invasion: managing the weed-shaped hole in disturbed ecosystems. *Ecology Letters* 10 (9): 809-817

Butler, D.W. and Fairfax, R.J. (2003) Buffel Grass and fire in a Gidgee and Brigalow woodland: A case study from central Queensland. *Ecological Management & Restoration* 4 (2): 120-125.

Clark, A. and Corbett, C. (2004) *EnviroMark: a system for identifying and managing significant environments. Key Features Statement.* Greening Australia.

* Clarke, J. (2003) *Invasive Plant Prevention Guidelines.* Center for Invasive Plant Management, Bozeman, Montana USA. Available online at: http://www.weedcenter.org/products_pub/CIPM_prevention.pdf (accessed 11 January 2009).

CRC for Australian Weed Management 2003. *Weed management guides*. Available online at: http://www.weedscrc.org.au/publications/weed_man_guides.html (accessed 6 February 2009)

CRC Weed Management 2007 Weed Management Guide – Coolatai Grass (*Hyparrhenia hirta*). Available online at: http://www.weedscrc.org.au/documents/wmg_coolatai.pdf (accessed 25 February 2009).

CRC for Australian Weed Management (2008) Weed Management guide: Buffel grass (*Cenchrus ciliaris*). Available online at: http://www.weedscrc.org.au/documents/wmg_buffel%20grass.pdf (accessed 25 February).

CSIRO (2008). *Water availability in the Condamine-Balonne. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project.* CSIRO, Australia. Available online at: http://www.csiro.au/files/files/pl3s.pdf (accessed 21 February 2009).

* Csures, S. and Edwards, R. (1998) *Potential environmental weeds in Australia: candidate species for preventative control*. Environment Australia, Canberra ACT. Available online at: http://www.weeds.gov.au/publications/books/pubs/potential.pdf (accessed 9 February 2009).

Cupitt, S. (2007) *Wetlands in the Condamine Catchment.* A Greening Australia report for the Condamine Alliance, Toowoomba Qld.

DAFF and DEW (2007a). *National environmental alert list.* Australian Departments of Agriculture, Fisheries and Forestry and the Environment and Water Resources (Australian Government), Canberra ACT. Available online at: http://www.weeds.gov.au/weeds/lists/alert.html (accessed 20 February 2009).

DAFF and DEW (2007b) *Factors influencing weeds.* Departments of Agriculture, Fisheries and Forestry and the Environment and Water Resources (Australian Government), Canberra ACT. Available online at: http://www.weeds.gov.au/weeds/why/factors.html (accessed 21 February).

Davies, K. W. & Sheley, R. L. (2007) A conceptual framework for preventing the spatial dispersal of invasive plants. *Weed Science*, 55.

DECC (2008) *Invasion of native plant communities by exotic perennial grasses – key threatening process listing.* Department of Environment and Climate Change (NSW Government), Sydney NSW. Available online at: http://www.environment.nsw.gov.au/determinations/ExoticPerennialGrassesKTPListing.htm (accessed 13 February 2009).

DEWHA (n.d.) *Listings since commencement of EPBC Act*. Department of Environment, Water, Heritage and the Arts (Australian Government), Canberra ACT. Available online at: http://www.environment.gov.au/cgi-tmp/publiclistchanges.38ad498f9cdee74f2e3e.html (accessed 9 February 2009).

DEWHA (2008) *Approved Conservation Advice for Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland.* Department of Environment, Water, Heritage and the Arts (Australian Government), Canberra ACT. Available online at: http://www.environment.gov.au/biodiversity/threatened/communities/pubs/88-conservation-advice.pdf (accessed 25 February 2009).

DEWHA (2009a). Brigalow (*Acacia harpophylla* dominant and co-dominant). In *Community and Species Profile and Threats Database*. Department of the Environment, Water, Heritage and the Arts (Australian Government), Canberra ACT. Available online at: http://www.environment.gov.au/sprat (accessed 25 February 2009).

DEWHA (2009b). Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions. In *Community and Species Profile and Threats Database.* Department of the Environment, Water, Heritage and the Arts (Australian Government), Canberra ACT. Available online at: http://www.environment.gov.au/sprat. (accessed 25 February 2009).

DPI&F (2009) *Declared plants of Queensland*. Fact Sheet PP1, Land Protection (Invasive Plants and Animals), Department of Primary Industries and Fisheries (Queensland Government), Brisbane Qld. Available online at: http://www.isaac.qld.gov.au/community/documents/IPA-Declared-Plants-Qld-PP1.pdf (accessed 25 February 2009).

EPA (2006) *Wetland management profile: inland non-arid swamp wetlands.* Ecosystem Conservation Branch, Environmental Protection Agency (Queensland Government), Brisbane Qld. Available online at: http://www.epa.qld.gov.au/publications/p01869aa.pdf/Inland_nonarid_swamp_wetlands.pdf (accessed 25 February 2009).

EPA (2007) *Condamine NRM Region - Wetland Summary Information*. Environmental Protection Agency (Queensland Government), Brisbane Qld. Available online at: http://www.epa.qld.gov.au/wetlandinfo/site/MappingFandD/WetlandMapsAndData/SummaryInfo/NRM-1.jsp (accessed 20 February 2009).

EPA (2009) *Regional ecosystems*. Environmental Protection Agency (Queensland Government), Brisbane Qld. Available online at: http://www.epa.qld.gov.au/nature_conservation/biodiversity/regional_ecosystems/ (accessed 25 February 2009)

Fensham, RJ (1996) Land clearance and conservation of inland dry rainforest in north Queensland, Australia. *Biological Conservation* 75: 289-98.

Fensham, R.J. (1997) Options for conserving large vegetation remnants in the Darling Downs, south Queensland. In *Conservation outside nature reserves* P. Hale and D. Lamb (eds.) pp. 419-423. Centre for

Conservation Biology, University of Queensland, Brisbane. Available online at: http://www.southwestnrm.org.au/information/downloads/Conservation-Outside-Nature-Reserves-28.pdf (accessed 25 February 2009).

Fensham, R.J. (1999) Native grasslands of the central highlands, Queensland, Australia: Floristics, regional context and conservation. *Rangelands Journal* 21: 82-103.

Fensham, RJ, Fairfax, RJ and Cannell, RJ (1994) The invasion of *Lantana camara* L. in Forty Mile Scrub National park, north Queensland. *Australian Journal of Ecology* 19: 297-305.

Glanznig, A. (2006). Weed Proofing Australia: A Way Forward on Invasive Garden Plants. CRC for Australian Weed Management, *Weeds in the Media 2006*, 11-20. Available online at: http://www.wwf.org.au/publications/wwf10pointplan/ (accessed 19 February 2009).

Goodland, A. (2000) *Grassy ecosystem significant sites of the Darling Downs, Queensland: locations and management recommendations*. World Wildlife Fund for Nature Australia, Spring Hill, Brisbane Qld.

Gosper, C.R., Stansbury, C.D. and Vivian-Smith, G. (2005) Seed dispersal of fleshy-fruited invasive plants by birds: contributing factors and management options. *Diversity & Distributions* 11 (6): 549-558.

Gosper, C.R. and Vivian-Smith, G. (2009) Approaches to selecting native plant replacements for fleshy-fruited invasive species. *Restoration Ecology* 17 (2): 196-204.

Greene, D.F. and Johnson, E.A. (1989) A Model of Wind Dispersal of Winged or Plumed Seeds. *Ecology* 70 (2): 339-347.

Groves, R.H., Boden, R. and Lonsdale, W.M. (2005) *Jumping the garden fence: invasive garden plants in Australia and their environmental and agricultural impacts.* A CSIRO report for WWF-Australia. WWF-Australia, Sydney.

Hastings, A., Byers, J.E., Crooks, J.A., Cuddington, K., Jones, C.G., Lambrinos, J.G. et al. (2007). Ecosystem engineering in space and time. *Ecology Letters*, 10: 153–164.

Hennessy, K., B. Fitzharris, B.C. Bates, N. Harvey, S.M. Howden, L. Hughes, J. Salinger and R. Warrick, 2007: Australia and New Zealand. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 507-540. Available online at: http://www.gtp89.dial.pipex.com/11.pdf (accessed 21 February 2009).

Humphries, SE, Groves, RH, Mitchell, DD, Hallegraeff, GM and Clark, J (1991) Plant Invasions. Kowari, 2. Australian National Parks and Wildlife Service, Canberra.

Invasive Animals CRC (2007) *Invasive animals distribution and abundance maps*. Available online at: http://www.invasiveanimals.com/regions/national-invasive-animal-distribution-and-abundance-maps/ (accessed 25 February 2009).

Johnson, H. (2003) *Shelterbelts for control of wind erosion*. Landcare Notes LC0422. Department of Sustainability and Environment (State of Victoria). Available online at: http://www.dpi.vic.gov.au/dpi/nreninf.nsf/childdocs/-1C62D26CD3AF6FE44A2568B300051289-

8E21A59E53B35BEFCA256BC80005C14F-CAC238F4CEE8BBA14A256DEA00297AE2-049EBACF76BED58DCA256D6B00175A23?open (accessed 21 February 2009).

Johnson RW (2004) Vegetation survey of the Brigalow Research Station, Theodore, Queensland. *Proceedings of the Royal Society of Queensland* 111: 39–61.

Macdonald, M.J., Whalley, R.D.B., Sindel, B.M., Julien, M.H. & Duggin, J.A. (2006). Flood induced recruitment of lippia (*Phyla canescens*). In: B. Hackney, K. Bailes, J. Pilz and H. Burns (Eds) *Proceedings of the 21st Annual Conference of The Grassland Society of NSW*, Wagga Wagga, NSW, pp. 135-136

McDonald, W.J.F. (1996) *Spatial and temporal patterns in the dry season subtropcial rainforests of eastern Australia, with particular reference to the vine thickets of central and southern Queensland*. PhD thesis, Botany Department, University of New England, Armidale. (cited in McDonad 2007)

McDonald, W.J.F. (2007) *National recovery plan for the "Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions" ecological community*. Draft prepared by the Queensland Parks and Wildlife Service for the Department of the Environment, Water, Heritage and the Arts, Canberra.

Mack, M.C. & D'Antonio, C.M. (1998). Impacts of biological invasions on disturbance regimes. *Trends in Ecology and Evolution*, 13: 195–198.

Martin, T.G., Campbell, S. and Grounds, S. (2006) Weeds of Australian rangelands. *The Rangeland Journal* 28: 3–26.

MLA (2009) *Weeds*. Meat & Livestock Australia Limited, North Sydney NSW. Available online at: http://www.mla.com.au/TopicHierarchy/InformationCentre/FeedAndPastures/Weeds/default.htm (accessed 21 February 2009).

NPWS (2003) *Kirramingly Nature Reserve: plan of management.* NSW National Parks and Wildlife Service, Narrabri NSW. Available online at: http://www.environment.nsw.gov.au/resources/parks/pomfinalkirramingly.pdf (accessed 25 February 2009).

Panetta, F.D. and McKee, J. (1997) Recruitment of the invasive ornamental, *Schinus terebinthifolius,* is dependent upon frugivores. *Austral Ecology* 22 (4): 432-438.

PowerLink (2005) *Control of declared pests*. AM–PR–0039, pp42-50. Available online at: http://www.ghd.com.au/aptrixpublishing.nsf/AttachmentsByTitle/prj_lilyvale-blackwater_EIS-AppE_pdf/$FILE/EIS_appE.pdf (accessed 16 February 2009).

QMDC (2005) *Main roads: making inroads*. Case study (lippia) series. Queensland Murray Darling Committee Inc., Toowoomba Qld. Available online at: http://www.qmdc.org.au/publications/download/75/fact-sheets-case-studies/weeds-pests/main-roads-making-inroads.pdf (accessed 20 February 2009)

Queensland Government (n.d) *Queensland Weeds Strategy 2002-2006.* Available online at: http://www.dpi.qld.gov.au/documents/Biosecurity_EnvironmentalPests/IPA-QLD-Weed-Strategy.pdf (accessed 25 February 2009).

Seabrook, L., McAlpine, C. A. and Fensham, R. (2007) Spatial and temporal analysis of vegetation change in agricultural landscapes: A case study of two brigalow (Acacia harpophylla) landscapes in Queensland, Australia. *Agriculture, Ecosystems and Environment*, *120* 2-4: 211-228.

Skatssoon, J. (2005) *Invasion of the drought-proof plants.* News in Science (07/03/2005), ABC Science Online, Australian Broadcasting Corporation. Available online at: http://www.abc.net.au/science/news/stories/s1317624.htm (accessed 22.February 2009).

Stansbury, C.D. (2001) Dispersal of the environmental weed Bridal Creeper, *Asparagus asparagoides*, by Silvereyes, *Zosterops lateralis*, in south-western Australia. *Emu* 101: 39–45.

Thorp, J.R. and Lynch, R. (2000) *The determination of weeds of national significance*. Commonwealth of Australia & National Weeds Strategy Executive Committee. Available online at: http://www.weeds.org.au/docs/WoNS/ (accessed 25 February 2009).

TRC (2008) *Carnival of Flowers WaterWise Statement.* Toowoomba Regional Council, Toowoomba Qld. Available online at: http://www.toowoombacarnivalofflowers.com.au/index.php?option=com_content&view=category&layout=blog&id=78&Itemid=1080 (accessed 25 February 2009).

van Klinken, R.D. (2006) *Report of the first Australian lippia workshop (Narrabri, 18 October 2006).* Unpublished. 16 pp. Available online at: http://www.weedscrc.org.au/documents/wshop_lippia_oct%2006.pdf (accessed 21 February 2009).

Virtue, J.G., Groves, R.H., Panetta, F.D., 2001. Towards a system to determine the national significance of weeds in Australia. In: Virtue, J.G., Groves, R.H., Panetta, F.D. (Eds.), *Weed Risk Assessment*. CSIRO Publishing, Australia, pp. 212–214.

White, J. (2004) Australian Agricultural Company—weed seed spread protocol. In: *Prickly Acacia National Case Studies Manual: Section 5: Case studies—innovations in management*. Available online at: http://www.weeds.org.au/docs/Prickly_Acacia_Mgmnt-5.pdf (accessed 14 February 2009).